State of California
Department of Fish and Wildlife

Memorandum

Date: February 10, 2016

To: Fish and Game Commission

From: Charlton H. Bonham
Director

Subject: Status Review of Northern Spotted Owl

The Department of Fish and Wildlife (Department) has prepared the attached Status Review for consideration by the Fish and Game Commission (Commission) regarding the Environmental Protection Information Center's Petition to list the Northern Spotted Owl *(Strix occidentalis caurina)* as threatened or endangered pursuant to the California Endangered Species Act (CESA, specifically Fish and Game Code section 2074.6). The Commission received the petition on September 7, 2012. The attached status review represents the Department's final written review of the status of Northern Spotted Owl (NSO) and is based upon the best scientific information available to the Department. The status review contains the Department's recommendation that listing of the NSO as threatened is warranted.

Regarding the scientific determinations of the threats to the NSO, the Department finds that without protections afforded by CESA, the continued existence of NSO is in serious danger or is threatened by the following listing factors individually or in combination as described in the report:

1. Present or threatened modification or destruction of its habitat;
2. Competition; and
3. Other natural occurrences or human-related activities.

If you have any questions or need additional information, please contact Eric Loft, Chief, Wildlife Branch at 916-445-3555.

Attachment

STATE OF CALIFORNIA
NATURAL RESOURCES AGENCY
DEPARTMENT OF FISH AND WILDLIFE

REPORT TO THE FISH AND GAME COMMISSION
A STATUS REVIEW OF THE
NORTHERN SPOTTED OWL
(*Strix occidentalis caurina*) IN CALIFORNIA

CHARLTON H. BONHAM, DIRECTOR

CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
January 27, 2016

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The Department is extremely grateful for the valuable comments provided on an earlier draft of this report by the following reviewers: Lowell Diller, Katie Dugger, Alan Franklin, Betsy Glenn, Rocky Gutiérrez, and John Hunter. The conclusions in this report are those of the Department of Fish and Wildlife and do not necessarily reflect those of the reviewers.

Report to the Fish and Game Commission
A Status Review of the Northern Spotted Owl in California
January 27, 2016

Executive Summary

Pursuant to the California Endangered Species Act (CESA), the California Department of Fish and Wildlife (Department) has prepared this status review report and recommendation to the Fish and Game Commission (Commission) to inform its decision on whether to designate the Northern Spotted Owl (*Strix occidentalis caurina*) as an endangered or threatened species. The Commission received a petition from the Environmental Protection Information Center on September 7, 2012 to list the Northern Spotted Owl as Threatened or Endangered under CESA. On February 6, 2013, the Department transmitted its evaluation of the petition to the Commission and on August 7, 2013, the Commission voted to accept the petition and advance the Northern Spotted Owl to candidacy. The Commission published findings of its decision to advance the species to candidacy on December 27, 2013, triggering the preparation of a status review by the Department. The Department provides this report to the Commission based upon the best scientific information available pursuant to Fish and Game Code section 2074.6.

The Northern Spotted Owl is one of three subspecies of Spotted Owls, the other two being the California Spotted Owl (*S. o. occidentalis*) and the Mexican Spotted Owl (*S. o. lucida*). The current range of the Northern Spotted Owl extends from southwest British Columbia through the Cascade Range, coastal ranges, and intervening forested lands in Washington, Oregon, and California. In California, the range runs south along the coast from Oregon border to Marin County, across the Klamath Mountains east to the Cascade Range where it meets the range of the California Spotted Owl near the Pit River.

Generally, nesting and roosting habitat in California consists of older structurally complex forests that also include variable-aged stands and hardwood forest components in the core area of the owl's home range. Northern Spotted Owl nesting and roosting habitat on the coast of California often consists of younger forests compared to interior portions of the range due to rapid growth and structural development of coastal redwood forests. Foraging habitat is composed of a variety of forest and non-forest vegetation types, occurs across the broader home range, and is largely a function of prey abundance and availability. In much of California, woodrats are the main component of the Northern Spotted Owl diet, but other prey items (e.g., flying squirrels, mice, voles, gophers, hares, small to medium sized birds, bats, and insects) are also taken with less frequency. Dispersal habitat for Northern Spotted Owl consists of stands with adequate tree size and canopy closure to provide protection from avian predators, and that have at least minimal foraging opportunities.

The primary threats to the continued existence of Northern Spotted Owl in California are the rapid expansion of a novel competitor, the Barred Owl, into the range of the Spotted Owl, a rapid and accelerating decline in population size and demographic rates (e.g., survival, reproduction, occupancy), and loss of habitat due to wildfire and timber harvest. Additional threats include potential increases in frequency and severity of wildfires, widespread occurrence of marijuana cultivation on public and private lands, shifts in weather patterns related to climate change, effects of climate change on wildfire patterns and forest vegetation distribution, and the spread of the non-native fungus-like pathogen responsible for Sudden Oak Death Syndrome.

Northern Spotted Owl populations are declining throughout the range of the subspecies and annual rates of decline have been accelerating in many areas, including in California. The range-wide population of Northern Spotted Owl is estimated to have declined by 3.8% per year since 1985. On three large study areas in California, vital rates estimated from long-term datasets, including fecundity, survival, site occupancy, and rate of population change are declining, and the rates of population decline have accelerated in recent years on all three areas. The declines in vital rates and populations in California have deteriorated to levels previously restricted to more northerly portions of the subspecies' range in Washington and Oregon. Population sizes at California study areas have declined 31-55% since the 1990s and these declines are accelerating. The rates of site occupancy at known territories in these California study areas and on additional private lands in the Cascades have declined by 39-49% since 1995. The ongoing and increasing effects of Barred Owls on Northern Spotted Owl populations, coupled with other threats including habitat loss due to timber harvest and wildfire and reduced recruitment due to climate change, will lead to additional declines in Spotted Owl populations unless additional management intervention is undertaken.

Barred Owls were historically residents of eastern United States, southern Canada, and disjunct regions of south-central Mexico, but have expanded into western North America and now occur throughout the range of the Northern Spotted Owl. Barred Owls were first detected in California in 1976, but large numbers of detections did not occur until the 1990s and 2000s. Today, nearly 2,000 Barred Owl records exist within the Department's species database. Barred Owls are now having a negative impact on Northern Spotted Owl populations at a range-wide level. Documented impacts from Barred Owls include altered behavior of Spotted Owls (e.g., reduced calling), displacement of Spotted Owls from preferred high quality habitat, decreased survival and occupancy rates, and increased extinction rates. The most recent demographic study that analyzed nearly three decades of Northern Spotted owl data on 11 study areas across the species' range indicated the primary cause of population declines was competition with Barred Owl, largely as a result of negative effects on Northern Spotted Owl apparent survival and occupancy rates. Within the three California demographic study areas, Barred Owl numbers have continued to increase, while Northern Spotted Owl populations, occupancy and apparent survival have declined substantially. The only exception to this is in an area where Barred Owls were experimentally removed. Removal experiments appear to be successful at mitigating the negative impact to Northern Spotted Owls and are feasible at a local-scale. Given the level of decline of Northern Spotted Owl associated with the presence of Barred Owl, management actions that consider removal of Barred Owl at a broad scale, or other management actions such as targeted forest management to benefit Spotted Owls are necessary in order to stem the ongoing declines. Without these actions, the Northern Spotted Owl will likely continue to experience accelerated declines across its range in California, much like those documented in more northerly portions of the range in Washington and Oregon where Barred Owl have been established longer.

The majority of the nesting and roosting habitat lost from the California portions of the Northwest Forest Plan area has been attributed to wildfire, and most of that loss has occurred in the California Klamath Province. Several variables complicate the interpretation of studies of Spotted Owl response to fire, including variation in fire severity at a burn site, fire size, fire history and pre-fire forest composition, post-fire salvage logging, and the timing and duration of research post-fire. In some cases, Spotted Owl will use burned areas for foraging across all burn severity types; although nesting and roosting activities generally occur only in unburned or low-severity burn areas. After fire occurs, Spotted Owls will generally avoid large areas of high severity burn or areas experiencing extensive post-fire salvage logging; though it is difficult to separate the effects of severe burns from the impacts of salvage logging. In southern Oregon, Northern Spotted Owls showed declines in occupancy and survival rates following fire. Impacts of wildfire on Spotted Owl are likely due to changes in forest composition and structure and changes in prey abundance and availability. In recent decades, wildfires have become more frequent, larger, and have burned at uncharacteristically high severities in some portions of California. Conditions that support more frequent, large, and severe fires are projected to increase due to climate change. Therefore, Northern Spotted Owl habitat loss due to wildfires will likely continue to present a risk to owls in the future. In addition, habitat loss from post-fire salvage logging needs to be assessed due to the potential additive impacts on Northern Spotted Owl.

Climate change will likely have increasing impacts on the Northern Spotted Owl's throughout its range, with many climate projections forecasting wetter winters, colder winters in some areas, earlier springs, and hotter drier summers, with the frequency and duration of extreme climatic events (e.g., heat waves, wildfire, and heavy rain or snow) increasing over time. In addition, forests within California will likely experience some level of elevational and latitudinal shifts, changes in species composition, and alterations in fire regimes. The Northern Spotted Owl relies heavily on specific forest structure components and tree species composition, as well as associated prey species within these forests, and has been shown to be negatively impacted by certain local weather patterns. It is uncertain how changes in forest structure and species composition, fire regime, and precipitation and temperature associated with climate change will impact Northern Spotted Owl habitat and demographic rates; though evidence suggests that these trends play a role in both owl population dynamics (e.g., survival, population growth, and reproductive rates) and prey populations.

Although the rate of habitat loss has declined since the implementation of the Northwest Forest Plan in 1994, nesting and roosting habitat continue to be lost, with wildfire the leading cause of loss on federal land and timber harvest the leading cause of loss on nonfederal land. The three provinces in California have lost 9%-16% of nesting and roosting habitat since 1993, but habitat recruitment through forest succession has compensated for much of these losses. The California Klamath Province has experienced the largest habitat loss in the range of the Northern Spotted Owl with wildfire alone removing 10.7% of nesting and roosting habitat since 1993. Due to rapid growth of forests in the coastal redwood region, the net change in extent of nesting and roosting habitat in the California Coast Province has been positive. High levels of timber harvest at some activity centers has resulted in degradation of habitat at Northern Spotted Owl territories in both the coastal and interior regions, and may have caused local declines in occupancy and demographic rates. The extent of this habitat loss at the territory-scale is unknown.

Marijuana cultivation has increased in California forests since the passage of the "Compassionate Use Act" (Proposition 215) in 1996 that made it lawful to grow marijuana for certain medical purposes. Illegal marijuana cultivation (i.e., trespass grows) on public and private land are also widespread in California. The increase in grow sites may negatively impact Spotted Owls through degradation and removal of important habitat (e.g., clearing conifer or riparian stands), as well as exposure to toxins, specifically anticoagulant rodenticides, used at cultivation sites.

Sudden oak death is caused by a non-native, fungus-like pathogen and is expanding its distribution through a substantial portion of the Northern Spotted Owl range in California. Pervasiveness of this disease is not projected to subside in the future, with higher risk areas noted in northern California coastal forests. In most cases, impact to Northern Spotted Owl habitat likely includes large-scale die-off of tanoaks and other affected hardwood species (e.g., live oak, California bay laurel), reduction of hardwood canopy closure, and simplified canopy structure. These changes in forest structure will likely have negative effects on Northern Spotted Owl prey. Disease and parasites documented in Spotted Owls include West Nile Virus, borreliosis, Trichomonosis, blood or intestinal parasites, lice, fleas, ticks and flies.

Disease occurrence in Northern Spotted Owls is likely under-reported because owls tend to inhabit remote areas where carcass recovery is difficult. Therefore, the relatively low disease prevalence attributed to California's Northern Spotted Owl population in the literature may be due to the poor detection rate of carcasses, not necessarily an indication of lack of infection in the population. In addition, most research has not assessed the impacts of disease on survival or reproductive fitness. Further research is needed regarding the type of diseases most prevalent in the Northern Spotted Owl population and whether they have an impact on demographic rates.

The best available scientific information indicates that the petitioned action is warranted, and the Department recommends to the Commission that the Northern Spotted Owl be listed as Threatened under the California Endangered Species Act. This report also includes management recommendations for the recovery of the species.

Regulatory Framework

Petition Evaluation Process

A petition to list the Northern Spotted Owl (*Strix occidentalis caurina*) as threatened or endangered under the California Endangered Species Act (CESA) was submitted to the Fish and Game Commission (Commission) on September 7, 2012 by the Environmental Protection Information Center. A petition evaluation report was prepared by the Department of Fish and Wildlife (Department) and submitted on February 14, 2013, to assist the Commission in making a determination as to whether the petitioned action may be warranted based on the sufficiency of scientific information (Fish & G. Code, §§ 2073.5 & 2074.2; Cal. Code Regs., tit. 14, § 670.1, subds. (d) & (e)).

The Department's charge and focus in its advisory capacity to the Commission is scientific. A petition to list or delist a species under CESA must include "information regarding the population trend, range, distribution, abundance, and life history of a species, the factors affecting the ability of the population to survive and reproduce, the degree and immediacy of the threat, the impact of existing management efforts, suggestions for future management, and the availability and sources of information. The Petition shall also include information regarding the kind of habitat necessary for species survival, a detailed distribution map, and other factors the Petitioner deems relevant" (Fish & G. Code, § 2072.3). Focusing on the information available to it relating to each of the relevant categories of focus, the Department recommended to the Commission that the petition be accepted.

Status Review Overview

The Commission published findings of its decision to advance the species to candidacy on December 27, 2013, triggering the Department's process for conducting a status review to inform the Commission's decision on whether to list the species.

This written status review report, based upon the best scientific information available, indicates whether the petitioned action is warranted, presents preliminary identification of habitat that may be essential to the continued existence of the species, and provides management recommendations for recovery of the species (Fish & G. Code, § 2074.6). Receipt of this report is to be placed on the agenda for the next available meeting of the Commission after delivery. At that time, the report will be made available to the public for a 30-day public comment period prior to the Commission taking any action on the Department's recommendation.

Existing Regulatory Status

Endangered Species Act

The U.S. Fish and Wildlife Service (USFWS) listed the Northern Spotted Owl as threatened under the Endangered Species Act (ESA) in 1990. Critical habitat designation occurred in 1992 and 2008. The 2008 designation was challenged in court and in 2009 the USFWS requested voluntary remand of the 2008 designation. A new final rule designating critical habitat was published in December 2012. The first final recovery plan for the Northern Spotted Owl was issued in 2008 and revised in 2011.

Migratory Bird Treaty Act

The Migratory Bird Treaty Act prohibits anyone from taking, killing, or keeping any native bird, its parts, or its nest, without a permit or license. All raptors native to the U.S. are covered by this law. A Special Purpose Possession Permit and/or Endangered Species Permit (depending on species), is required under the Migratory Bird Treaty Act to keep raptors.

California Endangered Species Act

After the Commission voted to accept the petition in December, 2013, the Northern Spotted Owl became a State candidate for threatened or endangered status under CESA, commencing with section 2050 of the California Fish and Game Code.

California Bird Species of Special Concern

The Department currently designates the Northern Spotted Owl as a Species of Special Concern.

Fish and Game Code

The Fish and Game Code includes certain protections for raptors, including the Northern Spotted Owl. Sections applicable to owls include the following:

> Section 3503 - It is unlawful to take, possess, or needlessly destroy the nest or eggs of any bird, except as otherwise provided by this code or any regulation made pursuant thereto.
>
> Section 3503.5 - It is unlawful to take, possess, or destroy any birds in the orders Falconiformes or Strigiformes (birds-of-prey) or to take, possess, or destroy the nest or eggs of any such bird except as otherwise provided by this code or any regulation adopted pursuant thereto.
>
> Section 3513 - It is unlawful to take or possess any migratory nongame bird as designated in the Migratory Bird Treaty Act or any part of such migratory nongame bird except as provided by

rules and regulations adopted by the Secretary of the Interior under provisions of the Migratory Treaty Act.

California Board of Forestry and Fire Protection

The California Board of Forestry and Fire Protection and the California Department of Forestry and Fire Protection (CAL FIRE) have designated Northern Spotted Owl as a "Sensitive Species" as identified in the California Forest Practice Rules (Cal. Code Regs., tit. 14, § 895 et seq.; hereafter Forest Practice Rules). These sections also define Northern Spotted Owl -related terminology, including "activity center," "Northern Spotted Owl breeding season," and "Northern Spotted Owl Evaluation Area." Specific requirements for the disclosure of information on Northern Spotted Owls in the context of timber harvesting, which in all but one case avoid take of Northern Spotted Owl, are provided by Forest Practice Rules sections 919.9 and 919.10. Section 919.9 details the type of information about Northern Spotted Owl required in project documents submitted to CAL FIRE. This information is intended to be utilized by CAL FIRE to determine whether take of Northern Spotted Owl, in conjunction with timber harvest and related activities, would be avoided according to the criteria for determining take avoidance found in Section 919.10. Other language within Section 919 also compels methods to avoid take of Northern Spotted Owl. Sections 919.2 and 919.3 set up protections of bird nests through buffers and avoidance of sensitive areas, while section 919.1 describes how snags will be retained. Section 919.16 details the protections afforded to late successional forests, which are a component of Northern Spotted Owl habitat.

International Union for Conservation of Nature

The International Union for Conservation of Nature Red List of Threatened Species status for the Spotted Owl range-wide is "Near Threatened" because the "species has a moderately small population which continues to decline in northern and western parts of its range."

Biology and Ecology of the Northern Spotted Owl

Life History

Species Description

The Northern Spotted Owl is a medium-sized dark brown owl, with a barred tail, round, elliptical or irregular white spots on head, neck, back, and underparts, yellowish green bill, and dark brown, almost black, eyes surrounded by prominent facial disks (Gutiérrez et al. 1995). Overall, its length is approximately 46 to 48 centimeters (18 to 19 inches) (Forsman et al. 1993). Males and females are dimorphic in size, with males averaging about 13 percent smaller than females (USFWS 2011). Males weigh between 430 to 690 grams (0.95 pound to 1.52 pounds), and females weigh between 490 to 885 grams (1.1 pounds to 1.95 pounds) (Gutiérrez et al. 1995, P. Loschl and E. Forsman pers. comm. 2006 in USFWS 2011).

Taxonomy and Genetics

The American Ornithologists' Union recognizes the Northern Spotted Owl as one of three subspecies of Spotted Owls. The two other subspecies are the California Spotted Owl (*S. o. occidentalis*), ranging in the southern Cascade Range of northern California south along the west slope of the Sierra Nevada and in mountains of central and southern California, and the Mexican Spotted Owl (*S. o. lucida*) ranging from southern Utah and Colorado south to Michoacán, Mexico. The taxonomic separation of these three subspecies is supported by genetic, morphological, and biogeographic information (Barrowclough and Gutiérrez 1990, Gutiérrez et al. 1995, Barrowclough et al. 1999, Haig et al. 2004a, Chi et al. 2005, Henke et al. 2005, Barrowclough et al. 2005, Funk et al. 2008, AOU 2011). The Marin County population of Northern Spotted Owl is genetically isolated from other Spotted Owl populations in California (Barrowclough et al. 2005).

Barrowclough et al. (1999) found evidence of gene flow across all three subspecies boundaries, but based on haplotype analyses, concludes that these occurrences are infrequent. There is a recognized hybrid zone between the Northern and California Spotted Owl, which is historically recognized near the Pit River in California separating the Southern Cascades and Northern Sierra Nevada Mountains (Courtney et al. 2004, Barrowclough et al. 2005). Barrowclough et al. (2011) suggest that the hybrid zone between the two subspecies occurs from just south of the Pit River to just north of Lassen Peak (95% CI), with an estimated standard width of 94 km. There is evidence of some genetic mixing of California Spotted Owl into the Northern Spotted Owl range, but fewer examples of the opposite gene flow (Barrowclough et al. 1999, Courtney et al. 2004). For instance, in the Klamath region of California, 20.3% of owls were genetically classified as California Spotted Owls, and among all Northern Spotted Owls sampled across their range in Oregon, Washington, and California, 12.9% contained California Spotted Owl haplotypes (Haig et al. 2004a).

Until recently, there has been little evidence in the literature of loss of genetic variation and population bottlenecks for the Northern Spotted Owl (Courtney et al. 2004). However, a recent genetic study across the range of the Northern Spotted Owl (Washington Cascade Mountains, Oregon Cascade Mountains, Oregon Coast Ranges, and Klamath Mountains of Oregon and California) provides some evidence that recent population bottlenecks may have occurred, with more prominent bottlenecks in the Washington Cascade Mountains as compared to other regions included in the analysis (Funk et al. 2010).

The range expansion of Barred Owl (*Strix varia*) into the Northern Spotted Owl range has resulted in some hybridization between the two species, however hybridization is relatively uncommon (Barrowclough et al. 1999, Gutiérrez et al. 2007; see Figure 34 of this report). Hybridization may occur more frequently in an area if the Spotted Owl becomes rare and the Barred Owl more abundant (Gutiérrez et al. 2007). The majority of hybrids that have been genetically evaluated resulted from a cross between a female Barred Owl and a male Spotted Owl (Haig et al 2004b,). In addition, field observations have confirmed that a majority (if not all) of paired Barred Owl and Northern Spotted Owls are between a female Barred Owl and a male Spotted Owl (Kelly and Forsman 2004, Diller pers comm. 2015). First generation hybrids share phenotypic and vocal characteristics of both parent species (Hamer et al. 1994). Second generation hybrids are often difficult to distinguish from Barred or Spotted Owls in the field and genetic testing may be the only sure method of identification (Kelly and Forsman 2004). Both first and second generation hybrids were found to be reproductively viable in some cases (Kelly and Forsman 2004).

Geographic Range and Distribution

The current range of the Northern Spotted Owl extends from southwest British Columbia through the Cascade Range, coastal ranges, and intervening forested lands in Washington, Oregon, and northern California, as far south as Marin County (USFWS 1990). The transition between subalpine to alpine forests marks the upper elevation limit at which Northern Spotted Owls are known to occur (Forsman 1975, Forsman et al. 1984). Prior to the mid-1800s, Northern Spotted Owls are believed to have inhabited most old-growth forests or stands throughout the Pacific Northwest, including northwestern California (USFWS 2011). Although the overall range is not known to have changed, the Spotted Owl has become rare in certain areas, such as British Columbia, southwestern Washington, and the northern coastal ranges of Oregon (USFWS 2011, Dugger et al. 2016). Local declines have been observed in many portions of the range (see Status and Trends and Barred Owl sections of this report).

The range has been partitioned into 12 physiographic provinces based on landscape subdivisions with different environmental features (Thomas et al. 1990; Figure 1). This total range of the Northern Spotted Owl has been estimated to include an area of 230,690 km^2 (57 million acres; USDA and USDI 1994).

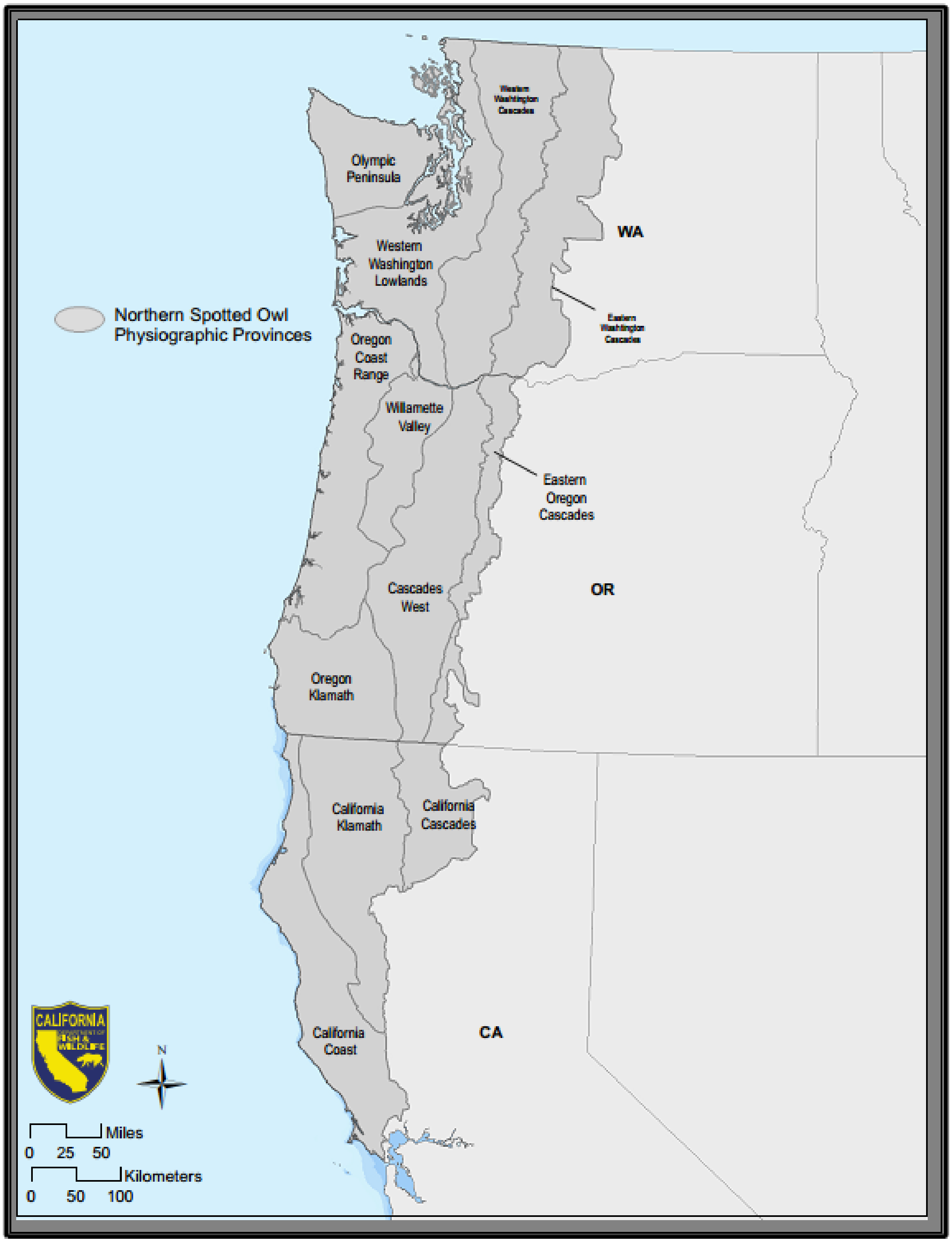

Figure 1. The 12 physiographic provinces within the Northern Spotted Owl range.

The 12 physiographic provinces are distributed across the subspecies' range as follows:

- Four provinces in Washington: Eastern Washington Cascades, Olympic Peninsula, Western Washington Cascades, Western Washington Lowlands
- Five provinces in Oregon: Oregon Coast Range, Willamette Valley, Western Oregon Cascades, Eastern Oregon Cascades, Oregon Klamath
- Three provinces in California: California Coast, California Klamath, California Cascades

In California, the Northern Spotted Owl range runs south as far as Marin County in the Coast Ranges and across the Klamath Mountains of northern California east to the Cascade Range where it meets the range of the California Spotted Owl near the Pit River (Figure 2). The California Coast Province extends from the Oregon border to San Francisco Bay and from the ocean to the western border of national forest lands. The California Klamath Province is between the California Coast Province to the west and the California Cascades Province to the east, and is a continuation of the Oregon Klamath Province, with a southern boundary at the Clear Lake Basin in the inner Coast Range. The California Cascades Province is bounded on the west by the Sacramento Valley and the Klamath Mountains, on the east by the Modoc Plateau and Great Basin, and to the south by the Sierra Nevada Mountains (USFWS 1992, Courtney et al. 2008).

Reproduction and Development

The Northern Spotted Owl is relatively long-lived with a long reproductive life span (Forsman et al. 1984, Gutiérrez et al. 1995), with wild owls living 20 years or more. Northern Spotted Owls do not build their own nest, but instead seek naturally occurring nest sites such as broken-top trees, tree cavities, dwarf mistletoe brooms (*Arceuthobium douglasii*), debris accumulations, or nests built by other wildlife (e.g., abandoned raptor nests, squirrel nests; Gutiérrez et al. 1995). Dwarf mistletoe distribution coincides with the distribution of Douglas-fir from southern British Columbia to central Mexico (Hadfield et al. 2000), and provides an important component of nesting habitat, enabling Northern Spotted Owls to nest within younger tree stands in some regions (USFWS 2011).

Owls are reproductively mature at 1 year of age, but generally do not reproduce for the first time until adulthood (≥3 years) and less frequently as subadults (<3 years) (Gutiérrez et al. 1995). Courtship initiates in February or March, with the first eggs laid in late March through April (Miller et al. 1985, Franklin 1992, Forsman et al. 2002). Timing of breeding onset varies by latitude and elevation, with delayed nesting occurring at higher elevations and latitude (Forsman et al. 1993). Females typically lay 1 to 2 eggs per clutch, with 3 eggs per clutch rarer, and 4 eggs per clutch only documented on occasion (Forsman et al. 1984, USFWS 1990, Gutiérrez et al. 1995). Incubation, performed exclusively by the female, lasts about 30 days (Gutiérrez et al. 1995, Courtney et al. 2004). The female will leave the nest only briefly to eat prey brought in by the male, defecate, preen, regurgitate pellets, and defend the nest area (Gutiérrez et al. 1995, Diller pers. comm. 2015). The male provides food to the female during incubation and early brooding, after which both adults will hunt and provide food for the young (Gutiérrez et al. 1995). Chicks generally leave the nest in late May or in June (at 34-36 days old) and continue to be dependent on their parents into September until they are able to fly and hunt on their

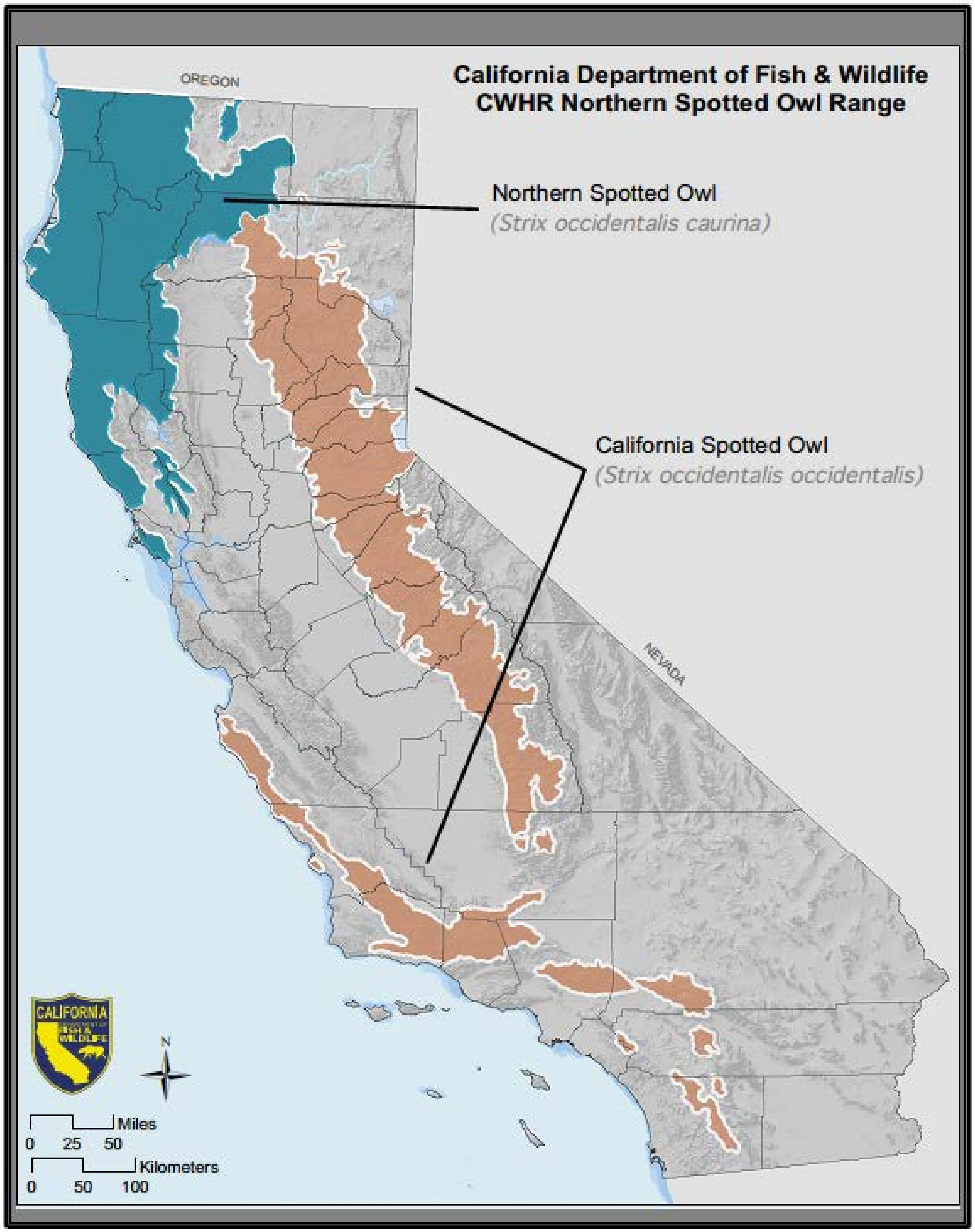

Figure 2. The California Wildlife Habitat Relationship (CWHR) depiction of the Northern Spotted Owl and California Spotted Owl range.

own (Forsman et al. 1984, USFWS 1990, Gutiérrez et al. 1995). Young may also leave the nest prematurely (15-25 days old or earlier) and may have to navigate up downed woody debris or tree limbs to return to the nest (Gutiérrez et al. 1995, Diller pers. comm. 2015). Adults can typically be found roosting with young during the day for the first few weeks after the young leave the nest, after which adults typically only visit their young during the night to deliver food (Forsman et al. 1984). In September juveniles begin to disperse, and by early November most juveniles have left their natal area (Gutiérrez et al. 1985, Miller et al. 1997, Forsman et al. 2002, Courtney et al. 2004). In a California study, starvation and predation were causes of mortality in juvenile Northern Spotted Owls during dispersal (Gutiérrez et al. 1985).

Individual Northern Spotted Owls do not always breed every year, and strong biennial patterns in breeding propensity and reproductive success are observed throughout their range (Anthony et al. 2006, Forsman et al. 2011, Dugger et al. 2016). The reason for this biennial breeding pattern is unknown, but may be due to the large time investment and energy cost to produce young (Forsman et al. 2011), although recent research suggests the costs of reproduction are not responsible for these patterns in California Spotted Owls (Stoelting et al. 2015). Annual variation in reproductive success may be related to weather conditions and fluctuations in prey abundance, but may also be related to individual variation, age, and habitat quality within the territory (Forsman et al. 1993, Forsman et al. 2011). Turnover at a site (i.e., one member of the owl pair is replaced by a new individual) may also negatively influence reproductive success (Thome et al. 2000). Small clutch size, temporal variation in nesting and nest success, and low productivity by young birds (<3 years of age) all contribute to low annual fecundity for the Northern Spotted Owl (Gutiérrez 1996).

Population Density

Population density (i.e., number of individuals per unit of area) of Northern Spotted Owls has been estimated for specific study areas, but not across the subspecies' entire range; several estimates of density are available from sites in California (Table 1). Density estimates for Northern Spotted Owls are difficult to obtain due to the level of effort required to survey all potential suitable habitat in a given area. Furthermore, population densities can only be determined for territorial individuals since the "floater" or non-territorial Spotted Owls do not readily respond to surveys utilizing broadcast lure calls.

Using population density to assess Northern Spotted Owl population is problematic for various reasons. Density values reported in different study areas may not be comparable as the area surveyed and the analytical method used to arrive at a density estimate differs. For instance, estimates of population density using empirical counts (i.e., naïve count without accounting for detection probabilities) can underestimate density because many owls in an area may go undetected. Conversely, if a substantial number of owls in the area are not banded, the empirical counts can result in overestimates since owls moving throughout the area may be double counted. For these reasons it is more appropriate to assess occupancy and rate of population change to assess Northern Spotted Owl population, both of which are discussed later within this report.

Table 1. Population density estimates for Northern Spotted Owls within various study areas throughout the range in California. Early estimates were identified as studies occurring in the 1990s, while later estimates were identified from studies over the last several years.

Source	Density Measure	Location
early density estimates		
Franklin et al. 1990 [a]	0.235 territorial owls/km^2 0.544 number of owls/ km^2 of habitat 0.660 number of owls/ km^2 of habitat	Willow Creek Study Area in Humboldt County
Tanner and Gutiérrez 1995 [b]	0.219 owls/km^2	Redwood National Park in Humboldt County
Diller and Thome 1999 [a]	0.092 owls/km^2 (Klamath) 0.351 owls/km^2 (Korbel) 0.313 owls/km^2 (Mad River) 0.209 owls/km^2 (mean)	Northern California coast study area in Humboldt, Trinity and Del Norte counties (Green Diamond Resource Company)
later density estimates		
GDRC 2015 [b]	0.042 owls/km^2 (northern) 0.192 owls/ km^2 (southern)	Green Diamond Resource Company land in Humboldt County
Roberts et al. 2015 [b]	0.068 territories/km^2 (1989-2003) [d] 0.068 territories/km^2 (2003-2007) 0.069 territories/km^2 (2011-2013)	Sierra Pacific Industry lands in Trinity, Siskiyou, Shasta, Modoc and Lassen counties [c]
MRC 2014 [b]	0.285 owls/km^2 0.172 occupied territories/km^2 of area surveyed 0.113 pairs/km^2	Mendocino Redwood Company in Mendocino County
HRC 2013 [b]	0.184 occupied territories/km^2 of area surveyed 0.336 owls/km^2 of area surveyed	Humboldt Redwood Company in Humboldt County

[a] Density estimate statistically derived including 95% confidence interval.
[b] Density estimate an empirical count without confidence intervals.
[c] Densities were reported for Modoc and Lassen counties in this study; however these counties are not within the range of the Northern Spotted Owl. Sierra Pacific Industry lands in this study overlap with the California Spotted Owl range.
[d] Estimate result includes assumptions that were not tested.

As apparent from the reports of density estimates in Table 1, there is some variation among studies, especially those using empirical count data, even though most studies occurred in coastal forests. This variation in density may be attributed to habitat availability, habitat heterogeneity, territoriality, weather patterns, and presence of Barred Owls (Franklin et al. 1990, Diller and Thome 1999, Courtney et al. 2004, Sovern et al. 2014). Another possible explanation of the variation is that data collection and analysis varied among the studies (e.g. use of naïve empirical counts rather than statistically derived estimates). Given this variation, it is not possible to extrapolate density across the entire California range for Northern Spotted Owl, because density estimates are not comparable between study areas and over time these data cannot be used to interpret Northern Spotted Owl population status in California.

Broad-scale patterns of density (and abundance) of Spotted Owls are sometime inferred by the distribution of recorded Northern Spotted Owl activity centers across the landscape. However, caution must be used when examining Northern Spotted Owl activity center distribution as a substitute for density or abundance. Activity center sites may not represent the actual number or density of owls across the range in California due to the nature of how the data are collected and reported. Data are often collected inconsistently based on local project-level monitoring needs and not all data are reported to the Department's database. Also, activity centers are generally retained in the database over time regardless of annual occupancy status (see Status and Trends section of this report).

An activity center is a known Northern Spotted Owl site documented from survey detections (See Appendix 2 for a more detailed definition of activity center). Records from the Department's Spotted Owl Database indicate that generally fewer activity centers occur in the drier portions of the interior Klamath and Cascade ranges, compared to the Coastal Range and wetter portions of the Klamath Province (Figure 3). The 2011 Recovery Plan (USFWS 2011) acknowledges lower interior numbers of Northern Spotted Owls stating, "…the dry forest portion of the Spotted Owl's range hosts a minority of the overall population…" It appears many activity centers within the California Coast Province have been documented only beginning in the 1990s. This is due to increased survey effort by private timber companies following the listing by the federal government rather than an increase in Spotted Owl territories in the California Coast Province.

Some timber companies have reported increases in Northern Spotted Owl activity centers, though this increase may not represent a net increase in number of owls on the landscape, but rather a dynamic nature of habitat on timberlands and how owls respond to these shifts. For instance, Green Diamond Resource Company reported the addition of 58 new sites since 1994 in a portion of their property in Humboldt and Del Norte counties that is completely surveyed each year, and attributes this (at least in part) to improved habitat conditions as forests mature (GDRC 2015). However, this does not indicate a net increase in owl sites across the ownership, because other sites have been lost due to timber management and the influence of Barred Owls. Humboldt Redwood Company has also reported an increase in number of owl activity centers since 2008, but acknowledges the possibility that the increase may be due to the displacement of Spotted Owls to new activity centers as a result of increasing numbers of Barred Owls (HRC 2015). Large timber companies in the coastal portion of the range have identified a large number of activity centers on their ownerships, with more than 200 activity centers on some ownerships. Consistent with the general pattern, private ownerships in the interior report fewer Northern Spotted Owl activity centers, but some timber companies still report close to a hundred activity centers (Calforests 2014).

Home range size and habitat distribution may also play a role in understanding distribution of Northern Spotted Owls across the landscape in California (see Territoriality, Home Range, and Core Use Areas section below). Home range size varies from north to south, with larger home ranges in the northern portion of the range than in the southern portion of the range (Courtney et al. 2004). This variation across the range likely influences observed patterns in numbers since Northern Spotted Owls are territorial and generally exclude other conspecifics from their territory. Distribution of habitat within home ranges may also strongly influence owl distribution on any given landscape.

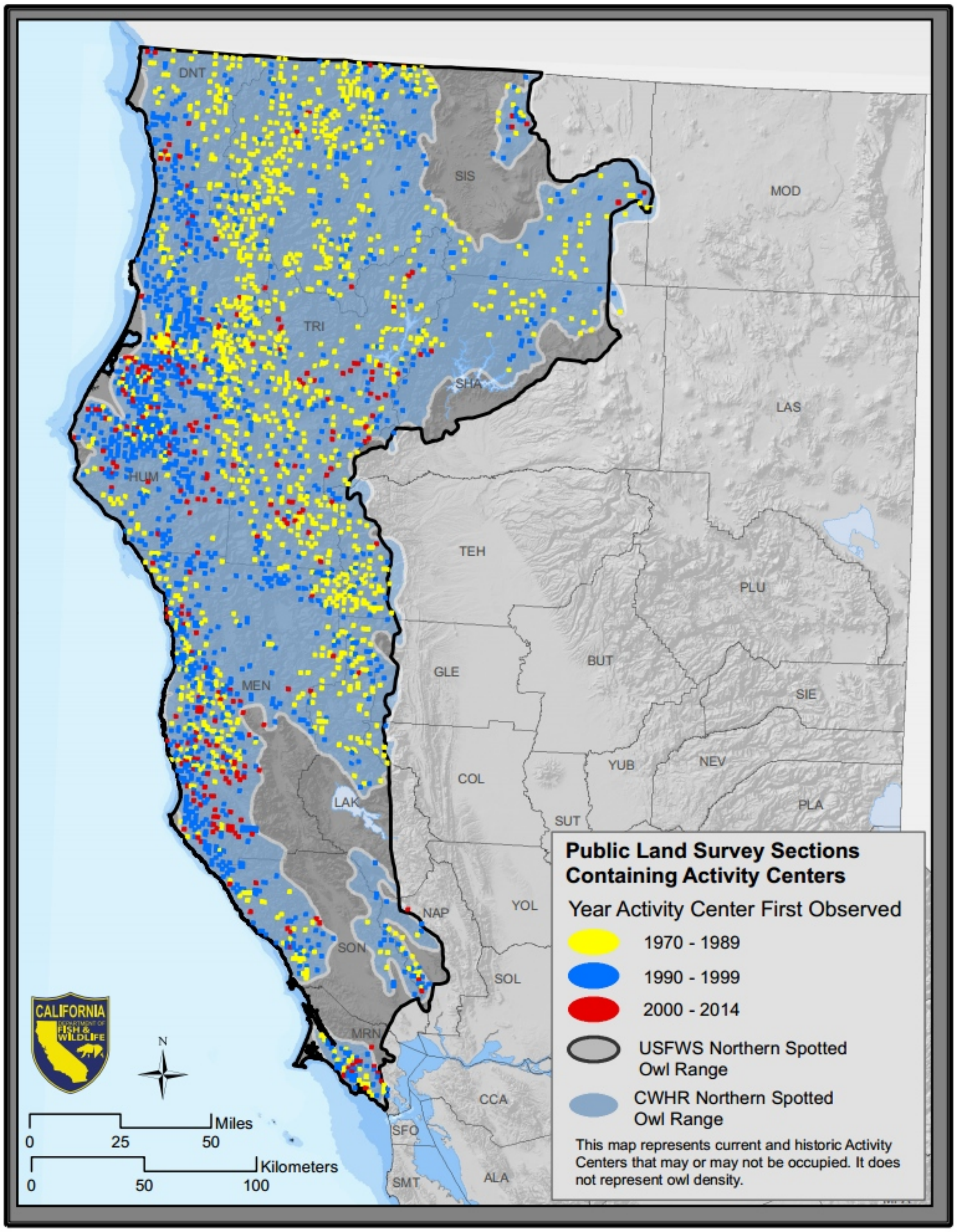

Figure 3: Public Land Survey Sections containing Northern Spotted Owl activity centers in California documented within the Department's Spotted Owl Database, 1970-2014. A large portion of the increase in number of activity centers over time can be attributed to an increase in survey effort. A portion of the more recent activity centers may have resulted from new territories in areas of habitat recruitment; this is most likely in the coastal redwood portion of the range where forest growth is relatively fast and owls have been shown to use younger forests. Establishment of new activity centers may also represent displacement of owls from previously occupied habitat by Barred Owls or due to habitat loss. For these reasons, and the fact that the number of occupied activity centers in any given year is unknown, activity centers do not necessarily reflect current abundance or density.

Hunting and Food Habits

As described in Forsman et al. (1993), Northern Spotted Owls are sit and wait (e.g., perch and pounce) predators. They mostly hunt during nighttime hours (i.e., nocturnal), but will forage during the day as well (Forsman et al. 1984, Sovern et al. 1994, Forsman et al. 2001). Generally, flying squirrels (*Glaucomys sabrinus*) are the main component of the diet in Douglas-fir and western hemlock forests within the northern portion of the owl's range (in much of Washington and Oregon); whereas in the southern portion of the range (Oregon Klamath, California Klamath, and California Coast provinces) dusky-footed woodrats (*Neotoma fuscipes*) are the main component of the diet (Forsman et al. 1984, 2001, 2004, Zabel et al. 1995, Hamer et al. 2001). Other prey items seen in the owl's diet in smaller proportions include deer mice, tree voles, red-backed voles, shrews, gophers, snowshoe hare, rabbits, bushy-tailed woodrats, chipmunks, small to medium sized birds, bats, and insects (Forsman et al. 1984, 2001, 2004, Ward et al. 1998, Hamer et al. 2001, Wiens et al. 2014).

A study in the southern portion of Oregon adjacent to the California border found a roughly equal biomass of flying squirrels (38.6%) and woodrats (37.1%) in the diet of Northern Spotted Owls within the southern coast region (including portions of the Oregon Klamath and Oregon Coast Range provinces) (Forsman et al. 2004). The same study found a higher biomass of woodrats in the diet of owls (48.5% woodrat vs. 30.2% flying squirrel) in the interior southwest region (including portions of the Oregon Klamath and Western Oregon Cascades provinces), and a higher biomass of northern flying squirrels in the diet of owls (50.7% flying squirrel vs. 18.2% woodrat) in the Eastern Oregon Cascades (Forsman et al. 2004). A study in Humboldt and Del Norte counties of coastal California indicated that dusky-footed woodrats comprised 45% of the frequency and 74% of the prey biomass, but tree voles and flying squirrels were also important in the overall composition of the owl's diet (Diller et al. 2010). In the California Klamath and California Cascades provinces, Farber and Whitaker (2005) identified biomass of major prey items consisting of 58.3% woodrat species and 29.2% northern flying squirrel on privately owned timberland (Farber and Whitaker 2005). In the Cascades portion of the study area, northern flying squirrels made up the majority of the total individual prey items, but woodrat species still made up more of the total biomass (46.7% woodrat vs. 34.0% flying squirrel; Farber and Whitaker 2005). Overall, these results suggest a higher proportion of woodrats in the diet of Northern Spotted Owl in much of the Klamath region of Oregon and California, and on the California Coast. Results of studies from the Cascades in the interior of California and southern Oregon are mixed, but suggest that in some regions woodrats are the primary prey, and in others flying squirrels are the primary prey.

Weathers et al. (2001) found that California Spotted Owls had low basal metabolic rates and, on average, can meet their energy requirements by consuming one northern flying squirrel every 1.8 days or one woodrat every 3.7 days. Similar work has not been conducted for Northern Spotted Owls. Given similarities between these two subspecies this low metabolic rate may be similar in Northern Spotted Owls; however, differences in phylogeny, habitat requirements, weather patterns, and other factors could lead to differences in metabolic rates. Regardless, this finding shows that the larger size of woodrats can meet more of an owl's energetic needs per prey item. Ward et al. (1998) found that

Northern Spotted Owls that were successful breeders selected sites with abundant woodrats, thus providing some evidence of the energetic benefit of this larger and more abundant prey source.

As discussed in the subsequent sections of this report, evidence demonstrates that prey abundance and availability affect selection of habitat and home range size of Northern Spotted Owls across their range. Owls tend to use a larger space and select old-growth forests with less edge habitat for foraging when flying squirrels are the dominant prey item, whereas, in southern parts of their range where woodrats are more common in the diet, home ranges are smaller and include more edge habitat (Courtney et al. 2004). Therefore, prey abundance and availability is likely one driving force for spatial configuration of habitat used by Northern Spotted Owls in California.

Territoriality, Home Range, and Core Use Areas

Northern Spotted Owls are highly territorial, actively defending an area using aggressive vocal displays, and even physical confrontations on rare occasions (Forsman 1983, Franklin et al. 1996, Van Lanen et al. 2011). Because of their strong territoriality, broadcast surveys are generally a very effective method for determining presence of resident Spotted Owls (Reid et al. 1999); however, calling may be suppressed by the presence of Barred Owls (see Barred Owl section of this report).

Home range size (i.e., the total area utilized by an individual owl for all its life needs) varies for Northern Spotted Owls depending on the setting and structure of the habitat (e.g., canopy closure, understory composition, and slope), number of available nesting and roosting sites, and location relative to suitable foraging habitat (Forsman et al. 1984, Glenn et al. 2004, Schilling et al. 2013). In general, Spotted Owls have a broad home range with a centrally located nest and roosting site. For this reason, Spotted Owls are considered central place foragers during the breeding season when they are tied to a central nesting or roosting site (Bingham and Noon 1997, Rosenberg and McKelvey 1999). Typically, Northern Spotted Owl home ranges have a greater amount of older forest near the nest and within the core area of use, and more diverse forest types and ages on the periphery of their ranges (Carey and Peeler 1995, Hunter et al. 1995, Swindle et al. 1999). Estimates of annual home range size vary across the Northern Spotted Owl's range (Table 2).

Home ranges of Northern Spotted Owls commonly overlap with those of neighboring Spotted Owl pairs, indicating that the defended area (i.e., territory) is smaller than the full home range which is used for foraging (Forsman et al. 1984, Solis and Gutiérrez 1990, Wiens et al. 2014, Forsman et al. 2015). As mentioned earlier, Northern Spotted Owl home ranges are larger in the northern portion of the range and smaller in the southern portion of their range, presumably due to differences in predominant prey types (Zabel et al. 1995, Forsman et al. 2001). Woodrats provide twice or more the biomass of flying squirrels and can occur at high population densities (Hamm 1995, Hughes 2005), therefore are thought to be more energetically favorable, which likely explains the smaller home range in the Northern Spotted Owl's southern portion of the range where woodrats are predominant in owl diets (Ward et al 1998, Franklin et al. 2000). The portion of the home range used during the breeding season can be significantly smaller than that used in the remainder of the fall and winter (Forsman et al. 1984, Sisco

1990 as cited in USFWS 2011, Forsman et al. 2015), possibly due to prey dynamics and exploratory excursions in search of better habitat during the winter (Forsman et al. 2015).

Like many other animals, Northern Spotted Owls exhibit selective behavior by utilizing certain areas within their home range more intensively than others (Carey and Peeler 1995, Bingham and Noon 1997). These areas of disproportionate use, termed core use areas, commonly include nest and roosting sites and access to dependable food sources. Bingham and Noon (1997) used breeding-season owl telemetry relocations and an adaptive kernel algorithm and found that Northern Spotted Owls spent 60 to 75% of their time in their core use areas. The mean core use area size for Northern Spotted Owl pairs in this study was 166 hectares (SE = 26 hectares, range = 68-184 hectares). Adding one standard error to the mean size of pairs' core area, and assuming a circular shape for the purpose of evaluating and managing habitat, a core use area of this size would have a radius of 0.49 mile. Carey and Peeler (1995) had similar findings near Roseburg, in southern Oregon.

Disproportionate use of core areas is likely influenced by territoriality in Northern Spotted Owls, and the core use area is likely a good scale at which to evaluate and manage habitat since it is contains needed resources and is defensible. Observed territorial spacing of Northern Spotted Owls provides additional support for using a 0.5 mile-radius core use area for habitat management purposes. Half the nearest neighbor distance can be used to estimate the size of the defended portions of the home ranges. Half the mean and median nearest neighbor distances for nesting Northern Spotted Owls were 0.49 mile (Hunter et al. 1995) and 0.44 mile (Franklin et al. 2000), respectively. Additional support for the validity of managing habitat within core use areas estimated as a 0.5-mile radius area around activity centers is provided by studies that modeled habitat fitness potential (Franklin et al. 2000, Dugger et al. 2005) and probability of occupancy (Zabel et al. 2003). These studies found that important Northern Spotted Owl habitat relationships were well captured at scales of 0.44 to 0.50 mile. Other studies have shown that habitat conditions in the broader home range can affect Northern Spotted Owl occupancy, survival, and fitness (Meyer et al. 1998, Olson et al. 2004, Dugger et al. 2005); therefore these areas must also be considered when managing for Northern Spotted Owl habitat.

Table 2. Summary of annual home range and core home range sizes across the range of the Northern Spotted Owl. MCP = Minimum Convex Polygon, MMCP = Modified Minimum Convex Polygon, FK = Fixed Kernal, and AK = Adaptive Kernal.

	Annual Home Range in hectares (+/- one Standard Error)				Core area use in hectares	
Area	MCP	MMCP	95% FK	95% AK		Source
Oregon Coast	1,569(463)	1,018(160)				Carey et al. 1992
Oregon Coast	1,108(137) to 2,214(357)		842(115) to 1,344(247)		87(6) to 100(5) 95% FK	Glenn et al. 2004
Oregon Coast	2,272 (median)					Paton et al. 1990 (as reported in Thomas et al. 1990)
Oregon Coast	2,586 (median)					Thraikill and Meslow pers comm. (as reported in Thomas et al. 1990)
Oregon Coast	1,693 (median)					Carey et al. 1990 (as reported in Thomas et al. 1990)
Oregon Coast			2,507(332) to 3,165(490)			Wiens et al. 2014
Oregon Coast	817(214)					Zabel et al. 1995
Oregon Klamath	533(58)	472(43)				Carey et al. 1992
Oregon Klamath			576(75)		94(11), 95% FK	Schilling et al. 2013
Oregon Western Cascades	3,066(1080)				417(129), AK	Miller et al. 1992
Washington Eastern Cascades	3,419(826)		2,427(243)			Forsman et al. 2015
Washington Eastern Cascades	3,669(876)					King 1993
Washington Western Cascades	2,553 (median)					Various references as reported in Thomas et al. 1990
Washington Olympic Peninsula	4,019 (median)					Various references as reported in Thomas et al. 1990
California Klamath	755 to 1198 (median)				603 to 1016 (median)	Paton et al. 1990
California Klamath	412.8, all owls 676.8, pairs					Solis 1983

California Klamath	breeding: 157.0 to 677.9 winter: 1866 to 2507.1 annual: 266.3 to 2687.6					Sisco 1990
California Klamath	422(181) 591(234)					Zabel et al. 1995
California Klamath	412.9(196.9) 337.6(196.4) for males 538.0(144.2) for females					Solis and Gutiérrez 1990
California Klamath				522.7(72.7) at Mad River 676.9(108.6) at Ukonom	AK 111.8(18.5) at Mad River 146.5(25.4) at Ukonom	Bingham and Noon 1997[a]
California Coast	786(145)			685(112)	98(22), 95% AK	Pious 1995
California Coast			391(79) breeding 560(159) non-breeding			Weisel 2015

[a] This study included home range analysis for Northern Spotted Owls at Mad River and Ukonom study areas, and California Spotted Owls at a Lassen in northern California. Though not included in the table, home range and core area use for California Spotted Owl was 4263.3 (1954.2) and 813.4 (301.1), respectively. The Lassen study area was in the Cascade Range and results for California Spotted Owl here may correspond to area use by Northern Spotted Owls in this same region.

Dispersal

As discussed above, juveniles begin to disperse in the fall, with a few individuals beginning to disperse in early winter. Juvenile dispersal from the parental territory occurs in stages, as juveniles may temporarily settle in locations for up to 7 months before moving on to another temporary location, which may occur several times before individuals establish a territory of their own (Gutiérrez et al. 1985, Miller et al. 1997, Forsman et al. 2002). By late October, most young Northern Spotted Owls have dispersed from the natal area (Gutiérrez et al. 1985). LaHaye et al. (2001) found that successful juvenile California Spotted Owls often settled in territories previously used by pairs or single owls, which may suggest that owls were able to use some sort of cues that indicated some value of habitat quality when determining a territory of their own (Buchanan 2004).

In a study within Oregon and Washington, the median dispersal distance from fledging to a permanent territory was between 13.5 and 14.6 km (8.4-9.1 mi) for male Northern Spotted Owls and between 22.9 and 24.5 km (14.2-15.2 mi) for females (Forsman et al. 2002). Through band returns, dispersal distances for California Spotted Owls in southern California were determined to be 2.3 to 36.4 km (1.4-22.6 mi) for juvenile males, while juvenile females dispersed a distance of 0.4 to 35.7 km (0.2-2.2 mi) (LaHaye et al. 2001). Based on recapture of 368 Northern Spotted Owls initially banded as juveniles for their study area in Humboldt and Del Norte counties of coastal California, Green Diamond Resource Company reported dispersal distances of 0.8 to 150 km (0.5-93 miles), with a mean of 12.6 km (7.8 miles) for 179 males (one male with an unknown dispersal distance) and 1.3 to 141 km (0.8-87.4 miles) with a mean of 16.6 miles for 138 females (GDRC 2015). However, it should be noted that dispersal distances based on recapture data are inherently biased low, because the probability of recapture decreases with the greater distance that an individual moves. Using radio telemetry tracking on 13 juvenile Northern Spotted Owls, dispersal distances in a northwestern California study (within Six Rivers, Klamath, and Shasta-Trinity National Forests) ranged from 30 to 156 km (18.6-96.9 miles; Gutiérrez et al. 1985). While the majority of data available on dispersal pertains to Northern Spotted Owls in Washington and Oregon, and California Spotted Owls in California, it is likely that Northern Spotted Owls in California act similarly, because, while the populations are genetically and geographically distinct, they still share many ecological and behavioral characteristics.

Juvenile Northern Spotted Owls experience high mortality rates (>70% in some areas) during dispersal due to a variety of factors including starvation, predation, and vehicle strikes (Miller 1989, Franklin et al. 1999, USFWS 1990, Forsman et al. 2002). Habitat type used during dispersal may also have an effect on mortality. Miller et al. (1997) found that the probability of mortality decreased when dispersing juveniles utilized open sapling forests, but increased when clear cuts were utilized. Successful juvenile dispersal likely depends on locating suitable nesting, roosting and foraging habitat in proximity to other occupied sites or among occupied sites (LaHaye et al. 2001), as well as the presence of suitable habitat to disperse through (Miller et al. 1997, Buchanan 2004, Sovern et al. 2015).

Habitat Requirements

Descriptions of Geographic Provinces and Modeling Regions in California

Forests in the California range of the Northern Spotted Owl are diverse, and owls use habitat differently among these forest types. Historically the range of the Northern Spotted Owl has been separated into 12 physiographic provinces based on differences in vegetation, soils, geologic history, climate, land ownership and political boundaries (USFWS 2011; see Figure 1 and 4). Three of these provinces are in California – California Coast, California Klamath, and California Cascades. The range of forest types used and forest characteristics that influence habitat quality vary regionally across California; general owl habitat within each province is described below.

In addition to province delineations, habitat modeling conducted for the 2011 Revised Recovery Plan (USFWS 2011) identified 11 modeling regions range-wide, five of which occur in California (Figure 4). These modeling regions were developed to capture regional differences in forest environments in acknowledgement of the fact that Northern Spotted Owls exhibit different habitat associations in various portions of their range, and focused on differences in habitat rather than political boundaries or ownership type. For this reason, four of the five modeling regions in California extend into Oregon where similar habitat occurs. Modeling regions that overlap with the California Coast, California Klamath and California Cascade provinces are described below under the appropriate province description.

<u>California Coast Province</u>

A description of the California Coast Province is provided below, as defined in the 1992 Northern Spotted Owl recovery plan (USFWS 1992):

> "The California Coast province extends from the Oregon border to San Francisco Bay and from the ocean to the western border of national forest lands. The coastal part of the province encompasses the majority of the redwood forest habitat type. Inland forests are Douglas-fir and mixed Douglas-fir/hardwood types, the latter often interspersed with chaparral and grasslands."

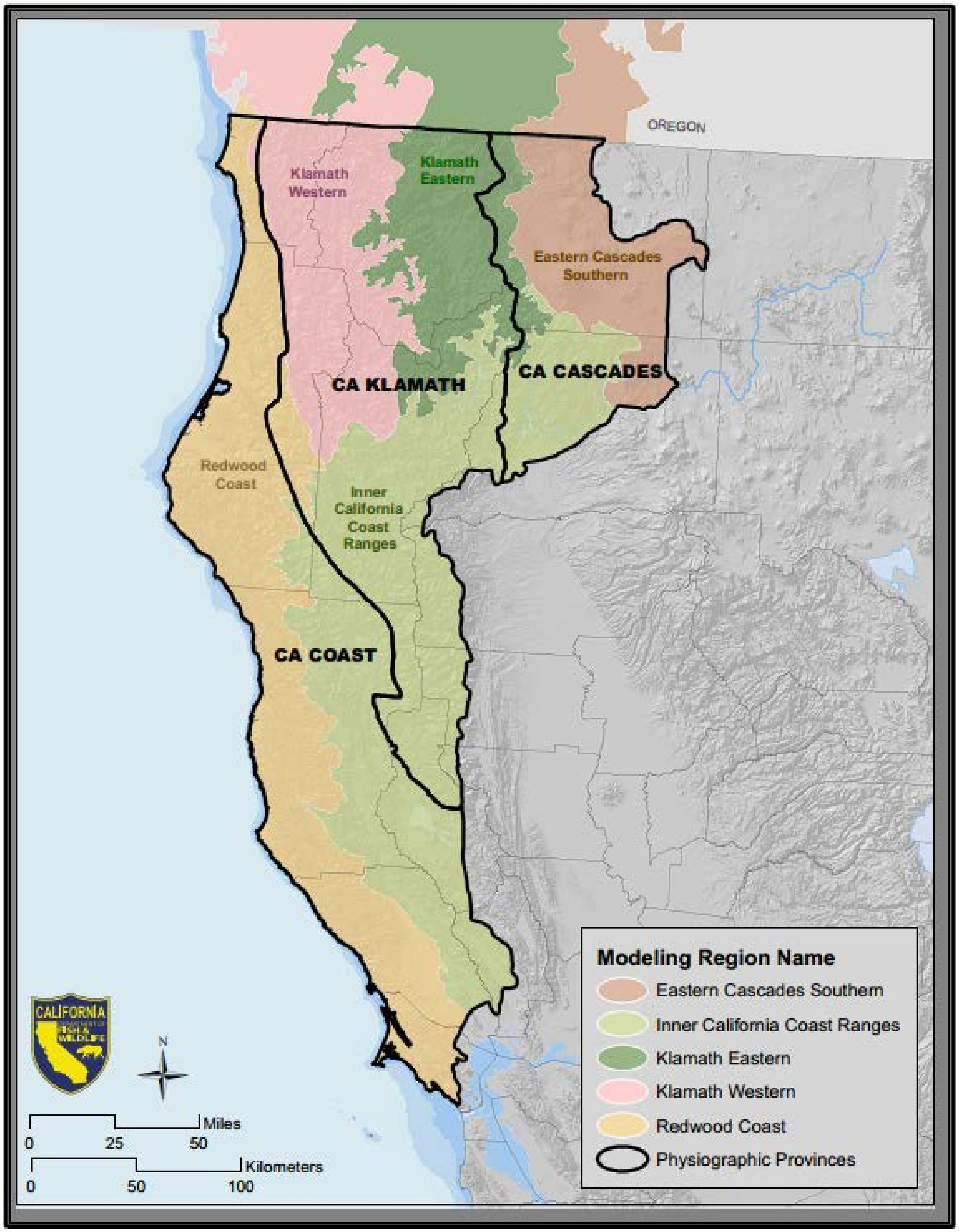

Figure 4. Modeling regions and physiographic provinces in California described in the 1992 Northern Spotted Owl recovery plan and the 2011 Revised Recovery Plan for Northern Spotted Owls.

Two modeling regions described in Appendix C of the 2011 Revised Recovery Plan (USFWS 2011) are included in the California Coast Province, the Redwood Coast (RDC) and Interior Coast (ICC) regions. The RDC is described below:

> "This region is characterized by low-lying terrain (0 to 900 m) with a maritime climate; generally mesic conditions and moderate temperatures. Climatic conditions are rarely limiting to Spotted Owls at all elevations. Forest communities are dominated by redwood, Douglas-fir-tanoak forest, coast live oak, and tanoak series. The vast majority of the region is in private ownership, dominated by a few large industrial timberland holdings. The results of numerous studies of Spotted Owl habitat relationships suggest stump-sprouting and rapid growth rates of redwoods, combined with high availability of woodrats in patchy, intensively-managed forests, enables Spotted Owls to maintain high densities in a wide range of habitat conditions within the Redwood zone. This modeling region contains the Green Diamond and Marin DSAs [density study areas]." (USFWS 2011, pg. C-9 and C-10).

Most of coastal northwestern California has experienced high levels of historical logging, mainly in the form of large clearcuts, which has resulted in younger forests. However, these young redwood and mixed conifer-hardwood stands appear capable of supporting higher numbers of Northern Spotted Owls compared to younger forests in other regions, particularly in areas where hardwoods provide a multilayered structure within a conifer stand (Thomas et al. 1990, Diller and Thome 1999, Diller et al. 2012, Weisel 2015). As discussed elsewhere in this report, high densities do not necessarily indicate high quality habitat (i.e., habitat conferring high survival and fecundity). It is thought that stump-sprouting of redwoods and evergreen hardwoods (e.g., tanoak, madrone, California bay), rapid growth rates of redwoods, and high abundance of prey (mainly woodrats) in patchy intensively managed stands (e.g., small-patch clearcuts with residual old trees), allow owls to occupy this habitat in higher numbers in this region (Thomas et al. 1990, Folliard et al. 2000, USFWS 2011, Diller et al. 2012). Northern Spotted Owls are heat-intolerant and select cool summer roost sites to help thermoregulate (Barrows 1981). Therefore, significantly cooler summer temperatures in coastal forests as compared to high summer temperatures in interior forests also likely result in higher suitability of younger redwood forest stands as compared to younger inland stands.

The Redwood National and State Parks in coastal northern California are thought of as a stronghold for remaining old-growth redwood forests in California and provide pristine Northern Spotted Owl habitat, with approximately 16,670 hectares of old-growth and 18,219 hectares of second-growth (i.e., ≥ 40 years old) forests (Schmidt 2015). Despite this, Northern Spotted Owl occupancy within the park is low, thought to be an artifact of the recent expansion of Barred Owls into this area (see the Barred Owl section of this report for further discussion).

The ICC differs strikingly from the adjacent coastal redwood region, and is described below:

> "This region… differs markedly from the adjacent redwood coast region. Marine air moderates winter climate, but precipitation is limited by rain shadow effects from steep elevational gradients (100 to 2,400 m) along a series of north-south trending mountain ridges. Due to the

> influence of the adjacent Central Valley, summer temperatures in the interior portions of this region are among the highest within the Spotted Owl's range. Forest communities tend to be relatively dry mixed conifer, blue and Oregon white oak, and the Douglas-fir-tanoak series. Spotted Owl habitat within this region is poorly known; there are no DSAs and few studies have been conducted here. Spotted Owl habitat data obtained during this project suggests that some Spotted Owls occupy steep canyons dominated by live oak and Douglas-fir; the distribution of dense conifer habitats is limited to higher elevations on the Mendocino National Forest." (USFWS 2011, pg. C-12, C-13).

The southern limit of the owl's range in Marin County (part of the California Coast Province and the RDC region) contains coast redwood, Bishop pine (*Pinus muricata*) and Douglas-fir forests and mixed evergreen-deciduous hardwood forests (e.g., California bay, tanoak and coast live oak) which are regularly used by Northern Spotted Owls (Jenson et al. 2006, USFWS 2011). Stralberg et al. (2009) found that owls inhabiting Marin County mixed forests were equally likely to be found in conifer dominated stands or hardwood dominated stands, and there did not seem to be a preference for any one tree species for owl nest sites.

<u>California Klamath Province</u>

A description of the California Klamath Province is provided below, as defined in the 1992 Northern Spotted Owl recovery plan (USFWS 1992):

> "The California Klamath province is between the California Coast province and the California Cascades province. It is a continuation of the Oregon Klamath province, south to the Clear Lake Basin in the inner Coast Range. The area is mountainous and covered primarily with Douglas-fir forests. Mixed Douglas-fir/pine forests are common at lower elevations with Douglas-fir/true fir forests at higher elevations."

Two modeling regions described in Appendix C of the 2011 Revised Recovery Plan (USFWS 2011) make up the majority of the California Klamath Province, the Western Klamath (KLW) and Eastern Klamath (KLE) regions. The ICC modeling region, which is described above, represents a relatively small southern portion of the California Klamath Province. The KLW is described below:

> "A long north-south trending system of mountains (particularly South Fork Mountain) creates a rain shadow effect that separates this region from more mesic conditions to the west. This region is characterized by very high climatic and vegetative diversity resulting from steep gradients of elevation, dissected topography, and the influence of marine air (relatively high potential precipitation). These conditions support a highly diverse mix of mesic forest communities such as Pacific Douglas-fir, Douglas-fir tanoak, and mixed evergreen forest interspersed with more xeric forest types. Overall, the distribution of tanoak is a dominant factor distinguishing the Western Klamath Region. Douglas-fir dwarf mistletoe is uncommon and seldom used for nesting platforms by Spotted Owls. The prey base of Spotted Owls within the Western Klamath is diverse, but dominated by woodrats and flying squirrels. This region

> contains the Willow Creek, Hoopa, and the western half of the Oregon Klamath DSAs." (USFWS 2011, pg. C-12).

The KLE differs from KLW by the reduced influence of marine air and a slightly varying forest composition. The KLE is described below:

> "This region is characterized by a Mediterranean climate, greatly reduced influence of marine air, and steep, dissected terrain. Franklin and Dyrness ([1973]) differentiate the mixed conifer forest occurring on the "Cascade side of the Klamath from the more mesic mixed evergreen forests on the western portion (Siskiyou Mountains), and Kuchler (1977) separates out the eastern Klamath based on increased occurrence of ponderosa pine. The mixed conifer/evergreen hardwood forest types typical of the Klamath region extend into the southern Cascades in the vicinity of Roseburg and the North Umpqua River, where they grade into the western hemlock forest typical of the Cascades. High summer temperatures and a mosaic of open forest conditions and Oregon white oak woodlands act to influence Spotted Owl distribution in this region. Spotted Owls occur at elevations up to 1768 m. Dwarf mistletoe provides an important component of nesting habitat, enabling Spotted Owls to nest within stands of relatively younger, small trees. The western half of the South Cascades DSA and the eastern half of the Klamath DSA are located within this modeling region." (USFWS 2011, pg. C-12).

Numerous habitat use studies have been conducted in the California Klamath Province, and in similar habitat within southwestern Oregon (Table 3). These studies vary in methods used (e.g., habitat sampling vs. analytical modeling), scale (e.g., population vs. home range vs. smaller core area) and target metrics (e.g., occupancy vs. reproductive parameters vs. habitat use); therefore, if useful comparisons are to be made a clear understanding of these differences must be taken into account (Franklin and Gutiérrez 2002). Generally, Northern Spotted Owl habitat within the California Klamath Province consists of structurally complex mixed-species forests, with a component of large trees.

Table 3. Summary of Northern Spotted Owl habitat studies in the Klamath Province (partially adapted from USFWS 2009, Table III.C.1). Note: this is not an exhaustive list of all habitat studies within this province.

Study	Location	Scale	Method	Target Metric	Description of Selected or Suitable Habitat
Blakesley et al. 1992	northwestern California	core area	visual detections, ground sampling, USFS timber stratum maps	habitat use	coniferous forest characterized by trees >53.3cm in diameter, forests at 300-900 m elevations for roosting, and the lower third of slopes within a specific drainage
Carey et al. 1992	southwestern Oregon	territory	aerial photographs, forest inventory data, ground reconnaissance	habitat use	multi-layered canopy, average DBH of dominant trees >39.4 inches, large snags and logs
Dugger et al. 2005	southwestern Oregon	territory	aerial photographs, ground reconnaissance	demographic performance	conifer or mixed forest, >100 years; characterized by trees >13.8 inches DBH
Franklin et al. 2000	northwestern California	territory	satellite imagery, ground reconnaissance	demographic performance	forest comprised of >40% conifers, conifer QMD2 >21 inches, hardwood QMD >6 inches, canopy cover >70%
Gutiérrez et al. 1998	northwestern California	core area	satellite imagery, ground reconnaissance	habitat use	>30% canopy cover, >50% of conifer basal area comprised of trees >21 inches DBH
Hunter et al. 1995	northwestern California	core area	satellite imagery, ground reconnaissance	habitat use	>30% canopy cover, >50% of conifer basal area comprised of trees >21 inches DBH
Irwin et al. 2012	southwestern Oregon and northcentral California	territory	ground sampling, modeling	habitat use	Selection tied to increasing average diameter of coniferous trees and also with increasing basal area of Douglas-fir trees, increased with increasing basal areas of sugar pine hardwood trees and with increasing density of understory shrubs. Large-diameter trees (>66 cm) appeared important <400 m from nest sites.
Irwin et al. 2013	southwestern Oregon and northcentral California	territory	forest inventory from private and federal landowners, modeling	habitat use	Basal area (m^2/ha) between 35-60 in nesting period, and 30-54 in winter period, basal area of trees >66 cm was between 7-22 in nesting period, and 7-18 in winter period, QMD 37-60 in nesting period and 37-61 in winter period.

LaHaye and Gutiérrez 1999	northwestern California	core area	ground sampling	habitat use	83% of nests located in Douglas-fir, 60% of nests located in brokentop trees, nest within forests characterized by large (> 90 cm dbh) conifers, a hardwood understory, and a variety of tree sizes.
Meyer et al. 1998	western Oregon	core area	aerial photographs	habitat effects on occupancy and reproduction	conifer-dominated forest, trees >80 yrs and/or multi-layered canopy
Ripple et al. 1997	southwestern Oregon	core area	aerial photographs	habitat use	conifer-dominated forest, average DBH >19.7 inches, canopy cover >60%
Solis and Gutiérrez 1990	northwestern California	territory	timber type classification	habitat use	multilayered stands with a >85% canopy closure, >90.0 cm dbh conifers with a density of 37.5m^2/ha, small (~27.3 cm dbh) understory hardwoods with a density of 208.3 trees/ha
Zabel et al. 1993	northwestern California	territory	topographic maps, aerial photographs, and orthophotoquads	habitat use	stands dominated (in terms of basal area) by trees >20.9 inches DBH; >20% canopy cover of dominant trees and >70% canopy cover of trees >5.1 inches DBH
Zabel et al. 2003	northwestern California	territory	modified timber type classification, varied geographically	habitat effects on occupancy	nesting-roosting habitat: for most locations average DBH >17 inches and average conifer canopy cover >60%; foraging habitat: in all locations average DBH >9.8 inches and average conifer canopy cover >40%, additional criteria in some locations

California Cascades Province

A description of the California Cascades Province is provided below, as defined in the 1992 Northern Spotted Owl recovery plan (USFWS 1992):

> "The California Cascades province is bordered by the Oregon Cascades province, the Oregon and California Klamath provinces, and the north end of the Sierra Nevada. It is the link between the range of the northern Spotted Owl and the range of the California Spotted Owl. Suitable owl habitat, which is fragmented on a broad scale by high- and low-elevation areas containing marginal habitat, is predominately in two national forests. However, there are significant blocks and checkerboard ownership areas where industrial private lands can provide suitable habitat."

One modeling region described in Appendix C of the 2011 Revised Recovery Plan (USFWS 2011) makes up the majority of the California Cascades Province, Eastern Cascade-South (ECS). The ECS is described below:

> "Topography is gentler and less dissected than the glaciated northern section of the eastern Cascades. A large expanse of recent volcanic soils (pumice region: Franklin and Dyrness [1973]), large areas of lodgepole pine, and increasing presence of red fir and white fir (and decreasing grand fir) along a south-trending gradient further supported separation of this region from the northern portion of the eastern Cascades. This region is characterized by a continental climate (cold, snowy winters and dry summers) and a high-frequency/low-mixed severity fire regime. Ponderosa pine is a dominant forest type at mid-to lower elevations, with a narrow band of Douglas fir and white fir at middle elevations providing the majority of Spotted Owl habitat. Dwarf mistletoe provides an important component of nesting habitat, enabling Spotted Owls to nest within stands of relatively younger, smaller trees." (USFWS 2011, pg. C-11, C-12).

Compared to other provinces in California, little is known about the specific habitat needs of the Northern Spotted Owl in the California Cascades. In addition, no studies have been conducted to date evaluating habitat quality (the amount and type of habitat most beneficial to owls) across owl sites in the California Cascades Province. However, one study in the Western and Eastern Oregon Cascades provinces (Dugger et al. 2005) found a positive relationship between older forest within the core area and owl fitness (i.e. reproduction and apparent survival). Analyses of habitat use have been conducted on three large study areas at the interface of the southern Cascades and eastern Klamath Mountains in southern Oregon and north-central California (Irwin et al. 2012, 2013). These studies suggest optimal habitat for Northern Spotted Owls in these regions consists of large diameter trees embedded in a heterogeneous landscape of mixed-age and mixed-species forests. However, the degree to which the selection of these habitats by owls indicates improved demographic performance, and therefore habitat quality, is unknown.

Nesting, Roosting, Foraging and Dispersal Habitat

Northern Spotted Owls have been found in a wide variety of forest types, including Douglas-fir, Western hemlock, grand fir, white fir, ponderosa pine, Shasta red fir, mixed evergreen and hardwood, and redwood forests (Forsman et al. 1984), and generally use older structurally complex forest types for nesting, roosting and foraging activities (Thomas et al. 1990, Carroll and Johnson 2008, Carroll 2010, USFWS 2011). At a range-wide level, there is a clear importance of old and mature forested habitat for Northern Spotted Owls. Bart and Forsman (1992) found owls were about 40 times more common in areas with older forest compared to areas lacking older forest throughout the subspecies' range; however, the study did not account for a number of owl activity centers found subsequently during surveys of commercial timberlands in northwestern California. In northern California and in western Oregon, owl sites have been shown to contain more mature and old-growth forest than random locations on the neighboring landscape (Hunter et al. 1995, Meyer et al. 1998). In the southern portion of the Oregon Cascades, the amount of old forest was found to have a strong effect on Northern Spotted Owl extinction rates, with increased extinction rates corresponding to decreased amount of old forest within the core area, defined as a 167 hectare (~413 acre) circle around the nest sites or primary roost areas (Dugger et al. 2011).

However, some studies have found a mosaic of late-successional forests intermixed with various other seral stages are used by Northern Spotted Owls and may provide higher quality habitat than large, uniform blocks of older forests (Meyer et al. 1998, Folliard et al. 2000, Franklin et al. 2000, Franklin and Gutiérrez 2002, Zabel et al. 2003, Diller et al. 2012, Irwin et al. 2012). The transition or edge between old-growth forest and other vegetation types (e.g., shrubland, hardwoods) has also been shown to be an important habitat feature in some portions of the subspecies' range where dusky-footed woodrats are a primary prey species (Folliard et al. 2000, Franklin et al. 2000, Franklin and Gutiérrez 2002). In order to evaluate habitat requirements in the California Klamath and Cascades provinces, Zabel et al. (2003) developed models that predict occupancy using multiple definitions of Northern Spotted Owl habitat. Habitat descriptions evaluated included range-wide definitions that emphasized older forests and new definitions that incorporated more diverse forest types and abiotic attributes (e.g., old forests, younger forests representing foraging habitat, elevation, aspect, California-specific soil classes). Models based on these revised descriptions of nesting, roosting and foraging habitat types were better at predicting Northern Spotted Owl occupancy in California's interior forests than the range-wide model (Zabel et al. 2003).

The following discussions on habitat components (i.e., nesting, roosting, foraging, and dispersal) address range-wide knowledge of Northern Spotted Owl habitat, as well as knowledge of owl habitat specific to California.

Nesting and Roosting Habitat

Habitat selection has largely been evaluated for nesting and roosting habitat by comparing habitat surrounding occupied Spotted Owl sites to randomly selected sites (Solis and Gutiérrez 1990, Bart and Forsman 1992, Blakesley et al. 1992, Hunter et al. 1995, Thome et al. 1999). Descriptions of nesting and roosting habitat were provided in the early- to mid-1990s (Solis and Gutiérrez 1990, Thomas et al. 1990, Bart and Forsman 1992) and have been validated by extensive research across most of the range of Northern Spotted Owl (Gutiérrez et al. 1995, Hunter et al. 1995, Meyer et al. 1998, Lahaye and

Gutiérrez1999, Swindle et al. 1999, Weathers et al. 2001, Courtney et al. 2004, USFWS 2008a, USFWS 2011).

The following description of nesting and roosting habitat from the Conservation Strategy for the Northern Spotted Owl (Thomas et al. 1990) remains an accurate portrayal of what we know today throughout the range of the owl:

> “With the exception of recent studies in the coastal redwoods of California, all studies of habitat use suggest that old-growth forests are superior habitat for northern spotted owls. Throughout their range and across all seasons, spotted owls consistently concentrated their foraging and roosting in old-growth or mixed-age stands of mature and old-growth trees. Exceptions were found, but even they tended to support the usual observations that spotted owls nested in stands with structures characteristic of older forests....Structural components that distinguish superior spotted owl habitat in Washington, Oregon, and northwestern California include: a multilayered, multispecies canopy dominated by large (>30 inches dbh) conifer overstory trees, and an understory of shade-tolerant conifers or hardwoods; a moderate to high (60-80 percent) canopy closure; substantial decadence in the form of large, live coniferous trees with deformities- such as cavities, broken tops, and dwarf mistletoe infections; numerous large snags; ground cover characterized by large accumulations of logs and other woody debris; and a canopy that is open enough to allow owls to fly within and beneath it.”

Generally, older forested stands with a higher degree of complexity and a high canopy closure are thought to be preferred for nesting and roosting, in part, because they provide protection from predators and thermal exposure (Gutiérrez 1985, Weathers et al. 2001, Franklin et al. 2000) as well as provide nesting site options. Small-scale spatial habitat requirements in the immediate vicinity of the nest are important but not sufficient to support all activities (e.g., foraging) conducted at the larger spatial scale (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005, Diller et al. 2010, USFWS 2011). Consequently, nesting and roosting habitat is often only a small portion of the entire home range (Forsman et al. 1984, Solis and Gutiérrez 1990, USFWS 2011a).

To assess the success of the coordinated forest management plan for federal lands, the Northwest Forest Plan (NWFP) developed a habitat suitability map for nesting and roosting habitat across the Northern Spotted Owl range (Davis et al. 2011; see Figure 5 and the Northwest Forest Plan section of this report). The habitat suitability model was developed using MaxEnt model output, including variables for percent conifer cover, average conifer dbh , amount of large conifer (trees >30 in dbh per acre), diameter diversity, average stand height, and average stand age. Much of the highest suitable habitat in California is within the northwest portion of the range (including the northernmost portion of the California Coast Province and the western portion of the California Klamath Province) and along the coastal forests.

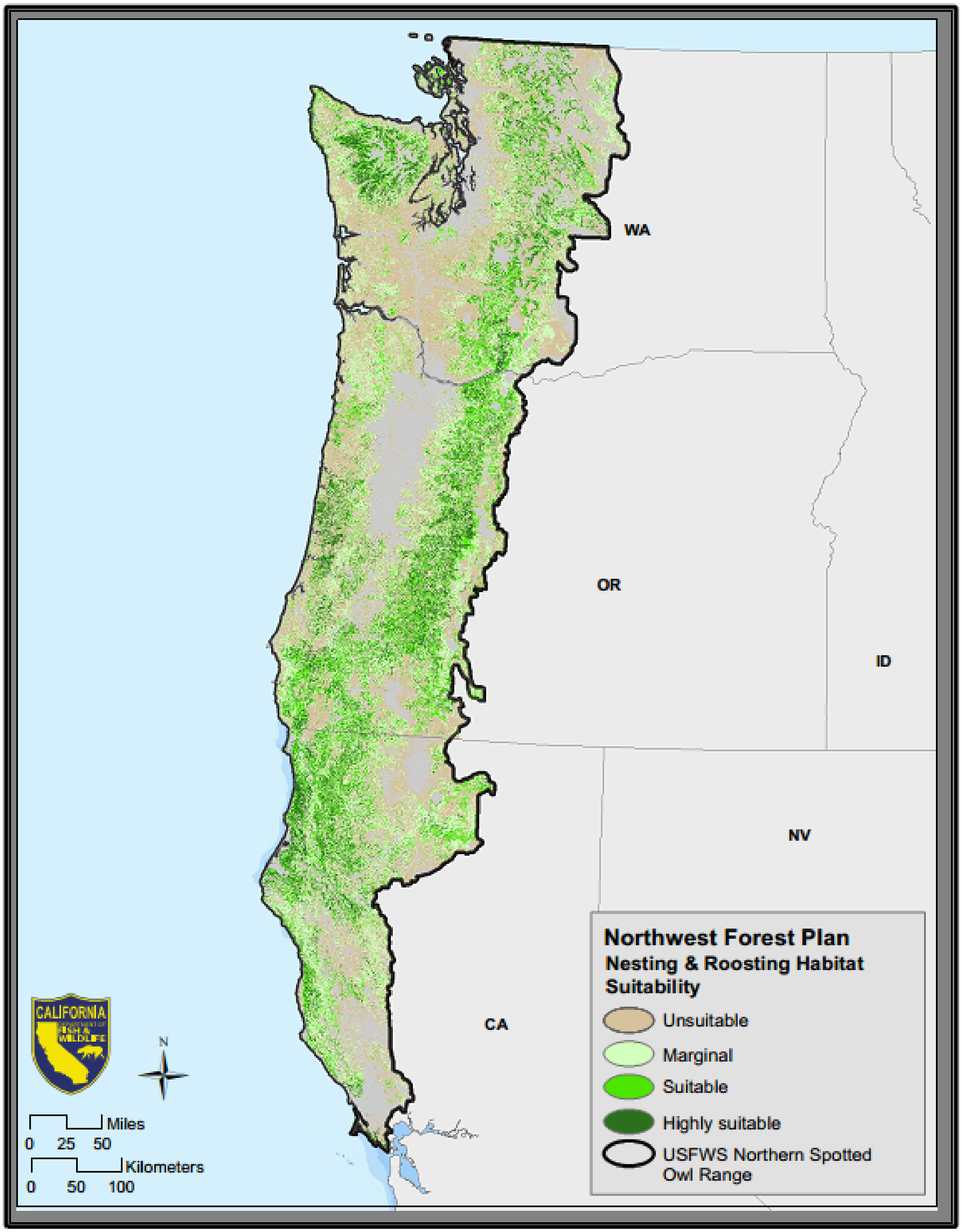

Figure 5. Northern Spotted Owl habitat suitability map showing the spatial distribution of nesting/roosting habitat (adapted from Figure 3-9, Davis et al. 2011).

Studies assessing Northern Spotted Owl habitat in California found older forests an important component in nesting and roosting habitat, but also included other forest types (e.g., hardwood) and age-classes interspersed within (Thomas et al. 1990, Hunter et al. 1995, Thome et al. 1999, Folliard et al. 2000, Irwin et al. 2012, 2013, Diller et al. 2012, Weisel 2015). In northwestern California, Northern Spotted Owls used old-growth with a higher frequency relative to this forest age class' distribution on the landscape, and similarly, used intermediate to young forests with a lower frequency (Solis and Gutiérrez 1990, Thome et al. 1999). Nest and roost sites on the Willow Creek Study Area (in northwestern California) occurred more frequently in mature and old-growth forest relative to availability of these forest types on the landscape, with both nest and roost sites having similar amounts of mature and old-growth forest types (Hunter et al. 1995). Irwin et al. (2012 and 2013) found that Northern Spotted Owls in southern Oregon and northwestern California selected areas with greater density and basal area of trees: >66 cm dbh (>26 in dbh) within 400 m (0.25 mi) of nest sites. The authors suggest a plausible optimal landscape for Spotted Owls in the region might include stands of large-diameter trees near nest sites which are embedded in a heterogeneous forest landscape of various selected foraging types. Analyzing owl habitat based upon characteristics used during nighttime foraging excursions, Irwin et al. (2012) found that owls selected mixed-aged and mixed coniferous forest stands. In this study, the Yreka study site included dry forest types on the California Cascade Province.

In the California Coast Province, young redwood forests along the coast have structural complexity similar to that of older forests elsewhere in the Northern Spotted Owl's range, thus providing nesting and roosting habitat within these younger forests. The rapid growth rate of redwoods, along with stump-sprouting and variable timber management practices, has shaped younger forest types within the coastal forests of Northern California (Thomas et al. 1990, Thome et al. 1999, Folliard et al. 2000, USFWS 2011, Diller et al. 2012). On managed timberland of Green Diamond Resource Company, within the coastal redwood forests of California, Northern Spotted Owls selected older more complex nest stands, i.e., areas with higher habitat heterogeneity that were in fairly close proximity to areas that had a high potential as foraging habitat (Diller et al. 2012).

Foraging Habitat

Spotted Owls are difficult to observe during nighttime foraging excursions, making descriptions of foraging habitat hard to obtain compared to nesting and roosting habitat. Information on use and selection of foraging habitat is generally based on telemetry studies that document owl locations throughout nighttime movements, though some potential errors are inherent, and may include triangulation of owls that are not stationary, proximity of triangulation to roads, and accounting for non-foraging activities (e.g., preening, resting, territory defense, interactions with their mate) during the night (Diller et al. 2010). Although it is difficult to determine when and where owls are actually obtaining prey, telemetry does provide some good information on how owls generally use the landscape and the diversity of forest types used during foraging excursions.

Foraging habitat may contain the typical older forest components of nesting and roosting habitat, but may also include younger forests and hardwood stands, as well as more open areas (Solis and Gutiérrez 1990, Zabel et al. 1995, Irwin et al. 2012, Irwin et al. 2013). Overall, foraging habitat consists of areas where prey species occur and are available for capture by owls (Ward 1990, Ward et al. 1998, Zabel et al. 1995). This habitat type occurs over a much larger portion of the home range, and may vary seasonally, with a larger area and younger forests used (Forsman et al. 1984, Solis and Gutiérrez 1990, Franklin et al. 2000, USFWS 2009, USFWS 2011). Foraging areas have been found to be associated with close proximity to the nest site location (Irwin et al. 2012) and with riparian zones (Hamer et al. 2007, Irwin et al. 2012, Wiens et al. 2014, Weisel 2015) across the range of the species. Northern Spotted Owls have been shown to avoid nonforested areas (e.g., recent clearcuts) and early forest successional stages for foraging (USFWS 2011, Irwin et al. 2013), likely a function of prey abundance and availability (Sakai and Noon 1993 and 1997).

In California, foraging habitat is generally composed of variable-aged conifer stands and a more diverse set of forest types (e.g., hardwood forests) and structural characteristics than in other areas of the range, thought to be a function of prey abundance and availability (Meyer et al. 1998, Franklin et al. 2000, Zabel et al. 2003, Irwin et al 2012 and 2013). Irwin et al. (2012) found in Oregon and northwestern California that Northern Spotted Owl foraging habitat appeared to be maximized in patches of trees with average quadratic mean diameter of 40 to 55 cm (15-22 inches). Irwin et al. (2013) found that Northern Spotted Owls used patches with more large trees and greater basal area within two study areas in the coastal redwood zone (Fort Bragg and Eureka).

As mentioned previously, there is a general shift in foraging habitat requirements from north to south within the owl's range due to changes in habitat composition and presence of prey. In the northern portion of the Northern Spotted Owl range where flying squirrels are the dominant prey, home ranges are larger and foraging habitat may have the same characteristics as nesting and roosting habitat, e.g., older forest stands (Zabel et al. 1995, Gutiérrez 1996, Courtney et al. 2004, USFWS 2011). Whereas, in southern parts of the Northern Spotted Owl range (e.g., California), where woodrats are more common in the diet, home ranges are smaller and may include more variable-aged stands including tanoak, oak and younger conifer stands (Zabel et al. 1995, Franklin et al. 2000, Courtney et al. 2004, USFWS 2009, Diller et al. 2010, Weisel 2015).

To better understand the importance of prey in Northern Spotted Owl habitat selection and space use, several studies investigated prey habitat use within owl habitat, and found that young and variable-aged forests and shrub cover provide good habitat for woodrats, a key prey species for Northern Spotted Owls in California (Sakai and Noon 1993, Hamm 1995, Carey and Peeler 1995, Sakai and Noon 1997, Ward et al. 1998). For instance, in California's coastal forests, Hamm (1995) found woodrats most abundant in seedling-shrub and sapling-poletimber. Similarly, Sakai and Noon (1993 and 1997) found higher woodrat abundance in sapling-poletimber within Douglas-fir-tanoak forests of northwestern California. Even though younger stands can provide high quality prey habitat, foraging activities in these areas may be limited due to a lack of perching sites (Carey et al. 1992, Sakai and Noon 1993, Diller et al. 2010), highlighting the importance of habitat heterogeneity.

Due to its high foraging potential, hardwood forest is often an important component of Northern Spotted Owl foraging habitat in California. In Six Rivers National Forest, California, Northern Spotted Owls used forests with a mixture of hardwood and conifer trees that provided a multilayered structure with high canopy closure (Solis and Gutiérrez 1990). In coastal California redwood forests, Northern Spotted Owls foraged in areas composed of older forests that included a high percentage of hardwood (Diller et al. 2010). Similarly, another coastal California study (Weisel 2015) found hardwood an important component to foraging use for Northern Spotted Owls; with a maximized hardwood basal area of $39m^2$/ha. In northwestern California near Yreka, Irwin et al. (2012) found probability of an area being selected for Northern Spotted Owl foraging increased with basal area of hardwoods and with increases in shrub counts (except in areas with high abundance of hardwoods and shrubs). In the northern Sierra Nevada Mountains, similar to the drier mixed-conifer forests of Cascade Mountains, hardwoods ≥20 cm (≥8 inches) were positively correlated to foraging habitat use for California Spotted Owls (Irwin et al. 2007).

Edge habitat (e.g., ecotones between older and younger forests or between other vegetation types) provides benefits for Northern Spotted Owls as certain habitat types that border older forest may contain higher numbers of preferred prey, the dusky footed woodrat (Carey et al. 1992, Sakai and Noon 1993, Ward et al. 1998, Franklin et al. 2000, Hamm et al. 2002), and surplus prey may venture into older forests making them more available to foraging owls (Sakai and Noon 1997). For instance, Northern Spotted Owls often forage near transitions between early- and late-seral stage forest stands in northern California, likely where prey species are more abundant or more readily available (Zabel et al. 1995). Likewise, in the California's coast redwood zone and the mixed conifer forests in the interior of the California range near Yreka, California, studies have shown that Northern Spotted Owls will forage in harvest-created hardwood and shrub habitat (i.e., within 6-30 year old clearcuts) that contain woody debris, scattered conifers and snags, and that are adjacent to older forests (Irwin et al. 2013). Foraging habitat selection in young coastal forests within Humboldt and Del Norte counties was higher if the nearest stand was either 6-20 years old or 21-41 years old, and lower if the nearest stand was either 0-5 or >41 years old (Diller et al. 2010). Within these same coastal forests, Northern Spotted Owls active at night were most likely to be found in older more complex forest stands that were in close proximity to younger stands that have high densities of woodrats (Diller et al. 2012). In northwest California, Northern Spotted Owls were found to forage in areas where the occurrence of prey was more predictable, within older forests and near ecotones of old forest and brush seral stages (Ward 1990 as cited in USFWS 2011).

The importance of habitat heterogeneity (i.e., variable-aged and mixed vegetation stands interspersed in old or mature forests) to Northern Spotted Owls in California was formally introduced by Franklin et al. (2000), but has also been corroborated by other studies (Franklin and Gutiérrez 2002, Hamm et al. 2002, Irwin et al. 2013, Diller et al. 2010). As a result, we now understand that Spotted Owl demographic rates (e.g., annual survival, reproductive output) benefit from a mosaic of older forest interspersed with younger forests or other vegetation types. As discussed above, young and variable-aged forests and shrub cover provide good habitat for woodrats, and it has been suggested that heterogeneous forests benefit Spotted Owls by providing increased foraging opportunities between nesting and roosting habitat and productive prey habitat. It is possible that preserving only old-growth without consideration of the importance of habitat heterogeneity could result in a decrease of prey abundance in some cases, thereby potentially having a negative impact on Spotted Owl demographic rates (Franklin and Gutiérrez

2002, Diller pers comm. 2015); however, this idea needs further investigation. See the Status and Trends section of this report for a more thorough discussion of Spotted Owl fitness in relation to habitat.

While variable-aged and mixed-species stands with some amount of open or edge habitat seem to be more important foraging habitat components in California, the importance of older forests as a component of foraging habitat across the entire range cannot be overstressed. Multiple studies have found that foraging habitat used by Northern Spotted Owls contained some amount of older forests (Carey et al. 1990, Solis and Gutiérrez 1990, Thome et al. 1999, Diller et al. 2010, Folliard et al. 2010, Irwin et al. 2012, Diller et al. 2012), an essential component for protection from predators and thermoregulation advantages (Gutiérrez 1985, Weathers et al. 2001, Franklin et al. 2000).

Dispersal Habitat

Current evidence indicates that dispersal habitat for Northern Spotted Owls consists of stands with adequate tree size and canopy closure to provide protection from avian predators and that have at least minimal foraging opportunities (Miller et al. 1997, Thomas et al. 1990, Forsman et al. 2002, Buchanan 2004, USFWS 2011). This may include younger forest stands with less diversity than nesting and roosting habitat, such as even-aged and pole stands, but should at the minimum contain some roosting structures and foraging habitat during this transient stage (Franklin and Gutiérrez 2002, Davis et al. 2011, USFWS 2011). In western Oregon, use of open sapling stands during dispersal decreased the probability of mortality, and use of clearcuts during colonization dispersal increased the probability of mortality (Miller et al. 1997), suggesting clearcut areas may not function well as dispersal habitat. A study in Washington found that dispersing juvenile owls selected stands with high canopy closure (>70%) and vegetation types similar to those selected by adults, suggesting that selection of stands for roosting, at least during dispersal, have greater canopy cover than previously thought (Sovern et al. 2015). Forsman et al. (2011) indicates that recruitment of owls into the breeding population likely depends on the amount and quality of dispersal habitat to ensure survival of dispersing owls.

Northern Spotted Owls have also been shown to disperse through highly fragmented forest landscapes and seem to use mature and old-growth forests more than that forest type's availability on the landscape during this phase (Miller et al. 1997, Forsman et al. 2002). Work done by Franklin and Gutiérrez (2002), suggests some amount of fragmentation or habitat heterogeneity may be beneficial for dispersing owls, depending on the matrix of habitat types, by providing variable foraging opportunities in more open habitats or along edges, while at the same time providing protection from predators in older forest components. Some speculate that corridors of dispersal habitat within fragmented landscapes act to facilitate rapid movement to areas of better habitat (USFWS 2011). There is little evidence that small openings in forest habitat influence the dispersal of Spotted Owls, but large non-forested valleys may act as barriers to both natal and breeding dispersal (Forsman et al. 2002). Water bodies may also function as barriers to dispersal, but this is not clearly understood (Forsman et al. 2002).

Dispersal habitat may well be the least understood of all the Northern Spotted Owl habitat components, especially since it has not been linked well with survival of owls. A clear understanding of dispersal habitat is important to the management of owl habitat across the Northern Spotted Owl's range. Buchanan (2004) stressed the importance of appropriate management of dispersal habitat and suggested that one of the greatest inadequacies of Northern Spotted Owl habitat management is the lack of retention of structurally complex forest components, such as snags and downed woody debris, at the time of or post timber harvest. In an attempt to document the level of change in dispersal habitat across the range over time, dispersal habitat models were developed for 1994-2007 in Global Information Systems (GIS), including variables for conifer at dbh ≥11 inches and conifer cover ≥40 percent (Davis et al. 2011; Figure 6). Inherently, the habitat model included some amount of nesting and roosting habitat since owls will disperse through this habitat type (Davis et al. 2011). The results show large continuous areas of dispersal habitat in the northern portion of the range in California, with small isolated patches north of Point Arena and in Marin County in the California Coast Province. This study indicates that dispersal habitat may not be a limiting factor in California, but refinement of the model parameters may be required to produce a more thorough and robust assessment. To better manage habitat and understand potential barriers to dispersal, components of this habitat type should be assessed more fully, such as radio telemetry studies on juvenile owls, studies on prey abundance and availability within dispersal habitat, and habitat modeling.

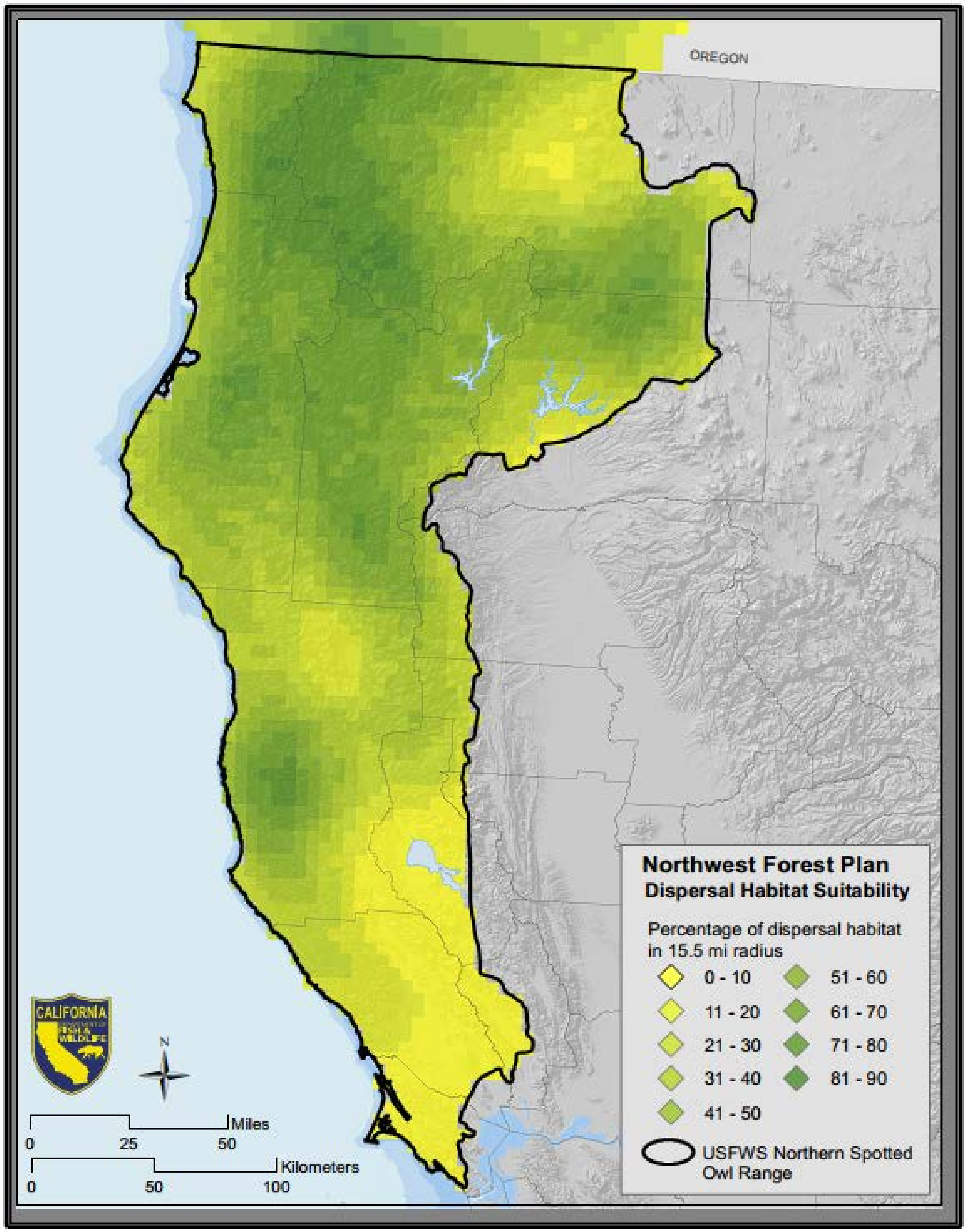

Figure 6. Northern Spotted Owl habitat suitability map showing the spatial distribution of dispersal habitat (adapted dispersal suitability model in Davis et al. 2011).

Status and Trends in California

Abundance

No range-wide estimate for abundance of Northern Spotted Owl exists because survey methods and effort conducted to date do not provide for reliable estimation of population size across the subspecies' range (USFWS 2011). Few areas across Washington, Oregon and California have been sufficiently sampled to accurately estimate densities of Northern Spotted Owls (Franklin et al. 1990, Tanner and Gutiérrez 1995, Diller and Thome 1999). As mentioned above, Northern Spotted Owl densities vary across the range and forest types and so extrapolating the few local estimates across the range of the subspecies would result in biased estimates of abundance (See Life History section of this report for detailed information on density estimates in California). Because Northern Spotted Owls have large home ranges it is necessary to systematically survey very large areas in order to obtain reliable estimates of density (Franklin et al. 1990). In addition, detection rates of spotted owls during nighttime call surveys vary widely, but are generally <1.0 (Olson et al. 2005, Anthony et al. 2006, Kroll et al. 2010, Forsman et al. 2011, Dugger et al. 2009, 2011). Current survey techniques do not effectively sample nonterritorial individuals (floaters), and may vary for territorial birds relative to whether they are breeding or not in any given year (Anthony et al. 2006, Forsman et al. 2011, Stoelting et al. 2015). Finally, the presence of Barred Owls in the landscape can decrease the detection rates of Spotted Owls, in some cases dramatically (Olson et al. 2005, Crozier et al. 2006, Kroll et al. 2010, Wiens et al. 2011, Dugger et al. 2009, 2011). Thus, without an effective sampling method that addresses the inability to detect all owls in a given area, it is not possible to provide an accurate estimate of abundance. See the discussion on occupancy in the Demographic Rates section of this report for potential effects of floater owls on occupancy rates at known owl sites.

A recent modeling exercise made use of the immense amount of data available on Northern Spotted Owl habitat requirements and availability, home range sizes, age-specific survival rates, age-specific fecundity, dispersal behavior, and impacts of Barred Owl on Spotted Owl survival, to model source-sink dynamics across the range of the owl (Schumaker et al. 2014). In addition to an evaluation of source-sink dynamics, outcomes of the model simulation included range-wide projections of population size, and the proportion of the simulated population in each modeling region and physiographic province noted in the USFWS Revised Northern Spotted Owl Recovery Plan (USFWS 2011). Simulated estimates of population size by geographic region indicate that Northern Spotted Owls may be most abundant in parts of southern Oregon and northern California (Table 4). The three California provinces were projected to support over 50 percent of the range-wide Northern Spotted Owl population. The model indicated that the Klamath region may be a stronghold for the population, with 50.1 percent within the Oregon Klamath and California Klamath provinces, and 37.1 percent within the Klamath East and Klamath West modeling regions. Model simulations indicated that habitat range-wide has the potential to support an estimated 3,400 female Northern Spotted Owls, with over 750 females in the Inner California Coast, Klamath East, Klamath West, Redwood Coast, and West Cascades South modeling regions (Schumaker et al. 2014). Although informed by the best available data to develop an assessment of source-sink dynamics across the range, the complexity of the model may limit its ability to accurately simulate population estimates. For example, differences in the simulated number of owls versus the numbers estimated in eight demographic study areas used for calibration ranged from 5 to 47 percent (Schumaker et al. 2014). For these reasons the results might best be treated as hypotheses rather than concrete inferences about Northern Spotted Owl populations. Nevertheless, the results suggest that California's population of Northern Spotted Owls may be an important component of the range-wide population.

Table 4. Simulated percent of range-wide Northern Spotted Owl population within modeling region and physiographic province based on model projections (adapted from Table 2 in Schumaker et al. 2014).

Modeling Region	Percent of Population	Physiographic Province	Percent of Population
North Coast Olympics	0.1	Washington Western Cascades	1.3
West Cascades North	0.1	Washington Eastern Cascades	1.6
East Cascades North	3.3	Washington Olympic Peninsula	>0.0
West Cascades Central	1.2	Washington Western Lowland	>0.0
Oregon Coast	1.0	Oregon Eastern Cascades	3.5
West Cascades South	15.3	Oregon Western Cascades	23.3
Klamath West	20.0	Oregon Coast	0.8
Klamath East	17.1	Oregon Willamette Valley	>0.0
Redwood Coast	16.4	Oregon Klamath	13.7
East Cascade South	3.8	California Coast	16.6
Inner California Coast	21.7	California Cascades	2.8
		California Klamath	36.4

Most surveys for Northern Spotted Owls have been conducted on areas proposed for timber management activities in order to assess the potential for impacting the species, or on demographic study areas where long-term research has been conducted throughout the subspecies' range (e.g., Forsman et al. 2011, Dugger et al. 2016). Although not designed for estimating density or abundance, pre-harvest surveys have dramatically increased knowledge on location of territorial owl sites (i.e., activity centers). As survey effort has expanded to new areas over time, the number of known activity centers has naturally increased. Although owls will shift locations of activity centers over time in response to changing forest landscapes, they exhibit high site fidelity to general nesting and roosting areas (Gutiérrez et al. 1995, Blakesley et al. 2006). Therefore, the increase in number of activity centers over time is more likely a result of expanded survey effort than establishment of new owl territories. In addition, across most of the Northern Spotted Owl range, establishment of new nesting and roosting habitat that is suitable for supporting an activity center is a slow process given tree species growth rate (Davis et al. 2015), and so a rapid increase in the number of activity centers due to colonization of new habitat is unlikely. Compared with other portions of the range, habitat development through forest maturation can occur relatively quickly on the redwood coast where Northern Spotted Owls have been shown to select relatively young forests (41-60 years old) for nesting and roosting, as long as all habitat requirements are present (Thome et al. 1999, Diller et al. 2010). For example, Green Diamond Resource Company has reported the addition of 58 new sites since 1994 in a portion of their property that is completely surveyed each year and attributes this at least in part to improving habitat conditions as forests mature (GDRC 2015). However, this does not indicate a net increase in owl sites across the ownership, because other sites have been lost due to timber management and the influence of Barred

Owls. The annual number of known Northern Spotted Owl sites on GDRC lands ranged from 99 to 186 from 1991 through 2014 (mean 134.5), with 122 sites known in 2014 (GDRC 2015), so new sites have not necessarily indicated a growing population. The number of newly established activity centers across the range as a result of newly available nesting and roosting habitat is unknown, but is likely small given that very little new suitable nesting and roosting habitat has developed in recent decades, and total acreage of suitable habitat has declined (Davis et al. 2015). See the discussion on mechanisms for habitat changes in the threats section for additional information on the topic of habitat loss and recruitment.

In California, the number of known Northern Spotted Owl activity centers increased starting in 1990 when listing under the federal Endangered Species Act resulted in a widespread increase in survey effort (see Figure 3). Through 1989, there were 1,366 known Northern Spotted Owl activity centers in California. By the year 1999, this number had increased to 2,799. As of 2014, the number of known Northern Spotted Owl activity centers was 3,116. The number of occupied activity centers in any given year is unknown because not all areas have been or can be surveyed on an annual basis (USFWS 2011). An increase in incidental detections of Barred Owls concurrent with an increase in Spotted Owl activity centers may also demonstrate an increase in survey effort (see Figure 34 in the Threats section of this report). Some unknown portion of historical Northern Spotted Owl sites are unoccupied in any given year because of habitat loss due to timber harvest or severe fires (Davis et al. 2015), displacement by Barred Owls (see Barred Owl section of this report), normal death of owls or their movement out of established territories, or other factors, therefore much of the data from early survey reports are outdated and of little use in addressing population abundance or distribution questions (Courtney et al. 2004). For these reasons and for the sampling reasons discussed above, the number of activity centers does not represent an index of abundance but rather the cumulative number of territories recorded as being in use by Northern Spotted Owl at some point in time across a dynamic landscape (USFWS 2011).

Demographic Rates

"Because the existing survey coverage and effort are insufficient to produce reliable range-wide estimates of population size, demographic data are used to evaluate trends in Spotted Owl populations" (USFWS 2011).

The U.S. Forest Service (USFS) and the U.S. Bureau of Land Management (BLM) initiated eight long-term demography studies within the range of the Northern Spotted Owl during the years 1985 to 1991 in order to provide data on the status and trends of Spotted Owl populations, and to inform the effectiveness of the NWFP on federal lands (Lint et al. 1999). An important part of the effectiveness monitoring program was the regular analysis of the data to estimate the status and trends of Northern Spotted Owls on federal lands (Lint et al. 1999). Thus, since an initial analysis in 1991 (Anderson and Burnham 1992) and another in 1993 (Burnham et al. 1994, 1996), every five years or so a meta-analyses of these data and data from other long-term demographic study areas are analyzed to estimate Northern Spotted Owl vital rates and, more recently, to investigate the factors associated with variation in these vital rates across the subspecies' range (e.g., Franklin et al. 1999; Anthony et al. 2006, Forsman et al. 2011, Dugger et al. 2016). The most recent meta-analysis conducted in January 2014 included 11 study areas including three areas in Washington, five in Oregon, and three in Northern California representing primarily federal, or mixed private/federal ownerships (Table 5; Dugger et al. 2016). These long-term Northern Spotted Owl demographic study areas collectively represent about 9% of the range of the Northern Spotted Owl, contain most habitat types used by the owl, and contain elements of most of the physiographic provinces in which the owl occurs (Forsman et al. 2011, Dugger et al. 2016; Figure 7). Thus, results from these study areas are believed to represent the status of Northern Spotted Owl populations on federal, and mixed private and federal lands across the species range. However, results likely depict an optimistic view of the overall population status of the Northern Spotted Owl on private lands because the three non-federal study areas are actively managed to protect Northern Spotted Owls and their habitat (Forsman et al. 2011, Dugger et al. 2016).

All study areas were surveyed annually and 22-29 years of data through 2013 were available for the 2014 meta-analysis (Dugger et al. 2016; Table 5). Standard protocols used on all study areas to ensure that efforts to determine historical site occupancy, to band and resight all territorial owls, and to assess nesting status of territorial females were consistent across all study areas (Forsman 1995, Franklin et al. 1996, Lint et al. 1999). The resulting survey data allows for the estimation of fecundity, apparent survival, recruitment, annual rates of population change, territory occupancy, and occupancy dynamics (i.e., local territory colonization and extinction rates) (Dugger et al. 2016). Northern Spotted Owl vital rates are evaluated separately for each individual study area and also across all study areas combined (i.e., meta-analysis). Most recently, in addition to the estimation of vital rates and trends, a suite of factors was investigated to determine potential effects on population vital rates, including Barred Owl presence, amount of suitable habitat, local weather, and regional climate patterns (Dugger et al. 2016). These meta-analyses likely represent the best population demographic information on an endangered species ever assembled (Gutiérrez 2008).

As discussed above, data collected from existing surveys are not sufficient to estimate population size or density of Northern Spotted owls, so the absolute number of owls on each study area over time cannot be assessed. However, the annual rate of population change for territorial spotted owls (i.e., lambda - λ), which reflects changes in population size from one year to the next due to annual reproduction, mortality, and movement into and out of a study area, has been estimated from the data collected on these long-term demographic study areas (e.g., Anthony et al. 2006, Forsman et al. 2011, Dugger et al. 2016).

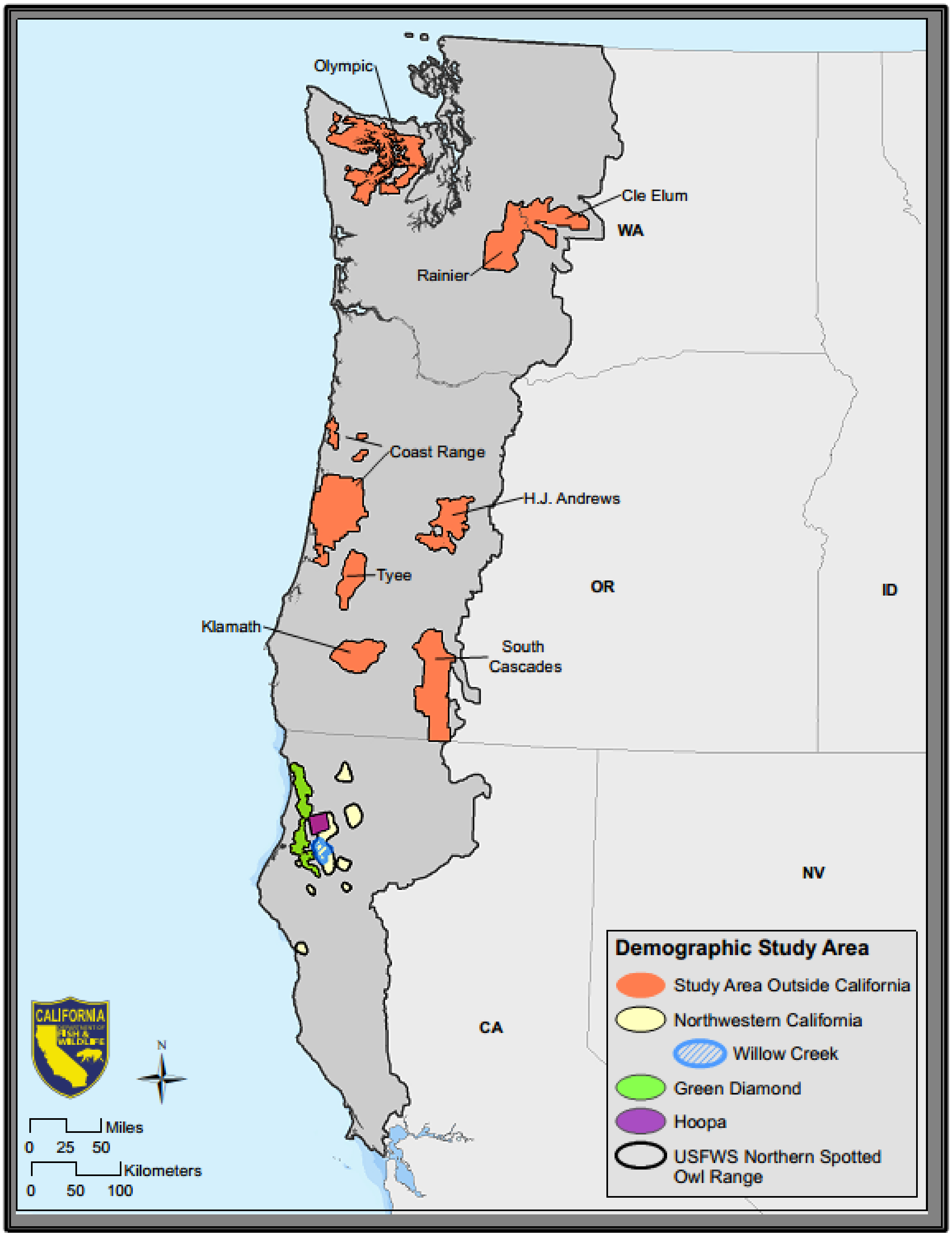

Figure 7. Locations of 11 Northern Spotted Owl demographic study areas used to assess vital rates and population trends.

Table 5. Descriptions of 11 demographic study areas used to assess vital rates and population trends through 2013 in Washington, Oregon, and California. Adapted from Tables 2 and 3 in Dugger et al. 2016.

Study Area	Area Code	Start Year**	Area (km^2)	Ownership
Washington				
Cle Elum*	CLE	1989	1,784	Mixed
Rainier	RAI	1992	2,167	Mixed
Olympic*	OLY	1990	2,230	Federal
Oregon				
Coast Ranges*	COA	1990	3,922	Mixed
H.J. Andrews*	HJA	1987	1,604	Federal
Tyee*	TYE	1990	1,026	Mixed
Klamath*	KLA	1990	1,422	Mixed
South Cascades*	CAS	1991	3,377	Federal
California				
NW California*	NWC	1985	460	Federal
Hoopa Tribe	HUP	1992	356	Tribal
Green Diamond Resources	GDR	1990	1,465	Private

*Indicates the eight study areas that are part of the federal monitoring program for the Northern Spotted Owl.
** Surveys have continued at all 11 study areas from the noted start date through the present time; however, Dugger et al. (2016) analyzed the data collected through 2013.

The three Northern Spotted Owl demographic study areas located in California and included in the most recent meta-analysis represent a diverse land ownership; the Northwest California study area (NWC) is primarily on federal land, the Green Diamond Resource Company study area (GDR) is on private land, and the Hoopa Indian Reservation study area (HUP) is on tribal land. These three study areas cover approximately 6% of the range of the Northern Spotted Owl in California (based on the USFWS range; use of the CWHR range would result in a larger percentage; see Figure 3). The NWC and HUP study areas were characterized by mixtures of mature and old-growth forest interspersed with young forests regenerating on areas that had been clearcut or burned. On the GDR study area, nearly all stands of old trees had been clearcut and converted to young forests that were less than 70 years old (Dugger et al. 2016). In 2009, a Barred Owl removal study was implemented on the GDR study area by partitioning the study area into treatment (Barred Owls lethally removed) and control (Barred Owls undisturbed) areas (Diller et al. 2014, Dugger et al. 2016). The treatment and control areas were evaluated separately to estimate the response of Northern Spotted Owl vital rates to the removal activities. This study is discussed in detail in the Barred Owl threat section of this report, and is also referenced in this section as necessary.

In California, the California Klamath and California Coast physiographic provinces are represented by the NWC, HUP, and GDR study areas. There is no demographic study area in the California Cascades physiographic province, but the South Cascades study area (CAS) is just across the border in Oregon, and inferences can be drawn from that study area. Also, a study conducted in the California Cascades provides valuable information on occupancy rates and trends in that physiographic province (Farber and Kroll 2012).

Below, we discuss estimates of the annual rate of population change, fecundity, survival, and occupancy at each of the study areas in California and the environmental factors that are associated with variation in these demographic rates from the most recent Northern Spotted Owl meta-analysis (Dugger et al. 2016). We report results of the larger range-wide assessments where appropriate to put the results from the California study areas into a broader range-wide perspective. In addition, we report results from CAS in southern Oregon because the study area occurs directly north of the California Cascades province and may reflect potential changes in the California Cascades. Few studies conducted outside the demographic study areas have collected the necessary data to assess spotted owl vital rates, but in several cases presence-absence data is available with which site occupancy modeling was conducted (e.g., Farber and Kroll 2012, MRC 2014, Campbell Global in Calforests 2014). Thus, we present results from other studies where additional data is available outside of the 11 long-term demographic study areas.

Rate of Population Change

A primary goal of the large scale monitoring at the demographic study areas and the regular coordinated analysis of data is to monitor population trends of the Northern Spotted Owl through estimation of lambda (λ, defined as annual rate of population change; Anthony et al. 2006, Forsman et al. 2011, Dugger et al. 2016). A λ of 1.0 indicates that a population is stationary, whereas values greater or less than 1.0 indicate increasing or declining populations, respectively. Annual rates of population change (λ) were estimated for each of the 11 study areas using capture histories for 5,992 territorial Northern Spotted Owls, representing 29,520 total encounters of banded owls (Dugger et al. 2016). Estimates of the annual rates of population change indicated population declines of 1.2% to 8.4% per year, depending on the study area, with a weighted mean estimate indicating a range-wide decline of 3.8% per year from 1985-2013 (Table 6). This annual rate of decline is nearly 1% higher than the previous estimate for the same study areas (Forsman et al. 2011). These results suggest that Northern Spotted Owl populations have declined throughout its range, and the rate of decline is accelerating on seven of the 11 study areas, including all three California study areas.

There is strong evidence for declining populations on all three California study areas, including HUP which was estimated to be stable during the previous assessment including data through 2006 (Forsman et al. 2011). Prior to the start of Barred Owl removal experiments at GDR in 2009, the rates of decline at California study areas ranged from 1.2% to 3.9% per year. The inclusion of time trend covariates in the best models further supports the evidence of accelerating decline on all three California study areas (Dugger et al. 2016). A decline was also observed just across the border in Oregon, where the Northern Spotted Owl population at the CAS study area has declined by an estimated 3.7% per year. Like the HUP study area in California, the population at the CAS study area in Oregon was stable through 2006 (Forsman et al. 2011).

Table 6. Trends in demographic parameters including fecundity, apparent survival, occupancy rates, and lambda (λ) for Northern Spotted Owls from 11 study areas in Washington, Oregon, and California, and estimates of mean lambda (λ) and percent population change, 1985–2013. Adapted from Table 25 in Dugger et al. 2016.

	Trends				Estimates	
Study Area[1]	**Fecundity**	**Apparent Survival**	**Occupancy**	**Lambda (λ)**	**Lambda (λ)**	**Population Change**[2]
Washington						
CLE	Declining	Declining	Declining	No trend	0.916	-77%
RAI	No trend	Declining	Declining	No trend	0.953	-61%
OLY	No trend	No trend	Declining	No trend	0.961	-59%
Oregon						
COA	Declining	No trend	Declining	Declining	0.949	-64%
HJA	Declining	Declining	Declining	Declining	0.965	-47%
TYE	Declining	Declining	Declining	Declining	0.976	-31%
KLA	Declining	No Trend	Declining	Declining	0.972	-34%
CAS	No trend	Declining	Declining	No trend	0.963	-44%
California						
NWC	Declining	Declining	Declining	Declining	0.970	-55%
HUP	Declining	Declining	Declining	Declining	0.977	-32%
GDR-CB[3]	Declining	Declining	Declining	Declining	0.988	-31%
GDR-TB[3]	Declining	Declining	Declining	Declining	0.961	-26%
GDR-CA[3]	**	**	Declining	**	0.878	-41%
GDR-TA[3]	**	**	N/A	**	1.030	-9%

[1] See Table 5 for study area codes.
[2] With the exception of the GDR study area, percent population change through 2011.
[3] GDR-TB = treatment areas before Barred Owls were removed; GDR-CB = control areas before Barred Owls were removed in treatment areas; GDR-TA = treatment areas after Barred Owls were removed (2009–2013); GDR-CA = control areas after Barred Owls removed in treatment areas (2009–2013).
** Too few years since Barred Owl removal to evaluate a trend.

Conversion of annual estimates of λ to estimates of realized population change allows for the portrayal of changes in population size over time relative to the population size in the initial year of study (Franklin et al. 2004, Dugger et al. 2016). These estimates show declines of 31% to 77% in populations across the range depending on study area (excluding Barred Owl removal areas). In California, population declines from the early 1990s through 2011 ranged from 31% to 55% for areas not receiving Barred Owl removal, with accelerated declines evident in recent years (Figure 8). The Barred Owl treatment area on the GDR study area has had an increasing population of Northern Spotted Owls since removal of Barred Owls began in 2009, but still has an estimated overall decline of 9% since 1992. In contrast, the control areas on the GDR study area had the lowest rate of decline among areas prior to 2009 (1.2% annual rate of decline), but has had a higher rate of decline since 2009 (12.2% annual rate of decline). This annual rate corresponds to a population decline of 41% on the control area, although confidence limits for λ are large and broadly overlap 1.0 due to the small number of years in the post-treatment sample. The CAS study area in southern Oregon has experienced a population decline of 44% since 1994.

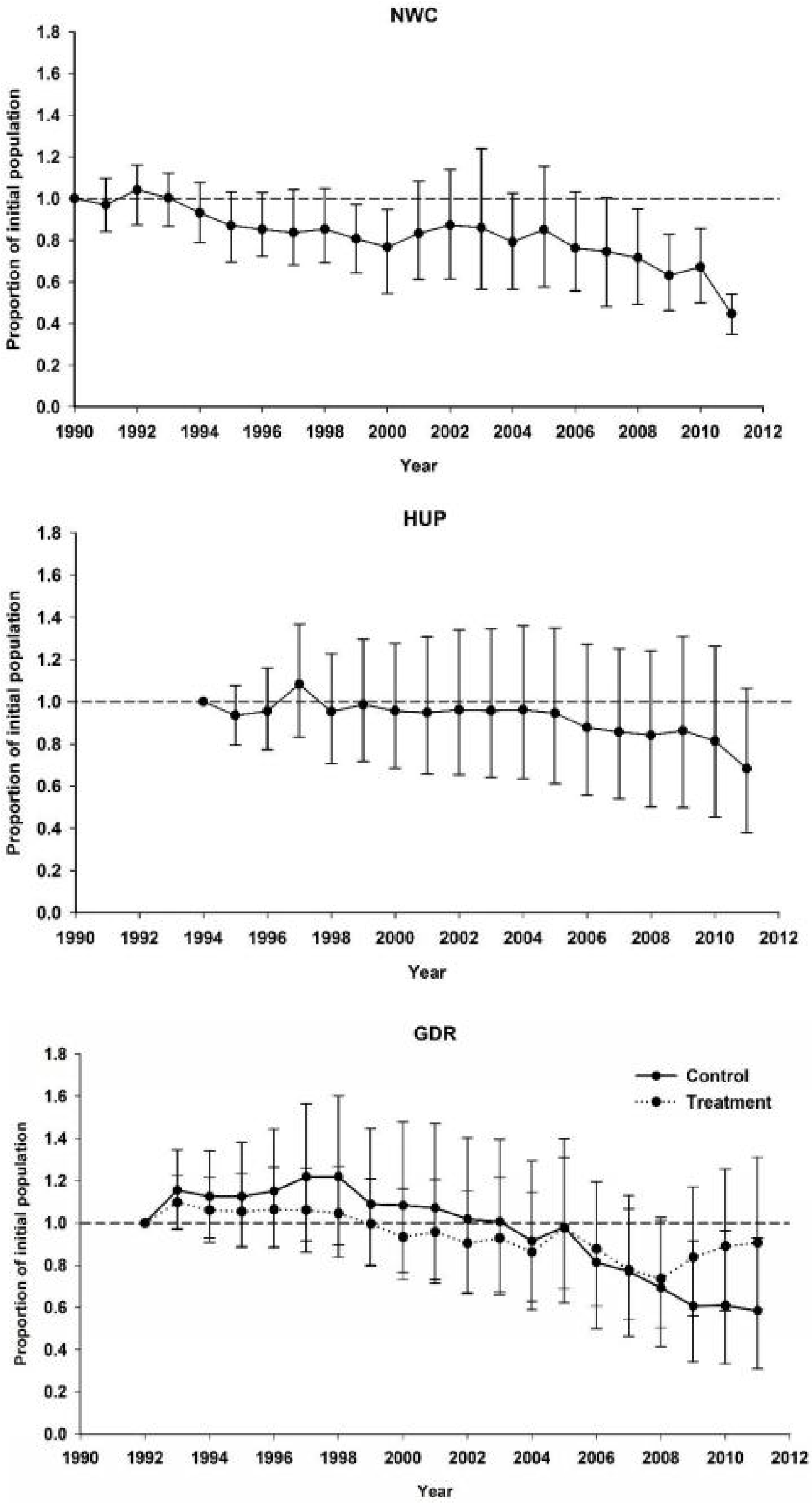

Figure 8. Annual estimates of realized population change with 95% confidence intervals for Northern Spotted Owls at 3 study areas in California. Estimates for the GDR study area are presented separately for control and treatment areas in relation to Barred Owl removals beginning in 2009 (adapted from Figure 5 in Dugger et al. 2016).

Annual rates of decline and the realized population changes continue to be highest in Washington and the COA study area of Oregon where Barred Owls have been well-established for a long time (Table 6). However, population declines are now occurring on study areas in California that were experiencing little decline or were stable through 2006 (i.e. Forsman et al. 2011), and the declines in California are accelerating (Dugger et al. 2016).

Fecundity

Fecundity (i.e., number of female young produced per adult female) was estimated using 12,969 records of the number of young produced by each territorial Northern Spotted Owl female per year (Dugger et al. 2016). Fecundity was influenced by the age of the female owl in all study areas, with mean fecundity generally lowest for 1-yr-olds, intermediate for 2-yr-olds, and highest for adults (Dugger et al. 2016). Mean annual fecundity of adult females ranged between 0.22 and 0.34 (number of female young produced per female per year) for most study areas with the HUP area in California having the lowest annual fecundity (excluding GDR Barred Owl control and treatment areas that have data for only the most recent five years) (Dugger et al. 2016). The CLE study area in Washington was exceptional in that it has had a much higher fecundity rate than other areas (0.57). The range-wide mean annual adult fecundity was 0.31 for 1985-2013. This estimate of fecundity over a 29 year period was lower than any previously reported meta-analysis estimate for Northern Spotted Owls (Anderson and Burnham 1992, Burnham et al. 1994, Forsman et al. 1996, Anthony et al. 2006, Forsman et al. 2011, Dugger et al. 2016).

Annual variation in fecundity is high for Northern Spotted Owls, due in part to the tendency to breed only every other year (see Figure 9 for California study areas). High annual variation can make it difficult to detect trends in fecundity relative to other vital rates that exhibit less temporal process variation (Dugger et al. 2016). Nevertheless, model results provide evidence for declining fecundity on all three study areas in California (see Table 6; Dugger et al. 2016), with strong evidence of decline at the NWC study area. There was little support for strong habitat associations with fecundity on most study areas, however, more nesting and roosting habitat was associated with higher fecundity at the NWC study area and more habitat in the territory core area was associated with higher fecundity at the GDR study area. Precipitation in the early nesting season was associated with a decline in fecundity at the HUP study area.

Annual reproductive rates have also been reported for private timberlands outside of the demographic study areas, although monitoring and analysis approaches are not standardized as in the 11 demographic study areas, so direct comparisons are not possible. Humboldt Redwood Company (HRC 2013) reported a decline in reproductive rates since 2009. In the coastal portion of the Northern Spotted Owl range in California, many areas reported consistently low reproductive success from 2011-2013, including some of the lowest reproductive rates on record in 2013. These low reproductive rates were reported despite weather conditions in 2013 that would typically support high reproductive rates. Similar results were observed on many timber company lands (Calforests 2014, HRC 2014, GDRC 2015), tribal lands (Higley and Mendia 2013), the NWC study area (Franklin et al. 2015), National Park Service lands (Ellis et al. 2013), and on county-owned land in Marin County (Cormier 2013). During 2011, 2012 and 2013 HUP study area showed unusually low reproductive rates of 0.05, 0.13, and 0.06 chicks fledged per pair, respectively. While the decline in reproduction coincided with a major increase in Barred Owls in many areas of coastal California, the reason for this widespread pattern of low reproductive success is not known.

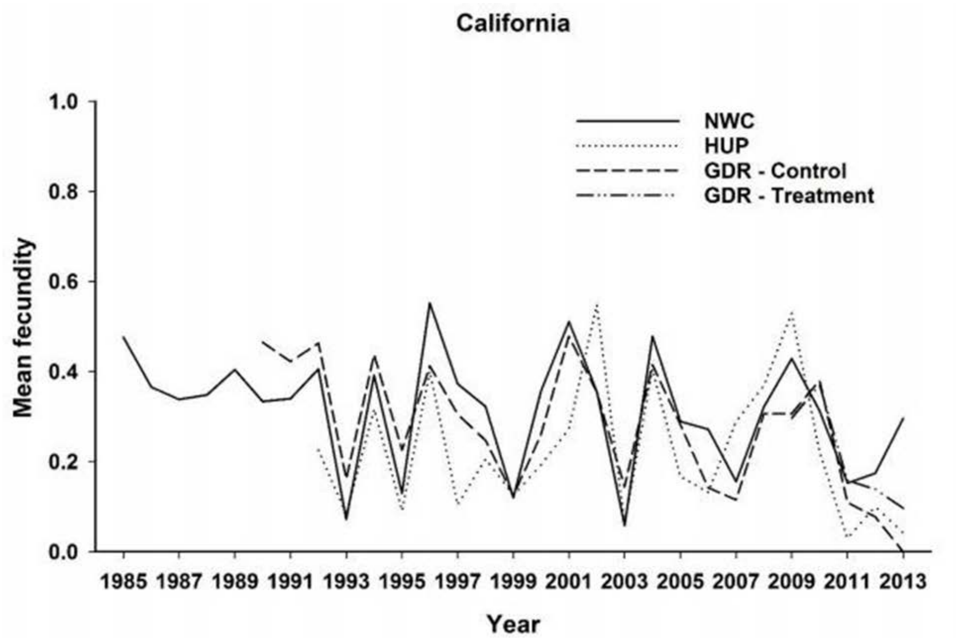

Figure 9. Annual fluctuations in mean fecundity (number of female young fledged per female) of Northern Spotted Owls in 3 study areas in California. Mean fecundity was graphed separately for the areas within the Green Diamond (GDR) study area where Barred Owls were removed (2009–2013; GDR-Treatment) and where Barred Owls were not removed (1990–2013; GDR-Control) (adapted from Figure 9 in Dugger et al. 2016).

Survival

The Northern Spotted Owl is a long-lived species, with high annual adult survival rates. The encounter histories of 5,090 owls were used to estimate apparent survival in 11 individual study areas across 22-29 years (Dugger et al. 2016) using Cormack-Jolly-Seber open population models and mark-resighting data (Lebreton et al. 1992). Mean estimates of apparent survival ranged from a low of 0.835 ± 0.020 on RAI study area, to a high of 0.870 ± 0.009 on HJA study area and 0.870 + 0.021 on GDR treatment areas after barred owl removals began (see Table 17 in Dugger et al. 2016). There was strong support for declining apparent survival in at least 8 of 11 study areas, including all three California study areas and the CAS study area in southern Oregon (see Table 6). These declines in apparent survival are concerning because adult survival is the most important vital rate influencing the rate of population change in long-lived birds, and Forsman et al. (2011) found that for most demographic study areas, changes in λ were driven mainly by changes in survival in Northern Spotted Owls. Franklin et al. (2000) argued that annual survival, which exhibited little annual variation, served as the baseline for λ while recruitment accounted for most of the annual variation in λ.

The best survival models that included the effect of Barred Owl detections found support for a negative effect of Barred Owl presence on apparent survival of Northern Spotted Owls in 10 of 11 study areas (Dugger et al. 2016). In addition, survival rates in the GDR study area were higher in treatment areas after Barred Owl removals began in 2009, increasing from 0.857 ± 0.009 before Barred Owl removals began to a high of 0.870 ± 0.021 after. Conversely, the GDR control areas that did not experience Barred Owl removal saw a decline in survival rates during the same time period from 0.858 ± 0.008 to a low of 0.804 ± 0.032 (Dugger et al. 2016).

Local weather and regional climate covariates occurred in top or competitive survival models for 10 of 11 study areas and in most cases the relationships were as predicted, but there was little consistency among areas as to which specific covariate was important. Increased precipitation during the early nesting period was associated with decreased survival rates at NWC study area and higher temperatures during the early nesting season were associated with higher survival at GDR study area. The meta-analysis which included evaluation of all study areas combined showed that adult apparent survival was higher when Pacific Decadal Oscillation was in a warming phase and lower when the Southern Oscillation Index was negative (negative Southern Oscillation Index indicates El Nino events). That is, higher adult apparent survival was observed when winters were warm and dry (positive association with Pacific Decadal Oscillation and negative association with Southern Oscillation Index) (Dugger et al. 2016).

In California, all three study areas in the recent analysis were shown to be experiencing declines in both fecundity and survival (Dugger et al. 2016). The previous two meta-analyses which analyzed data collected through 2004 and 2009, respectively, found evidence of declining fecundity on two California study areas and declining survival on one (Anthony et al. 2006) or two areas (Forsman et al. 2011). Therefore declines in fecundity and survival in the California portion of the range have become more widespread in the last decade. Results from the recent analysis indicated that declines in apparent annual survival in the California portion of the range of the Northern Spotted Owl may be reaching rates of decline previously observed only in Washington (Dugger et al. 2016). The overall assessment is that reproduction and recruitment from outside the study areas have not been sufficient to balance losses due to mortality and emigration, so the populations on study areas have declined over the 22-29 years included in the study.

Occupancy

Occupancy data are less resource-intensive to collect compared to the banding and resighting data required to estimate the demographic parameters discussed above. Estimation of survival and reproduction requires the capturing and banding of owls at known sites, and multiple annual visits to all sites in order to monitor survival and reproductive status from individually identifiable owls. Occupancy data is based on the presence or absence of owls from known sites, but individual owl histories are not required, and the monitoring of all sites each year is not required (i.e., “missing data” is allowed), although multiple visits per site within years are required in order to estimate detection probability. Due to the reduced requirement in survey effort and the need to visit known Northern Spotted Owl sites during pre-timber harvest monitoring, presence-absence data has frequently been collected and reported by timber companies and by other landowners (e.g., Cormier 2013, Ellis et al. 2013, Calforests 2014, Schmidt 2015).

In order for estimates of occupancy to be valid, survey methods should be consistent over time and the detection probability (the probability of detecting an owl if one is present) must be estimated; inconsistent survey effort can lead to high variation in detection probability which can bias estimates of occupancy and other vital rates if not accounted for in the modeling process. Occupancy estimation also assumes that the occupancy state at sites is closed within years and that sites are independent; in other words, occupancy does not change at a site within a season and detection of the target species at one site is independent of detecting the species at other sites (MacKenzie et al. 2006). Higley and Mendia (2013) observed banded Northern Spotted Owls in more than one territory within a single survey season and movement of owls up to several miles, and suggested that this may result in an inflated occupancy rate on the Hoopa Valley Indian Reservation. These movements represent potential violations of the assumptions of population closure and independent sites and Higley and Mendia (2013) believe that within-season movements may be more likely in areas where Barred Owls are present and displace Northern Spotted Owls. This issue might be resolved if movement is better understood. For example, if the movement occurs over long time periods or during specific seasons it might be able to be accounted for in the sampling design (MacKenzie et al. 2006). Alternatively, estimation of pair occupancy, rather than occupancy by any Spotted Owl (including single owls) may be the best way to avoid the issue of within-season movements by transient owls because the observed movement likely represents single nonterritorial birds.

In the recent meta-analysis of data from the 11 demographic study areas, territory occupancy dynamics were modeled on each study area with strong declines in estimates of occupancy observed at all 11 study areas since the 1990s (Dugger et al. 2016). In California, occupancy rates declined by up to 49%, with the occupancy rate for NWC study area declining from 79% to 47%, from 74% to 38% at HUP study area, and from 92% to 55% on control areas for GDR study area (Dugger et al. 2016). In addition, the declines in occupancy rates have been accelerated at NWC and HUP study areas (Figure 10), although the occupancy rate increased on the GDR treatment area following removal of Barred Owls (Dugger et al. 2016). In the Cascades of southern Oregon, the occupancy rate declined 36% (from 69% to 44%) at the CAS study area and the decline has also been accelerating since the last meta-analysis.

Patterns in site occupancy are achieved through two processes: colonization of previously unoccupied sites, and local extinction of previous occupied sites (MacKenzie et al. 2003, 2006). Thus, the annual probability of site occupancy can be derived from estimates of initial site occupancy (from 1st year of study), and subsequent estimates of annual colonization and local extinction rates (MacKenzie et al. 2003). Based on analyses using multi-season occupancy models that explicitly modeled the occupancy dynamics of both Barred Owls and Northern Spotted Owls on historic Spotted Owl territories (Richmond et al. 2010), the most consistent pattern in occupancy dynamics from the recent meta-analysis was the strong positive association between the presence of Barred Owl and territory extinction rates across all 11 study areas (Figure 11; Dugger et al. 2016). Increased occupancy rates of Spotted Owl territories by Barred Owls were associated with increased extinction rates of Northern Spotted Owls at these same territories. These results are consistent with previous analyses documenting the negative effect of Barred Owl detections or occupancy rates on Northern Spotted Owl extinction rates (Olson et al. 2005, Kroll et al. 2010, Dugger et al. 2011, Davis et al. 2013, Yackulic et al. 2012, 2014). In addition, Barred Owls had a negative effect on site colonization rates at 5 of 11 study areas in the meta-analysis, but this effect was not apparent in California (Figure 11; Dugger et al. 2016). The effect of Barred Owl on local extinction and colonization is evident in the extremely low occupancy rates seen at demographic study areas in Washington where the Barred Owl has been established for a longer time period, with occupancy rates at all Washington study areas below 25% and as low as 11% at the Cle Elum study area (Dugger et al. 2016).

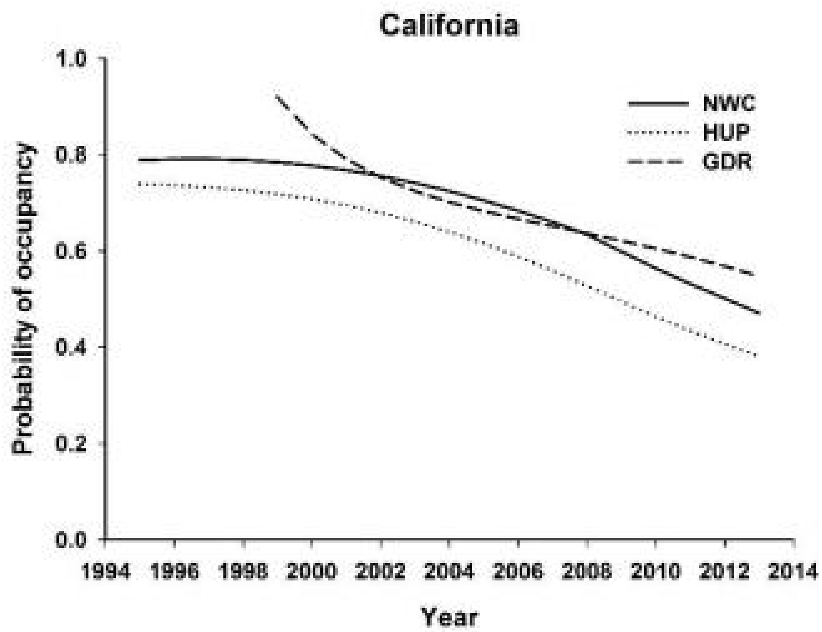

Figure 10. Estimates of the probability of territory occupancy for Northern Spotted Owls on three study areas in California (adapted from Figure 8 in Dugger et al. 2016).

The total amount of suitable owl habitat had a strong positive association with colonization rates at five study areas, including NWC study area (Dugger et al. 2016). Habitat covariates were also associated with extinction rates at 8 of 11 study areas with more suitable habitat at Northern Spotted Owl territories associated with decreased rates of extinction (Dugger et al. 2016). At NWC study area the total amount of suitable habitat in owl territories was positively associated with colonization rate and the amount of nesting and roosting habitat in the territory core was negatively associated with extinction rate, suggesting the importance of habitat at maintaining site occupancy in the Klamath Province in California.

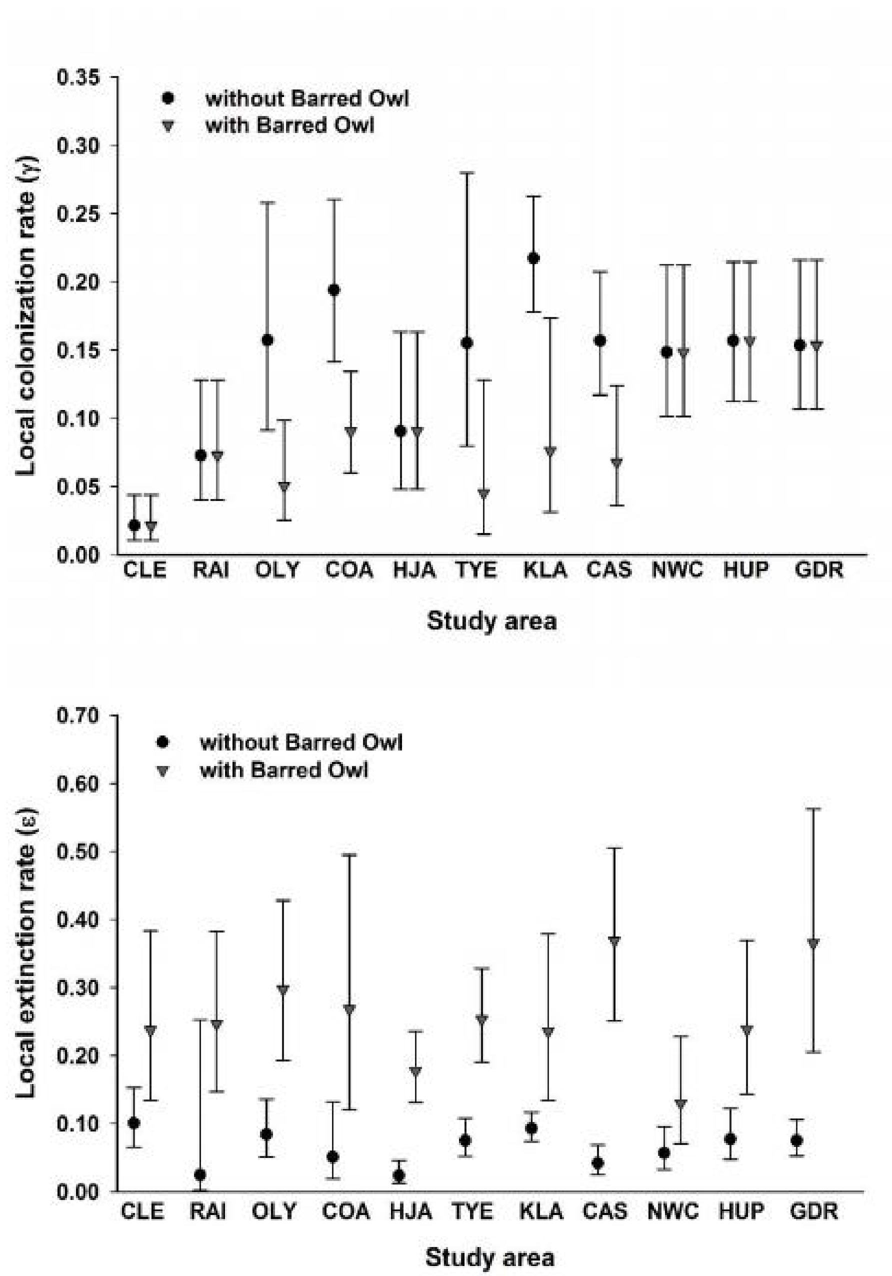

Figure 11. Mean local colonization and extinction rates with 95% confidence limits for Northern Spotted Owls on 11 study areas in Washington, Oregon, and California when Barred Owls are present (gray triangles) or absent (black circles) (adapted from Figure 7 in Dugger et al. 2016).

Declining occupancy rates must be considered when interpreting results of the demographic analysis of other vital rates because estimates of fecundity and survival rates are independent of population size. The estimated rates of fecundity and survival are per capita averages across all owls in a study area and so do not incorporate any direct measure of population size. If a study area experiences a declining number of territorial owls, which on average are experiencing reductions in rates of fecundity, the result will be far fewer owls produced each year. Even if Northern Spotted Owls at a given study area experience stable rates of fecundity over time, areas with declining occupancy rates will produce fewer young overall. Information on rates of survival and fecundity provide a clearer picture of potential mechanisms for population declines (i.e., determination of vital rates that are contributing most to the population declines and factors influencing those rates), but must be considered in association with the number of territorial owls and the factors that drive occupancy rate in order to understand the broader impact to a population.

Although occupancy will often reflect changes in local population size and can provide an alternative to the estimated rate of population change in assessing population status, it is not always appropriate to use an apparently stable occupancy rate to suggest a stable population size. Forsman et al. (1996) makes the following statement regarding occupancy and population declines:

> "…it is possible that in a declining population, observed densities of territorial owls might not change during early years of the decline simply because territorial owls that died could be replaced by floaters (owls without territories) (Franklin 1992). Thus, significant changes in density of territorial owls might not become apparent for many years, especially if the rate of population decline was small (e.g., 1-2% per year)."

Therefore, a lack of a significant decline in observed owl numbers over the short-term might not reflect vital rates in the local population. Although little is known about the floater population of Northern Spotted Owls at any study area, other than that they exist and that they do not readily respond to broadcast calling, the number of floaters is finite. The perception of population stability due to establishment of territories by floaters cannot continue indefinitely in a constantly shrinking population. The annual rate of population decline (λ) will actually increase as the floater population is depleted, because recruitment must then come entirely from continued, annual production of young. If a study area has a relatively robust population of floaters, or if emigration into the study area occurs, the total local population can decline for some time before declines in territory occupancy are observed. Although declines in occupancy can indicate a reduction in local abundance when survey efforts are consistent over time (Bigley and Franklin 2004), a stable occupancy rate may not necessarily indicate that a local population is stable, so estimates of survival and fecundity are also important for assessing the overall status of a population.

Outside of the three California demographic study areas, studies that have provided statistically rigorous estimates of Spotted Owl site occupancy in California are rare. In the southern Cascades and interior Klamath provinces of California where there are no demographic study areas, Farber and Kroll (2012) compiled presence-absence data from 1995-2009 at 63 Northern Spotted Owl sites located within a checkerboard landscape (intermixed federal and private ownership). Occupancy modeling showed that Spotted Owl occupancy probabilities for any detected owls (single or a pair) and for pairs declined approximately 40% over the 15 year period (Farber and Kroll 2012). Site occupancy for owls (single or a pair) declined from 0.81 (0.59-0.93) to 0.50 (0.39-0.60), and pair occupancy declined from 0.75 (0.56-0.87) to 0.46 (0.31-0.61). These results are from private timberlands in an area where Barred Owls occurred only as transients, suggesting that other factors were responsible for observed declines in occupancy, and are consistent with the declines observed on federal lands to the north at the CAS study area in southern Oregon (Dugger et al. 2016). Although estimates of occupancy rate are not available, Northern Spotted Owls appear to have been nearly extirpated from the 97,000 acre Redwood National and State Parks on the northern California coast in Del Norte and Humboldt counties. Forty Northern Spotted Owl activity centers were identified in the parks during the 1990s but most of these sites appear to now be occupied by Barred Owls only (Schmidt 2015). Only four Northern Spotted Owls were detected in these National Parks during 2013-2014, with only one pair observed; the last Northern Spotted Owl fledgling known to have been produced in the parks was reported in 2010 (Schmidt 2015). At the extreme southern edge of the Northern Spotted Owl range in Marin County, recent surveys of 30 historical Northern Spotted Owl sites have shown that naïve estimates of pair occupancy remained high at about 90% (Cormier 2013). Interestingly, this is a portion of the range where Barred Owls remain relatively uncommon.

The Department evaluated occupancy data and results provided by nine private timber management companies (Calforests 2014). In contrast to the above studies at demographic study areas and at other well-monitored areas that showed modeled declines in occupancy or displacement of Northern Spotted Owls, five of nine companies reported a stable trend in occupancy with one company reporting that the population size is variable. Two companies reported a mix of stable, declining, or increasing occupancy, depending on the time period, the method used to estimate occupancy rate, or the portion of the owl population assessed (Calforests 2014). However, several issues with the survey methods or analyses are apparent in data provided by these private timber companies. In at least two cases the samples appear biased due to surveying only the “best” sites every year or excluding sites where Barred Owl had been detected. In several cases survey methods varied from site to site, or from year to year. In most cases the companies reported on counts of occupied sites or on naïve estimates of occupancy (the proportion of surveyed sites that are occupied in a given year) without consideration of detection probability (Calforests 2014). Counts of occupied sites and detection probability are both influenced by survey effort and survey effort was not always reported. An example of this can be seen in data submitted by Mendocino Redwood Company, which appears to show a positive correlation between survey effort and naïve estimates of occupancy (MRC 2014). In several cases, the level of detail at which methods are described does not allow for evaluation of occupancy estimates.

The variability in survey methods used, reports of counts or naïve estimates of occupancy without consideration of detection probability, the sometimes inconsistent or biased methods used over time, and the limited description of methods results in little support for the conclusion by some timber companies that occupancy rates have been stable over time.

However, three timber companies reported results of occupancy modeling for ownerships in the coastal redwood region that incorporated estimates of detection probability. Of these, the Green Diamond Resource Company has participated in the large demographic study since 1990 and the large declines in occupancy at the study area are reported above. The Mendocino Redwood Company reported a slight decline in occupancy rates based on modeling of data collected for a subset of years from 2001-2008. Following this decline, the estimated occupancy rate remained relatively high at 0.78 in 2008, but no estimate of occupancy rate was presented for more recent years during which the local Barred Owl population has increased dramatically (MRC 2014). Campbell Global, L.L.C. manages timber lands for multiple owners, and reported on occupancy rates for two ownerships in Mendocino County (Calforests 2014) where occupancy dynamics were modeled using data from 1990-2010. Here, occupancy probabilities for single Northern Spotted Owls began to decline in 2003, while pair occupancy rates declined by 16-30% during the initial portion of the time period before stabilizing in 1997. The number of Barred Owls observed on the two ownerships in Mendocino County was low with only nine detections from 1999-2013; estimated pair occupancy rates on the two ownerships were 0.70 and 0.85 in 2010. In each of these cases the results of occupancy modeling on private land demonstrated evidence of declines in occupancy rates, providing additional evidence of declining occupancy in the California Coast province.

Habitat Effects on Demographics

Habitat quality has been evaluated in a number of ways including: assessing population density of owls in different habitat types, comparing vital rates between owl sites with different habitat conditions, estimating vital rates for populations of owls across broad areas that exhibit differences in landscape scale forest composition, and estimating vital rates at individual owl territories with specific forest structure and composition. The type, extent, and spatial configuration of forests in a high quality territory vary across the range of the Northern Spotted Owl and across regions of California. Many different combinations of habitat can support a productive Northern Spotted Owl pair with high fitness. Although the specific habitat requirements might vary across the range, the body of evidence suggests that regionally, there are consistent patterns in the amounts and distributions of various forest types that support high quality Northern Spotted Owl territories. As described in the Life History section of this report, Northern Spotted Owls in much of the California portion of the range use heterogeneous forest habitat with older forest required to support nesting and roosting activities. A reliance on a broader set of forest types in California as compared to other portions of the subspecies' range to the north may be due to differences in dominant prey.

In the most recent meta-analysis of all 11 demographic study areas throughout the range of the Northern Spotted Owl (see Figure 7; Dugger et al. 2016), the effect of habitat variables were evaluated for effect on occupancy (including local extinction and colonization rates), fecundity, survival, and rate of population change. The analysis of occupancy rates evaluated the effects of habitat at the scale of individual owl territories, whereas the analyses of survival, fecundity, and rate of population change evaluated the effects as average effects at the subpopulation scale (i.e., across the large study areas) (Dugger et al. 2016). Although modeling the average effect across large study areas is not as powerful at detecting effects that are influential at the territory scale (e.g., presence of Barred Owl or habitat conditions), data limitations required a coarser evaluation in order for methods to be consistently applied across study areas (Forsman et al. 2011).

Unlike the meta-analysis which evaluated the effects of habitat on survival, fecundity, and rate of population change as an average effect at a subpopulation scale, several studies have modeled vital rates and potential explanatory variables at the scale of individual owl territories (e.g., Franklin et al.

2000, Olson et al. 2004, Dugger et al. 2005, Diller et al. 2010). These studies have shown that certain habitat characteristics support high quality Northern Spotted Owl territories, with both the amount and spatial configuration of different habitat types at a territory contributing to levels of survival and fecundity, and therefore λ (as defined above; annual rate of population change) in the resident owls. To describe the differences in habitat quality based on demographic rates at Spotted Owl territories, Franklin et al. (2000) coined the term "habitat fitness potential" (HFP) defined as "...the fitness conferred on an individual occupying a territory of certain habitat characteristics". The habitat characteristics that influence HFP include the amount of nesting, roosting, and foraging habitat, as well as the amount of non-habitat. The spatial configuration of these different habitat types around an activity center has also been shown to be important in determining HFP; with habitat configuration being evaluated both in the core area and at the broader home range. Studies that have evaluated HFP vary somewhat in the size of core areas evaluated and whether core areas were static or dynamic (i.e., whether they were fixed in place or allowed to shift each year based on annual activity center locations). Availability of data for each study area also resulted in different definitions of mature or old forest (representing nesting and roosting habitat) and other vegetation types evaluated in each study. Depending on the study, additional attributes evaluated included non-habitat (e.g., nonforested areas and sapling stands), amount of edge between various land cover types, and abiotic attributes such as precipitation and temperature during different portions of the owl's breeding season. In addition, the Green Diamond study area, designed to evaluate the effectiveness of its Habitat Conservation Plan conservation strategy, included the effect of timber harvest and no-harvest set-aside areas on Spotted Owl demographic parameters (Diller et al. 2010). In addition to results from the meta-analysis, territory-based demographic studies in California and southern Oregon are summarized below and in Table 7.

Four territory-based demographic studies have occurred in southwestern Oregon and northwestern California and represent different geographic areas, forest types, primary prey and thus foraging ecology of Northern Spotted Owls. The results of studies located largely in the California Klamath Province (Franklin et al. 2000) and in the redwood coast region of the California Coast Province (Diller et al. 2010) potentially have the greatest relevance for much of California. However, a study conducted in the Cascades of Oregon just north of the California border (Dugger et al. 2005) may be more relevant to the California Cascades portion of the California range. As described in the Life History section, the dominant prey in an area can influence the types and configuration of habitat used by Northern Spotted Owls, with diet in most of the range in California dominated by woodrats. The diet of Northern Spotted Owls in each of these three study areas was dominated by woodrats, although flying squirrels make up a significant percentage of Spotted Owl diets in the Cascades (Forsman et al. 2004, Dugger et al. 2005). A fourth study, conducted in the Oregon Coast Range where flying squirrels are the dominant prey is also discussed (Olson et al. 2004).

<u>Occupancy</u>

In the meta-analysis, habitat was an important source of variation for Northern Spotted Owl demographics on many study areas, and vital rates were generally positively associated with a greater amount of suitable owl habitat (defined as older forest meeting the needs of nesting and roosting activities). The total amount of suitable Spotted Owl habitat had a strong positive association with site colonization rates at five study areas, including NWC study area in California, and higher amounts of habitat disturbance were associated with lower colonization rates in two areas (Dugger et al. 2016). Habitat covariates were also related to local extinction rates for Northern Spotted Owl pairs in 8 of 11 study areas, and a greater amount of suitable owl habitat was generally associated with decreased extinction rates (Dugger et al. 2016). These results indicate that the amount of suitable habitat is important in determining whether a site will be occupied by Northern Spotted Owl, and corroborate previous results from the southern Cascades just north of the California border with Oregon (Dugger et al. 2011) and in the Oregon Coast Range (Yackulic et al. 2012). Although the presence of Barred Owl has been shown to have the strongest effect on occupancy dynamics, and competition leads to a weaker relationship between habitat and Northern Spotted Owl occupancy (Yackulic et al. 2014), these studies show the importance of conserving large amounts of contiguous old-forest habitat to maintain Northern Spotted Owls on the landscape.

Survival

There is strong evidence from all four territory-based studies that Northern Spotted Owl survival increases with the amount of old forest in the core area and in the broader home range (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005, Diller et al. 2010). Both Franklin et al. (2000) and Dugger et al. (2005) found that survival declined rapidly when less than about 25% of a roughly 400 acre core area is composed of old forest. Survival is also linked to the amount of mid- and late-seral forest and the amount of non-habitat in the broader home range. In the Cascades, survival decreased dramatically at territories with more than 50% non-habitat (i.e., nonforest or saplings) (Dugger et al. 2005). In the Oregon Coast Range, survival also accelerated when the amount of mid- and late-seral forest in 1,750 acre home ranges declined below 50%, and was highest when about 70% of home ranges were composed of mid- and late-seral forest (Olson et al. 2004). Increases in early-seral or non-forest had a negative effect on survival (Olson et al. 2004). Differences in the proportion of non-habitat in home ranges that support high survival rates may be in part due to differences in dominant prey, with Northern Spotted Owls that consume primarily flying squirrels in the Olson et al. (2004) study area requiring more forested habitat.

In the California Klamath Province, Franklin et al. (2000) found that survival increased with the amount of edge between old forest and other vegetation types, presumably because of the availability of prey in these areas. On the redwood coast, owl sites with older forest stands and greater edge density had a positive effect on survival (Diller et al. 2010). Although Dugger et al. (2005) did not find any evidence that a mosaic of old forest intermixed with forests of intermediate age (with hardwood component) provided benefit to the Northern Spotted Owl, nor a benefit of edge in the core area, a negative quadratic relationship between owl survival and amount of non-habitat in the outer portion of the home range may suggest some benefit of an intermediate amount of “edge” in this larger area.

There is also some evidence that high quality habitat can improve survival in years of poor weather conditions. In high quality habitat in the California Klamath Province, Northern Spotted Owl survival declined by only 7.1% in cold, wet springs; whereas survival declined by 26.3% in poor habitat (Franklin et al. 2000).

Fecundity

Like survival, reproductive output on Northern Spotted Owl territories in the California Klamath Province increased with an increase in edge between old forest and all other habitat types in the core area, but unlike survival, decreased with increasing amount of older forest (Franklin et al. 2000). An increase in reproductive output with increases in edge was also demonstrated in the Oregon Coast Range, although edge was evaluated as the junction between both mid- and late-seral forests and early-seral or non-forest (Olson et al. 2004). The opposite relationship was true in the Cascades of southern Oregon where reproductive output increased with the amount of old forest in the core area (Dugger et al. 2005). On the redwood coast of California, four habitat covariates were associated with higher fecundity, and collectively represented areas having high habitat heterogeneity (Diller et al. 2010).

The range-wide meta-analysis provided little support for strong habitat associations with fecundity at the study area scale, however, more nesting and roosting habitat was associated with higher fecundity at the NWC study area and more habitat in territory core areas was associated with higher fecundity at the GDR study area (Dugger et al. 2016). The number of young produced appears to be higher in areas with larger amounts of older forest, at least in some California study areas.

Habitat Fitness Potential

Habitat fitness potential was maximized in the California Klamath Province when core areas were composed of at least 50% late-seral forest in a heterogeneous landscape with other vegetation types (including younger forests and nonforest habitats) (Figure 12). These sites had sufficient old forest to facilitate high survival and adequate edge habitat to facilitate both high survival and high reproductive output. Given this, Franklin et al. (2000) suggest that there is a trade-off between the amount of old forest and the amount of edge required to maximize survival and reproduction. Low amounts of old forest within a territory will not supply the high degree of edge required to support high reproductive output. The study in the Oregon Cascades (Dugger et al. 2005) concluded, "in general, territories with <40% old forest or old-growth habitat near the site center had habitat fitness potential <1, consistent with the relationships between both reproduction and survival and the amount of old forest habitat at the core". Values of HFP can be interpreted similar to those for λ, so values less than one indicate population declines. On the redwood coast of California, HFP was most sensitive to the location of the nest site relative to a no-harvest set-aside. Habitat fitness potential values were highest in the 0.5 mile buffer surrounding a set-aside, and sites with greatest fitness had roughly equal amounts of older and young forests (Diller et al. 2010). The two studies that evaluated a broader home range found that the amount of non-forested area and other forms of nonhabitat must be limited in order to support high HFP (Olson et al. 2004, Dugger et al. 2005).

Perhaps the most notable comparison is that Northern Spotted Owl sites with at least 50% old forest in the core area, intermixed with other forest and nonforest cover types, provided the maximum HFP in both the California Klamath and California Coast provinces (Franklin et al. 2000, Diller et al. 2010), indicating a need for high amounts of old forest in the core area among a heterogeneous mixture of other habitat types. A high amount of old forest in the core area (>40%) was also required in the southern Oregon Cascades in order to maintain values of HFP that were greater than 1.0.

Overall, Northern Spotted Owls require some minimum level of old forest within their core area and broader home range to optimize survival and reproductive output. It is also apparent that older forest mixed with other forest types (excluding non-habitat) benefits Northern Spotted Owl fitness in California and southern Oregon, at least partially due to the increased foraging opportunities along transitional edges. In spite of inconsistencies in methods used and minor differences in amount of old forest and edge that provide the highest habitat fitness for owls, the literature points to the benefits of a mosaic of forest types that contain sufficient older forest, especially around the core area, while limiting the amount of nonhabitat in the home range. Based on the studies in the Northern Spotted Owl range in California and southern Oregon, management that maximizes late-seral forest in the core area (at least 25% to support survival but ideally about 50% to maintain high HFP) while limiting the amount of nonforest or sapling cover types throughout the home range (no more than about 50%) would likely result in high quality Northern Spotted Owl territories.

Table 7. Comparison of four territory-based demographic studies in California and southern Oregon.

	Franklin et al. 2000	**Olson et al. 2004**	**Dugger et al. 2005**	**Diller et al. 2010**
Location of study	California Klamath Province	Oregon Coast Range	Western and Eastern Oregon Cascade provinces	Redwood Coast region of the California Coast Province
Definition of older forest evaluated in the study (representing nesting and roosting habitat)	Spotted owl habitat = mature and old-growth forest with QMD of conifers >53 cm (~21 in), QMD of hardwoods >15 cm (~6 in), percentage of conifers >40%, and overstory canopy coverage >70%	Late-seral forest = stands characterized by trees with >80 cm (~31.5 in) dbh; generally associated with high quality nesting, roosting, and foraging habitat. Mid-seral forest = stands characterized by trees with 24-80 cm (9.5 - 31.5 in) dbh.	Old forest = older (>100 years) conifer or mixed stands characterized by canopy cover >40% and trees >35cm (~14 in) dbh. Old growth = old (>200 years) conifer-dominated stands characterized by canopy cover >40% and trees >75 cm (~29.5 in) dbh.	Spotted owl habitat = mature second-growth >45 years and old-growth forests >180 years
Relationship between older forest and survival	**Positive** Survival declined rapidly at sites with less than **~100 acres** of spotted owl habitat in the core area (i.e. **<25%**) Core area = 390 acres	**Positive** In general, late-seral forest had a positive effect on survival. However, the best model showed highest survival when combined mid- and late-seral forest was about **70%** of the ~1,750 acre (1,500-m radius) circle	**Positive** Pseudothreshold relationship with survival rate dropping rapidly when proportion of old forest in the core drops below **~20-30%** (**~80-100 acres**) Core area ≈ 413 acres	**Positive** Survival increased with older aged nest stands, but this was contingent on also having greater edge density within a 600 m radius of the nest
Relationship between older forest and reproductive output	**Negative** Nonlinear relationship with reproductive output increasing when amount of older forest in the core area is less than **~75-100 acres**	**Negative** Reproductive output declined with increases in mid- and late-seral forest	**Positive** Linear effect with old growth forest in the core area providing the best model	**Somewhat positive** Older forest contributed to reproductive output but only if in a landscape with high habitat heterogeneity

Amount of older forest in the core area in high fitness territories[a]	Variable, with a trade-off between sufficient older forest to support survival and provide a high amount of edge, while providing other forest types in core area to support high reproductive output (see Figure 12; generally at least **~25%** older forest required in core with roughly **50%** supporting highest fitness)	N/A The best model included only the 1,500m diameter circle (~1,750 acres representing broader home range)	In general, territories with **<40%** of the 413 acre core (**~165 acres**) composed of older forests had habitat fitness potential <1.0	Variable but with greatest fitness at sites with roughly equal amounts of older and young forests
Effect of habitat in broader home range or 'outer ring' on vital rates[b]	N/A	Territories with high estimates for λ had a high amount of mid- and late-seral forest in the 1,750 acre area, but also have patches of nonforest within the mosaic of forest types	Survival declined when the amount of nonhabitat in the outer ring portion of the home range exceeded about **60%**	No effects on vital rates extended beyond 600m of the nest stand
Relationship of vital rates with the amount of non-habitat (e.g. non-forest areas, sapling stands)	Did not evaluate directly[c] but heterogeneous landscape of late seral habitat with other vegetation types (which included younger forests and open areas) had a positive influence on habitat fitness	Increases in early seral and nonforest had a negative effect on survival	Survival decreased dramatically when the amount of non-habitat exceeded **~50%** of the home range	Early seral stands were important to create habitat heterogeneity that had a positive influence on habitat fitness
Relationship of vital rates with amount of edge between older forest and other vegetation types[d]	Both apparent survival and reproductive output increased with increasing edge between spotted owl habitat and other vegetation types[e]	The best model showed a positive relationship between reproductive output and amount of edge between mid- and late-seral forest and the other types (early-seral and nonforest).	No support for either a positive or negative effect on survival or reproductive rate	Both apparent survival and reproductive output increased with increasing edge between spotted owl habitat and other vegetation types

[a]Size of the core area evaluated varies across studies. Franklin et al. (2000) evaluated a 390 acre core area. Olson et al. (2004) evaluated a ~279 acre core area, but their best model included only the 1,500m diameter circle (~1,750 acres). Dugger et al. (2005) evaluated a ~413 acre core area.

[b]Size of the broader home range or 'outer ring' evaluated varies across studies. Franklin et al. (2000) did not include an outer ring of habitat or broader home range in their modeling. Dugger et al. (2005) evaluated a ~3,455 acre outer ring. In addition to the core area, Olson et al. (2004) evaluated two larger circles of habitat of ~1,747 and ~4,473 acres.

[c]Franklin et al. (2000) differentiated only between "spotted owl habitat" as defined in the study and all other vegetation types. While they were unable to quantify the relative proportions of each, they indicated that “other habitats” were created naturally by fire, edaphic, and topographic factors and through human-caused (logging) disturbance.

[d]Edge is defined differently among the studies. Franklin et al. (2000) defined edge as occurring between mature forest (spotted owl habitat) and all other vegetation types. Olson et al. (2004) and Dugger et al. (2005) define edge as occurring between nonhabitat and all intermediate and mature forest types.

[e]Franklin et al. (2000) were unable to distinguish different types of edge, but suggested that edges between spotted owl habitat and clearcuts did not generate the type of mosaic that was observed in high-fitness territories.

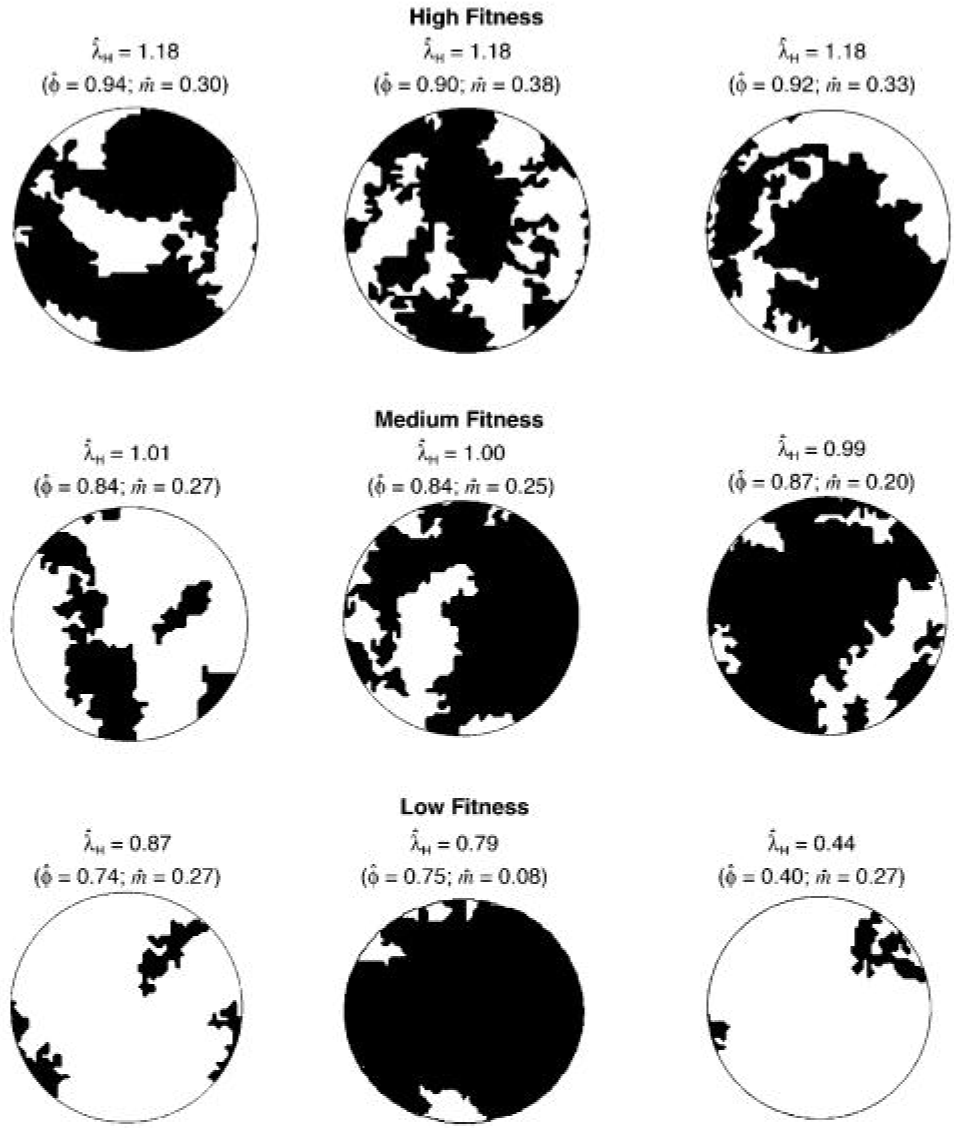

Figure 12. Landscape habitat characteristics in Northern Spotted Owl core areas (390 acres) at three levels of habitat fitness potential in northwestern California. Dark areas are mature and old-growth forests representing nesting and roosting habitat; white areas are all other vegetation types. Estimates of ϕ (apparent survival) and *m* (fecundity) are for owls ≥3 yr old (adapted from Figure 10, Franklin et al. 2000).

Source-Sink Dynamics

Source populations are those in which reproduction exceeds carrying capacity thereby providing a surplus of individuals, whereas sink populations are those where mortality exceeds local reproduction (Pulliam 1988, Dias 1996, Watkinson and Sutherland 1995). The concept of source-sink dynamics has been applied within many ecological studies to better understand movement (e.g., dispersal) interactions on the landscape while accounting for birth and death rates within population segments. Pseudo-sinks are populations that may be viable, but movement dynamics are difficult to distinguish based on complicated demographics and habitat connectivity (Watkinson and Sutherland 1995). These source-sink dynamics have been linked to habitat quality, generally with high quality habitat producing source populations, and low quality habitat producing sink populations (Dias 1996). Protected areas may serve different functions for vulnerable species depending on habitat quality and connectivity (Hansen 2011). Understanding source-sink populations can give us insight into appropriate and effective management actions that may benefit species habitat and populations at a local or range-wide level. For the Northern Spotted Owl, such principles are key to understanding connectivity (quality and function) between populations and how these populations may affect one another.

By applying source-sink modeling techniques and utilizing the immense amount of data available on Northern Spotted Owl life history and demography, Schumaker et al. (2014) conducted a simulation model characterizing Northern Spotted Owl movement dynamics between modeling regions and physiographic provinces noted in the USFWS Revised Northern Spotted Owl Recovery Plan (USFWS 2011). This modeling exercise included assumptions concerning complex parameters (e.g., movement, vital rates, density-dependence, environmental and spatial variation) and does not represent actual owl movements, and therefore, results should be considered only in a hypothetical sense. The purpose of this modeling exercise was recognized by the authors as an attempt to introducing new methodology (Schumaker et al. 2014).

For California, the Northern Spotted Owl populations within the Klamath region (Klamath West and Klamath East modeling regions; California Klamath physiographic province) and the Inner California Coast Range modeling region were projected by the model as source populations, while the California Coast Range and California Cascade physiographic provinces were projected as sink populations (Schumaker et al. 2014); Table 8). Source-sink strength was projected to be substantial for the East Cascade South modeling region (sink), Klamath East region (source), Inner California Coast region (source), California Coast Province (sink), and California Klamath Province (source).

Table 8. Model input of source and sink attributes within modeling region and physiographic province found in California (adapted from Table 2 in Schumaker et al. 2014). Includes percent of modeled range-wide population potential for each location, whether the location projected by the model to be a source or sink, and the strength of the sink/source as a percent of the best range-wide source or worst range-wide sink.

Location	Percent of population	Source or Sink	Source-Sink Strength
Modeling Regions			
East Cascade South	3.8	Sink	100
Redwood Coast	16.4	Sink	28.1
Klamath West	20.0	Source	51.1
Klamath East	17.1	Source	97.9
Inner California Coast	21.7	Source	100
Physiographic Provinces			
California Coast Range	16.6	Sink	100
California Cascades	2.8	Sink	35.9
California Klamath	36.4	Source	100

Schumaker et al. (2014) simulated hypothetical movement and contribution to overall population growth rate within modeling region and physiographic province source locations range-wide. Hypothetical movements and net flux of individuals in California are summarized graphically in Figure

13. Klamath modeling regions (Klamath West and Klamath East) were projected to provide a flux of individuals within (e.g., Klamath West to Klamath East), and to the Cascade modeling regions (East Cascade South and West Cascades South), Redwood Coast, and Oregon Coast. Percent of simulated net flux was most notable from Klamath East to East Cascade South regions. The Inner California Coast modeling region provided a simulated flux of individuals to Klamath and East Cascade South regions. The California Klamath Province was identified as a potential source providing a flux of individuals to the California Coast Range, California Cascades and Oregon Klamath provinces, with net flux most notable to the California Coast Range Province.

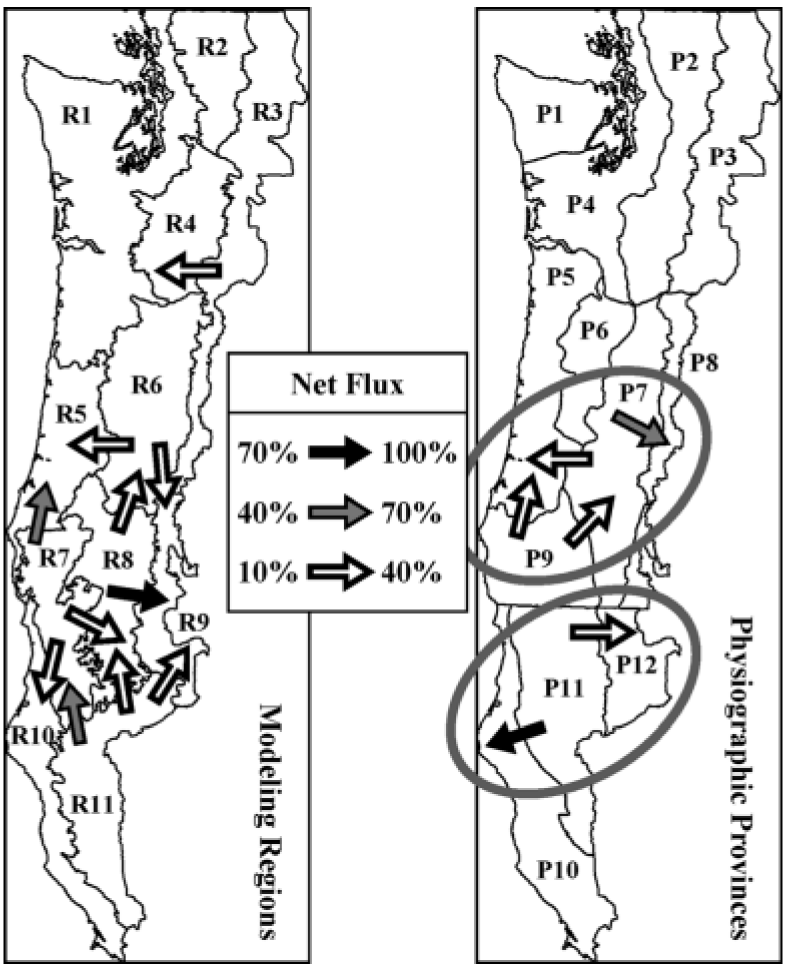

Figure13. A graphical presentation of the hypothetical net flux of Northern Spotted Owls between modeling regions and physiographic provinces (Schumaker et al. 2014, Table 3). Movements depicted do not represent actual owl movements. Black, gray and white arrows represent degree of flux, and arrows represent direction of flux. Gray ovals represent the two major patterns of NSO flux that emerged from the physiographic provinces model simulations, patterns that are also evident in the modeling regions. R7 = Klamath West, R8= Klamath East, R9 = East Cascades South, R10 = Redwood Coast, R11 = Inner California Coast, P10 = California Coast, P11 = California Klamath, and P12 = California Cascades.

Schumaker et al. (2014) presents a modeling approach that attempts to simulate complex ecological systems. One potential issue with this model is that it did not account for the competitive exclusion of

Northern Spotted Owls from their preferred habitat by Barred Owls (see the Barred Owl section of this report). However, the study does illuminate potential source-sink dynamics and suggests that California's population of Northern Spotted Owls is likely a significant component of, and source to the range-wide population. Furthermore, it provides the basis for designing landscape-level experiments to investigate source-sink dynamics relative to the protection of owl habitat and the importance of dispersal habitat, for the continued persistence of Northern Spotted Owls across their range.

Existing Management

Land Ownership Patterns in Northern Spotted Owl Range

The laws and regulations governing management of forests in the range of the Northern Spotted Owl vary depending on ownership. For this reason, the following discussion on existing management is partitioned based on ownership, with lands governed by a common set of regulations. In general, federal timberlands in the range of the Northern Spotted Owl are governed by the NWFP, with some federal ownership subject to more restrictive management (e.g., National Parks). Although tribal lands are subject to federal regulations for timber management, the tribes in the range of the Northern Spotted Owl in California have developed Forest Management Plans (FMPs) and are discussed separately. Nonfederal lands in California must comply with the Forest Practice Rules for commercial timber harvest. There are several options for complying with the Forest Practice Rules when developing a Timber Harvesting Plan depending on several factors including, but not limited to, size of ownership, presence of Spotted Owl activity centers, and qualification for an exemption. We present these options below and discuss the most important options in greater detail.

Federal lands contain less than half of the total forest land in the range of the Northern Spotted Owl (Mouer et al. 2011). Of an estimated 14.3 million acres of forested lands within the Northern Spotted Owl range in California, 6.4 million acres are publicly owned and 7.8 million acres are privately owned (2.3 million acres industrial and 5.5 million acres non-industrial) (Calforests 2013). Federal lands in the Northern Spotted Owl range in California are more concentrated in the interior portion of the range, with most USFS and BLM land occurring in the Klamath and Cascades provinces (Figure 14). The majority of the California Coast Province is under private ownership, though large tracts of public land occur along the coast, including both State and National parks. The most interior portion of the Northern Spotted Owl range in California (Cascades and eastern portion of Klamath provinces) has a combination of federal and private land, sometimes in a checkerboard pattern as a result of historical railway land grants (Figure 14). Tribal lands in California collectively represent 167,401 acres in the range of the Northern Spotted Owl and are located mostly within the Coast Province and the western portion of the Klamath Province.

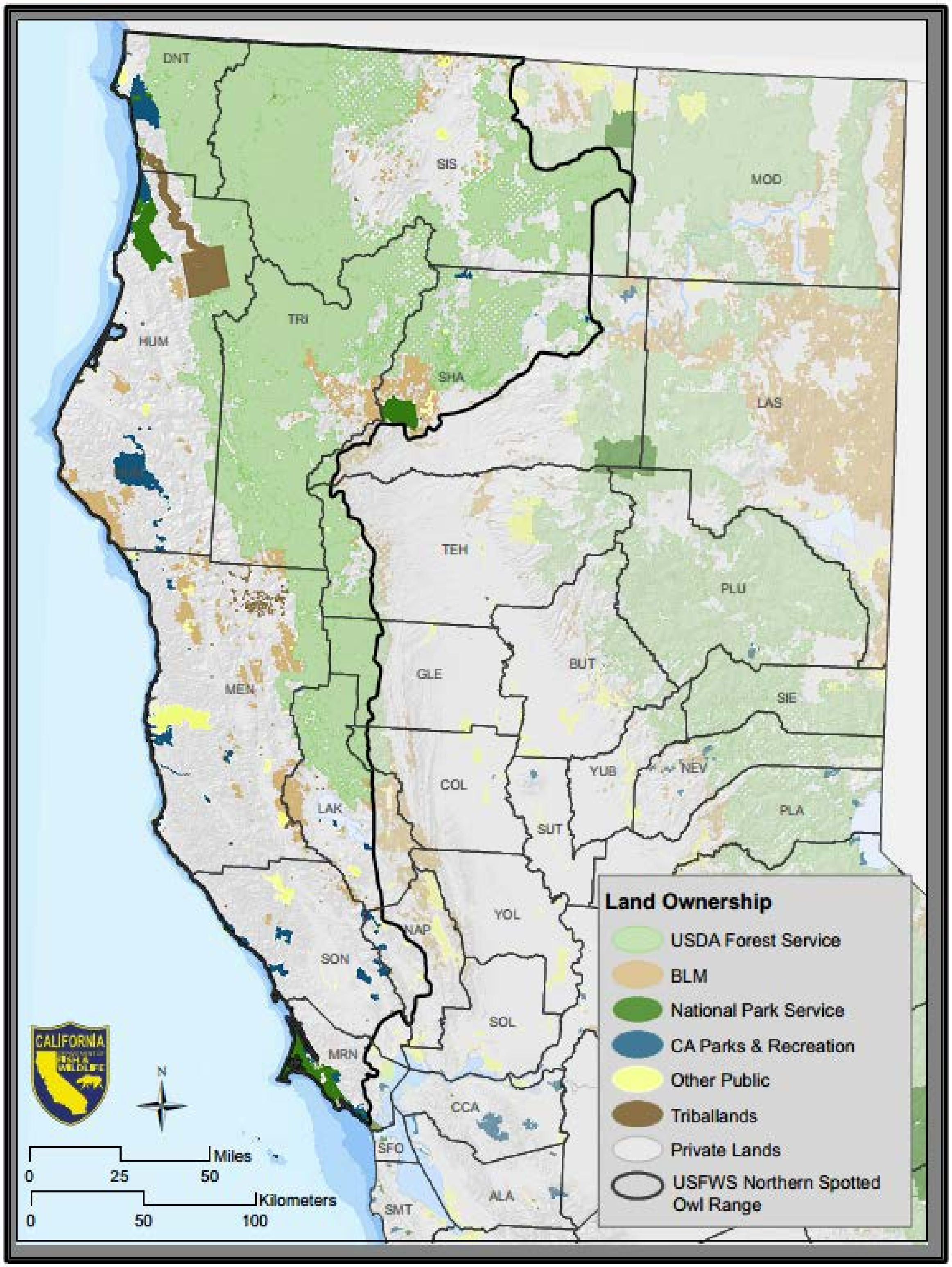

Figure 14. Land ownership within the Northern Spotted Owl range in California.

Critical Habitat Designation

In 2012, the USFWS revised the critical habitat designation for the Northern Spotted Owl (USFWS 2012b). The purpose of critical habitat is to designate land distributed within the entire range of the Northern Spotted Owl that provides "features essential for the conservation of a species and that may require special management," which includes forest types supporting the needs of territorial owl pairs throughout the year, including nesting, roosting, foraging, and dispersal habitat (USFWS website - http://www.fws.gov/oregonfwo/species/data/northernspottedowl/CriticalHabitat/default.asp). Critical habitat was identified using a modeling framework that considered both habitat requirements and demographic data, and considered uncertainties such as impacts of Barred Owl, climate change, and wildfire risk. Range-wide, 9.29 million acres of critical habitat are on federal land and 291,570 acres are on state land. All private lands and the majority of state lands were excluded from the designation. A map of critical habitat for California is shown in Figure 15, which includes 2,014,388 acres on federal land and 49,542 acres on state land. For management purposes, the critical habitat designation only affects federal actions and does not provide additional protection on non-federal lands, unless proposed activities involve federal funding or permitting. The critical habitat designation encourages conservation of existing high-quality Northern Spotted Owl habitat, and active management in potential and existing owl habitat to restore natural processes and increase forest resiliency to perturbations (USFWS 2012b).

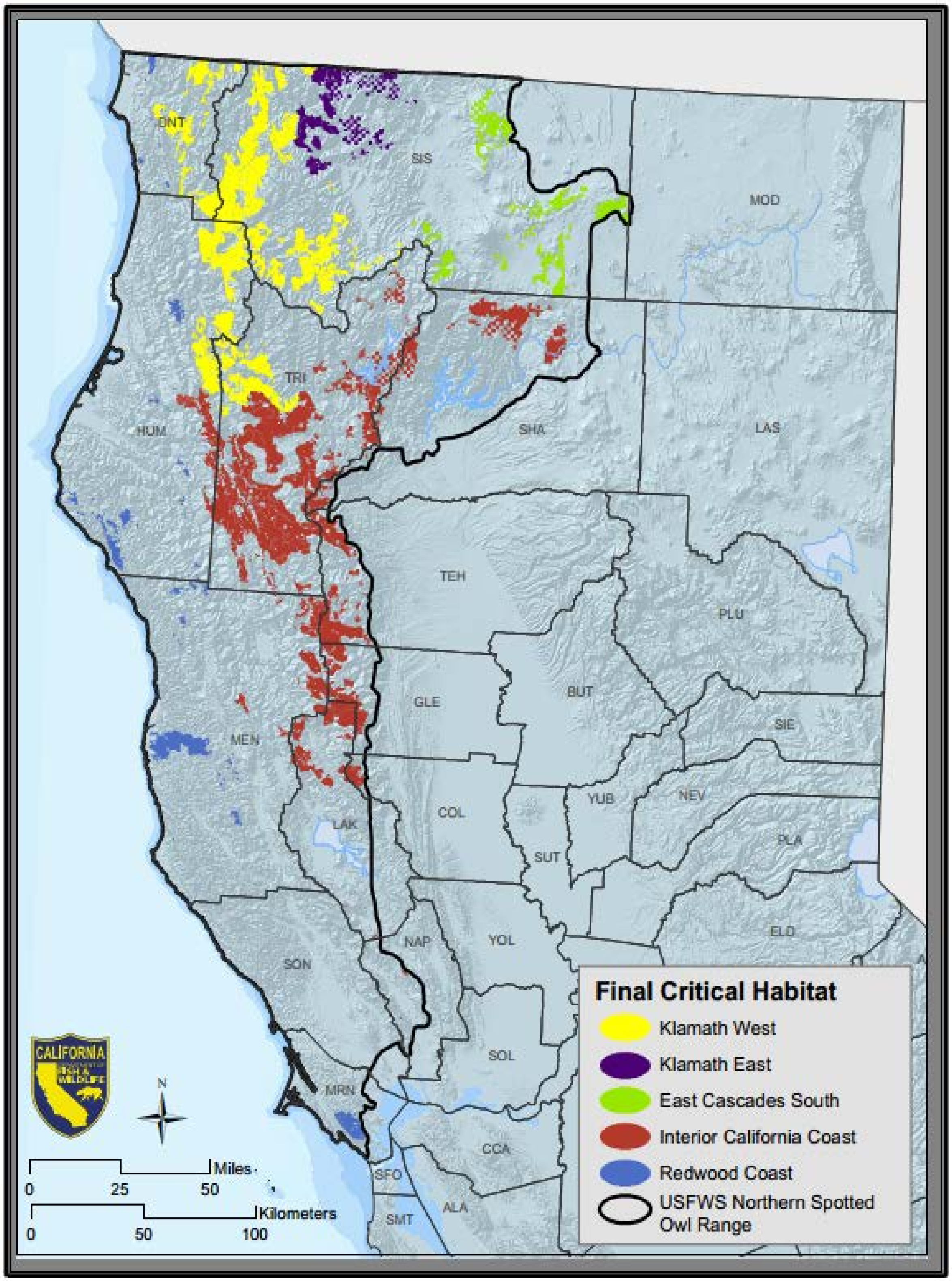

Figure 15. Critical Habitat designation for Northern Spotted Owl in California.

Federal Lands

Northwest Forest Plan

In the early 1990s, concern was raised regarding the adequacy of Northern Spotted Owl protection conveyed by federal plans. Litigation resulted in a court injunction on harvest of owl habitat (i.e. mature and old-growth forest). In 1993, President Clinton directed the Forest Ecosystem Management Assessment Team (FEMAT) to develop long-term management alternatives for maintaining and restoring habitat conditions to maintain well-distributed and viable populations of late-successional- and old-growth-related species. The FEMAT was instructed to maintain and restore habitat conditions for the Northern Spotted Owl (as well as the Marbled Murrelet). The FEMAT was also instructed to maintain and restore habitat conditions to support viable populations, well-distributed across current ranges, of all species known or reasonably expected to be associated with old-growth habitat conditions; and to maintain or create a connected, interactive, old-growth forest ecosystem on federal lands (FEMAT 1993; Thomas et al. 2006). In developing alternatives, the members of FEMAT relied heavily on recently completed conservation assessments, including a regional conservation strategy for the Northern Spotted Owl (Thomas et al. 1990). The analysis of the FEMAT alternatives in a final supplemental environmental impact statement (USDA and BLM 1994a) led to adoption of the land-allocation strategy contained in the record of decision (USDA and BLM 1994b), hereinafter referred to as the Northwest Forest Plan (NWFP). The NWFP amended nineteen existing USFS and seven BLM resource management plans within the range of Northern Spotted Owl. The intention of the NWFP is to improve current conditions and alter past practices that were detrimental to late-successional species, while also meeting needs for forest products, by protecting large blocks of remaining late-successional and old-growth forests, and to provide for the regrowth and replacement of previously harvested late-successional forest stands. To help facilitate decision-making and issue resolution during the implementation of the NWFP, the Regional Ecosystem Office was formed and is made up of members from USFS, BLM, National Park Service (NPS), and Environmental Protection Agency (EPA).

The NWFP covers over 24 million acres of federal land within the range of the Northern Spotted Owl, about 67% of which are allocated in one of several “reserved” land use designations (Thomas et al. 2006; Table 9; also see discussion of designations). In California, approximately 3.5 million acres of federal lands fall under the NWFP as reserved land (Table 10). This is approximately 6% of the 57 million acres of forested habitat within the Northern Spotted Owl’s California range. Reserved lands are intended to support groups of reproducing owl pairs across the species’ range. Unreserved land is defined as the federal land between reserved lands and is intended to provide recruitment of new owls into the territorial populations and is important for dispersal and movement of owls between larger reserves.

Table 9. Land-use allocations in the Northwest Forest Plan (adapted from Thomas et al. 2006).

Land-use allocation	Approximate Acres (%)
Congressionally reserved areas	7,323,783 (30)
Late-successional reserves	7,433,970 (30)
Managed late-successional reserves	102,242 (1)
Adaptive management areas	1,522,448 (6)
Administratively withdrawn areas	1,477,730 (6)
Riparian reserves	2,628,621 (11)
Matrix	3,976,996 (16)
Total	***24,465,790 (100)***

Table 10. Land-use allocations in the California portion of the Northwest Forest Plan.

Land-use allocation	Approximate Acres
Administratively Withdrawn	465,518
Congressionally Reserved	1,406,818
Late Successional Reserve and Adaptive Management Reserve	1,595,767
Total	***3,468,103***

Reserved land includes late-successional reserves (LSRs), managed late-successional areas (managed LSAs), congressionally reserved lands, and larger blocks of administratively withdrawn lands (Davis and Lint 2005). The LSRs cover about 30% of the NWFP area and were located to protect areas with concentrations of high-quality late-successional and old-growth forest on federal lands and to meet the habitat requirements of the Northern Spotted Owl (Thomas et al. 2006). Most LSRs were designed to accommodate at least 20 pairs of Northern Spotted Owls (FEMAT 1993). Timber harvesting is generally prohibited in LSRs. However, silviculture treatments (including thinning in stands less than 80 years old west of the Cascades and treatments to reduce the risk of large-scale disturbances) are allowed in LSRs to benefit the creation and maintenance of late-successional forest conditions. Timber harvest and post-fire salvage logging is allowed within managed LSAs to help prevent habitat destruction caused by large catastrophic events such as severe wildfires, disease, or insect epidemics. Congressionally reserved lands are those that were previously reserved by an act of Congress, such as Wilderness Areas, National Parks, and National Wildlife Refuges. Administratively withdrawn lands (AMA) are areas identified in current forest and district plans as being withdrawn from timber production and include recreational and visual areas, back country, and other areas not scheduled for timber harvest. In California, reserved lands occur primarily in the interior portion of the Northern Spotted Owl range in the Klamath and Cascades provinces, with smaller amounts of reserved lands on the coast (Figure 16).

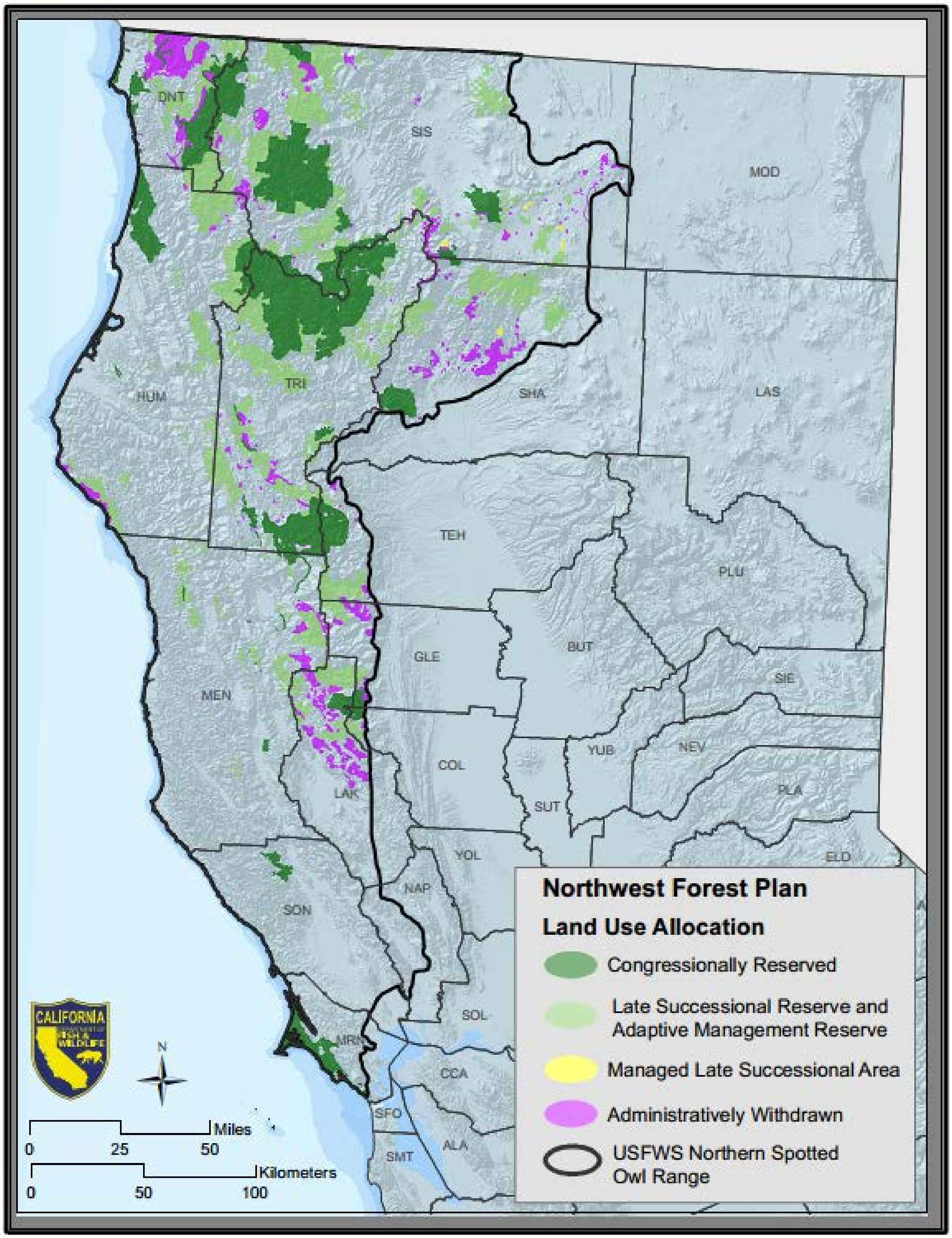

Figure 16. Northwest Forest Plan land use allocation within the Northern Spotted Owl range in California.

Federal lands between reserved lands were designed to provide dispersal habitat from one reserve to another. These lands include the matrix, riparian reserves, smaller tracts of administratively withdrawn lands and other smaller reserved areas such as 100-acre owl core areas (Davis and Lint 2005). The matrix represents the federal land not included in any of the other allocations and is the area where most timber harvesting and other silviculture activities occur. However, the matrix does contain non-forested areas as well as forested areas that may be unsuited for timber production. Three of the major standards and guidelines for matrix land management are: (1) a renewable supply of large down logs must be in place; (2) at least 15% of the green trees on each regeneration harvest unit located on National Forest land must be retained; and (3) 100 acres of late-successional habitat around owl activity centers must be protected (USDA and BLM 1994b). Timber harvesting is allowed within AMAs and like the matrix lands, AMAs are subject to the standards in the NWFP and in individual forest and district plans. Riparian reserves are a system of reserves defined by a set distance on each side of perennial and intermittent streams (Thomas et al. 2006) and may provide dispersal habitat for Northern Spotted Owls.

Standards and guidelines for the management of both reserved and unreserved lands are described in the Record of Decision associated with the NWFP (USDA and BLM 1994b, Attachment A). A summary of management on each land use designation is provided below.

<u>Late Successional Reserves</u>

Before habitat manipulation activities occur on LSRs, management assessments must be prepared. These assessments include a history and inventory of overall vegetative conditions, a list of identified late-successional associated species existing within the LSR, a history and description of current land uses within the reserve, a fire management plan, criteria for developing appropriate treatments, identification of specific areas that could be treated under those criteria, a proposed implementation schedule tiered to higher order plans, and proposed monitoring and evaluation components to help evaluate whether future activities, if carried out as intended, achieve the desired results. The following standards must be followed for timber management activities in LSRs:

- West of the Cascades – No timber harvest is allowed in stands over 80 years old. Thinning (pre-commercial and commercial) may occur in stands up to 80 years old in order to encourage development of old-growth characteristics.
- East of the Cascades and in California Klamath Province – Silviculture activities should be designed to reduce catastrophic insect, disease, and fire threats. Treatments should be designed to provide fuel breaks but should not generally result in degeneration of currently suitable owl habitat or other late-successional conditions. Risk reduction activities should focus on young stands but activities in older stands may be undertaken if levels of fire risk are particularly high.
- Post-fire salvage in disturbed sites of less than 10 acres is not appropriate. Salvage should occur only in stands where disturbance has reduced canopy closure to less than 40%. All standing living trees should be retained, including those injured (e.g., scorched) but likely to survive. Snags that are likely to persist until late-successional conditions have developed should be retained. Appropriate levels of coarse woody debris should be retained. Some salvage will be

allowed when it is essential to reduce fire risk or insect damage to late-successional forest conditions.

Managed Late Successional Areas

Innovative silviculture techniques may be applied in managed LSRs. Proposed management activities are subject to review by the Regional Ecosystem Office, although some activities may be exempt from review. Within managed LSRs, certain silviculture treatments and fire hazard reduction treatments are allowed to help prevent complete stand destruction from large catastrophic events such as high intensity, high severity fires; or disease or insect epidemics. Managed LSAs should have management assessments as described for LSRs. Standards and guidelines for multiple-use activities other than silviculture are the same as for LSRs.

Congressionally Reserved Lands

These lands are managed according to existing laws and guidelines established when the lands were set aside, and are generally managed to preserve natural resources (e.g., The National Park Service Organic Act of 1916, the National Parks Omnibus Management Act of 1998).

Administratively Withdrawn Areas

There are no specific timber/silviculture standards and guidelines associated with AMAs. These areas have been identified as withdrawn from timber production in forest or district plans.

Riparian Reserves

Riparian Reserves are managed to meet objectives of the Aquatic Conservation Strategy to help protect fish habitat and restore water quality. Timber harvest is prohibited within riparian reserves, including fuelwood cutting and salvaging (although some exceptions are made). Fuel treatment and fire suppression strategies and practices implemented within these areas are designed to minimize disturbance.

Matrix Lands

Matrix lands are open to timber harvest subject to the standards in the NWFP and in the individual forest and district plans. The objective for Matrix lands is to “provide coarse woody debris well distributed across the landscape in a manner which meets the needs of species and provides for ecological functions” (USDA and BLM 1994b). Standards for Matrix lands in the NWFP include:

- Coarse woody debris that is already on the ground is retained and protected from disturbance to the greatest extent possible during logging and other land management activities that might destroy the integrity of the substrate.
- Retention of at least 15% of the area associated with each cutting unit (stand).

- In general, 70% of the total area to be retained should be aggregates of moderate to larger size (0.5 to 2.5 acres or more) with the remainder as dispersed structures (individual trees, and possibly including smaller clumps less than 0.5 acres). Patches and dispersed retention should include the largest, oldest live trees, decadent or leaning trees, and hard snags occurring in the unit. Patches should be retained indefinitely (i.e., through multiple rotations to provide support for organisms that require very old forests).
- 100 acres of the best Northern Spotted Owl habitat must be retained as close to the nest site or owl activity center as possible for all known activity centers located on federal lands in the Matrix land and AMAs. These areas are managed in compliance with LSR management guidelines and are to be maintained even if Northern Spotted Owls no longer occupy them.

Adaptive Management Areas

AMAs were intended to be focal areas for implementing innovative methods of ecological conservation and restoration, while meeting economic and social goals. Although there have been some successes in experimentation, most AMAs have been managed similarly to Matrix lands (Thomas et al. 2006). The NWFP established 10 AMAs, two of which are in California: Goosenest in northeastern California and Hayfork, which is located mostly in the Klamath province. One of the primary goals of the Goosenest AMA is to investigate means of accelerating the development of late-successional forest properties in pine forests. Mechanical treatments (forest thinning) and prescribed fire have been used experimentally to evaluate effect on development of late-successional forest properties in pine forests (Ritchie 2005). The emphasis for Hayfork is to investigate effects of forest management practices on the landscape, including partial cutting, prescribed burning, and low-impact approaches to forest harvest. Standards and guidelines for LSRs and Congressionally Reserved Areas are followed where they fall within AMAs.

Section 7 Consultations

Section 7 of the Endangered Species Act requires all federal agencies to consult with the USFWS to ensure that any timber management action authorized, funded, or carried out by federal agencies is not likely to jeopardize the continued existence of a listed species, or destroy or adversely modify critical habitat (16 U.S.C. § 1536 subd. (a); 50 C.F.R. § 402). Section 7 requires the permitting instrument (i.e., biological opinion or letter of concurrence) to include measures to minimize the level of take to Northern Spotted Owl. Examples of take minimization measures may include:

- Restricted use of noise-generating equipment during the breeding season
- Retention of larger trees in owl nesting, roosting and foraging habitat
- Retention of snags , down woody material, and hardwoods
- Maintenance of existing nesting, roosting and foraging habitat within core areas and home ranges, and minimizing activities in nest groves
- Monitoring and surveys for Northern Spotted Owl throughout projects

Forest Stewardship Contracting

The Agricultural Act of 2014 ("Agricultural Act of 2014, Section 8205, Stewardship End Result Contracting Projects") grants the USFS and BLM authority to enter into stewardship contracting with private persons or public entities to perform services to "achieve land management goals for the national forests or public lands that meet local and rural community needs" (USFS 2009). Agreements allow contractors to remove forest products (goods) in exchange for performing restoration projects (services), the cost of which is offset by the value of the goods. Agreements may extend for up to 10 years.

Since the new authority became law, the USFS has awarded more than 30 stewardship projects, but it is unknown how many USFS stewardship projects are in California. There are some inconsistencies in information regarding the number of BLM stewardship projects. The BLM Stewardship Contracting Fact Sheet (http://www.blm.gov/style/medialib/blm/wo/Planning_and_Renewable_Resources/0.Par.13217.File.dat/stcontrBLM_Fact0115.pdf) lists two stewardship projects that do not occur in California. However, the BLM website (http://www.blm.gov/wo/st/en/prog/more/forests_and_woodland/0.html) lists three forest stewardships in California: Weaverville Community Forest, South Knob, and Hobo Camp.

Bureau of Land Management

The standards and guidelines from the NWFP apply to BLM lands except where existing resource management plans are more restrictive or provide greater benefits to late-successional forest related species.

Headwaters Forest Reserve

Headwaters Forest Reserve is located in the north coast region of California and was purchased by the Secretary of Interior and the State of California in 1999 to preserve a large stand of old-growth redwood forest. The Headwaters Forest Reserve Resource Management Plan (USDOI et al. 2003; USDOI and BLM 2004a) was developed with the goal to restore and maintain ecological integrity and to study ecological processes within the Reserve to improve management. Recreation and other management activities are constrained as necessary to be consistent with that primary goal. Old-growth forest habitat within the Reserve is managed to leave those systems undisturbed as core areas of optimal owl habitat. Second-growth forests are managed using tree thinning for restoration of old-growth characteristics. Priority is given to revegetating watershed restoration sites in old-growth areas and to treating harvested stands with old-growth remnants. Harvested stands that comprise early-mature and older seral stages (i.e., stands with an average stem diameter over 12 inches) are generally not thinned. Density-management treatments do not yield commercial forest products; all biomass is left on-site and may be lopped and scattered, piled and burned, or chipped. Chain saws, mechanical brush cutters, and chippers may be used. Permanent or temporary roads or skid trails are not developed for access for treatment sites, but temporary access routes may be developed where they will be subsequently removed during watershed restoration activities.

The desired outcome for Northern Spotted Owl is protection of existing habitat and expansion of suitable habitat for nesting, roosting, foraging, and dispersal habitat at the Reserve. The Resource Management Plan allows for the restoration of up to 2,757 acres of previously harvested stands. No suitable habitat for Northern Spotted Owl is to be removed or degraded during watershed restoration, forest restoration, or trail development. To the extent practicable, activities will be buffered from Northern Spotted Owl nesting habitat during the period of February 1 through July 31 by the use of vegetative or topographic screening and establishment of seasonal operating periods or a distance buffer of up to 0.25 mile. Off trail hiking is prohibited year-round.

Fuels in second-growth forests are managed through tree thinning with materials lopped and scattered, piled and burned, or chipped; broadcast burning is not employed within the Reserve. Fuels are not managed in old-growth forests and generally not in second-growth forest once they achieve early-mature seral stage. Fire suppression uses a minimum-impact strategy. In second-growth forests dozers may be used; resource damage will be minimized and full rehabilitation of dozer fire lines will be required after fire suppression. In old-growth forests road access will be limited to existing road systems; hand crews or helicopter bucket drops may be deployed to attempt to contain fire.

King Range National Conservation Area

The King Range National Conservation Area (NCA) is located along the northern California coast about sixty miles south of Eureka and 200 miles north of San Francisco. The King Range NCA Management Plan (USDOI and BLM 2004b; USDOI and BLM 2005) applies to 68,000 acres of forested land. All of the forested lands in the planning area have been designated as a LSR under the NWFP, and therefore must be managed to promote late-successional forest characteristics. All active forest management activities in the Management Plan are focused only in the Front Country Zone, a 25,661 acre zone representing a broad mix of uses and tools for management. Forest management activities in this zone are intended to develop more natural stand characteristics in areas that were previously harvested, improve watershed and fisheries health, and protection from wildfire risk. Some of these previously-logged areas have burned in high intensity fires, or are at risk for future fires of stand-replacing intensity. The primary goal in silvicultural treatments is to increase the Douglas-fir component in tanoak dominated stands, and "fireproof" this Douglas-fir component so that it has a greater chance to reach maturity.

The Management Plan calls for the protection of sufficient Northern Spotted Owl habitat to attract and support 20 breeding pairs within the King Range NCA, as well as monitoring of known owl sites and periodic surveys in suitable habitat. At the time of the Management Plan development (2004), there were 12-14 known Spotted Owl activity centers in the King Range NCA. No timber harvests takes place in those activity centers.

National Park Service

Redwood National and State Parks

Redwood National Park was established in 1968 and was expanded in 1978. Three California state parks established in the 1920s—Prairie Creek Redwoods State Park, Del Norte Coast Redwoods State Park, and Jedediah Smith Redwoods—were included within the 1968 congressionally designated national park boundary. Since 1994, the four park units have been managed jointly as Redwood National and State Parks (RNSP) to the greatest extent possible, although the state parks are administered by the California Department of Parks and Recreation and the national park is administered by the NPS. Collectively, RNSP covers approximately 131,983 acres of land in northwest California reaching from the shoreline of the Pacific Ocean to the mountains of the Coast Range. Approximately 97,000 acres (39,000 hectares) in RNSP are forested land, and of that, 41,192 acres (16,670 hectares) are old-growth forests and 45,019 acres (18,219 hectares) are second-growth forests (e.g., ≥40 years) (Schmidt 2015).

In 2000, a joint federal-state management plan was developed to provide a clearly defined, coordinated direction for resource preservation and visitor use and a basic foundation for managing these four parks (NPS 2000a, NPS 2000b). There are nine management zones within the RNSP, each with different types and levels of use, management, and facilities that are allowed. Three zones cover most of the combined park area – the two backcountry zones (42.1% mechanized and 13.3% nonmechanized), and the primitive zone (32.6%). The backcountry zones and primitive zone have the most restricted access, and resource modification and degradation from visitor use in these zones is low. The remaining 12% of the park area is made up of six relatively small zones which are managed for various resources and for visitor operational needs.

The RNSP General Management Plan (NPS 2000b) includes programs for watershed restoration, vegetation management, cultural resource management, interpretation and education, and facility development. Under the watershed restoration program, abandoned logging roads that contribute unnatural amounts of sediments into streams or threaten redwoods along park streams will be removed or treated to reduce erosion. The vegetation management program includes use of silviculture techniques in second-growth forests that accelerate the return of characteristics found in old-growth forests and management of fire to support resource management strategies, including restoration of fire in old-growth forests.

Prior to timber removal, the NPS will evaluate trees that are potential suitable nesting habitat for Northern Spotted Owl. The NPS will take measures to reduce noise disturbance and loss of suitable habitat within one mile of occupied and unsurveyed potential suitable nesting habitat by operating outside the breeding season, using quiet equipment, or by implementing daily limited operating periods for heavy equipment during the breeding season. Protective buffer zones are used around known owl nest sites where visitor use activities are likely to result in disturbance.

In 1978, Congress expanded RNSP to include 38,000 acres that had been logged between 1950 and 1978 using clearcut tractor logging. With the expansion of the RNSP, commercial operations including active forest management and silviculture thinning ceased which resulted in second-growth forest conditions "considered unhealthy from both a silviculture and an ecological standpoint" (NPS 2008, NPS 2009a). Many of the second-growth forest stands were primarily high-density, even-aged Douglas-fir stands with little canopy structure and no understory development. The focus of second-growth forest restoration is to reduce stand density (thinning) to promote growth of remaining trees while protecting adjacent old-growth forests, as well as maintaining water quality in riparian habitats, minimizing tanoak tree disturbance, and minimizing excessive fuel build-up on the forest floor.

In 2009, the NPS planned to apply thinning prescriptions throughout 1,710 acres in the South Fork of Lost Man Creek, with the prescription dependent upon slope steepness, available road access, presence of streams and wetlands, tanoak density, and proximity to old growth forest.

The USFWS issued a Biological Opinion (file number 8-14-2004-2133 81331-2008-F-00027, dated December 19, 2007) that concurred with the NPS determination that the project may affect but is not likely to adversely impact the Northern Spotted Owl. The project was expected to alter approximately 1,539 acres of suitable Northern Spotted Owl habitat. However, the habitat was considered poor quality and the short-term adverse effects on owls from habitat alteration to be negligible. The project was expected to have long-term benefits for Northern Spotted Owl due to retention and protection of deformed trees and snags, and habitat improvement through acceleration of development of late-successional forest structure.

In 2011, Redwood National Park completed a project to thin about 1,700 acres of second growth forest in the South Fork of Lost Man Creek (near the community of Orick) to accelerate the restoration of old-growth characteristics and functions.

The RNSP General Management Plan called for preparation of a comprehensive trail and backcountry management plan to guide the development of an expanded trail system and prescribe policies and regulations for the use of backcountry areas by hikers, bicyclists, and equestrians. The Trail and Backcountry Management Plan (NPS 2009b) details the construction of seven hiking trails totaling 14.6 miles, establishment of two bike trails totaling 10.3 miles, and construction of two new backcountry camps. Avoidance and minimization measures during construction include above ambient noise producing work conducted outside of the marbled murrelet noise restriction period (March 24-September 15) and Northern Spotted Owl presence surveys prior to construction (NPS and CDPR 2013).

Fire management in RNSP includes suppression of wildfires, prescribed fire, mechanical fuel reduction, fire ecology research and fire effects monitoring, and fire operations planning (NPS 2010a, NPS 2010b). Fire suppression preparations include installing water tanks, preparing access roads, and removing hazardous fuels. Management actions are designed to avoid or minimize adverse effects on listed, proposed, or candidate threatened or endangered species and minimizes the effects on sensitive species. The NPS has developed guidelines to reduce or eliminate potential adverse effects on sensitive species from fire suppression in RNSP.

Point Reyes National Seashore and Muir Woods National Monument

The Point Reyes National Seashore (PRNS) was established in 1962 and is located along the coast just north of San Francisco. The General Management Plan and Environmental Impact Statement for PRNS are currently under development.

Having gained a better understanding of the role of fire in ecosystem preservation and reducing fire risk, in 2004 the NPS proposed to revise PRNS's Fire Management Plan to expand the use of prescribed fire and mechanical treatment for all lands under its management (NPS 2004). In 2006, the Operational Strategy for the Fire Management Plan was published (NPS 2006a). The planning area for the Fire Management Plan includes the 70,046-acre PRNS as well as 18,000 acres of the Northern District of Golden Gate National Recreation Area. The Fire Management Plan allows up to 3,500 acres per year to be treated using prescribed fire and mechanical treatments. Measures in Northern Spotted Owl habitat include:

- Annually identify and map areas where Spotted Owls are nesting.
- Protect occupied and previously used nest sites from unplanned ignitions.
- Do not conduct prescribed burns within 400 m of an occupied or previously used nest site.
- Do not conduct mechanical treatments with mechanized equipment within 400 m of an occupied or previously used nest site between February 1 and July 31 (breeding season).
- Conduct post-treatment monitoring to ascertain any impacts.

Muir Woods National Monument is managed by the NPS as part of the Golden Gate National Recreation Area. The General Management Plan Environmental Impact Statement for the Golden Gate National Recreation Area and Muir Woods was completed in 2014 (NPS 2014). The Record of Decision was expected to be completed in spring 2014 but has not been completed to date.

The Fire Management Plan for Muir Woods allows up to 595 acres to be treated per year using mechanical treatments and prescribed fire (NPS 2006b). Measures to protect Northern Spotted Owl include:

- Treatment activities or any noise generation above ambient noise levels will not occur within 0.40 km (0.25 mile) of a known occupied or previously used nest site, or within potential Spotted Owl habitat between February 1 and July 31 (breeding season), or until such date as surveys conforming to accepted protocol have determined that the site is unoccupied or non-nesting or nest failure is confirmed.
- Mechanical fuel reduction activities in suitable habitat, known or potential, will not substantially alter the percent cover of canopy overstory and will preserve multilayered structure. When shaded fuel break features in suitable habitat are constructed, the resulting multilayered canopy will only be reduced to a height of 6 to 8 feet, or along roadways as needed for emergency vehicle clearance.
- Prior to fire management activities, project areas will be surveyed for the presence of dusky footed woodrat nests. If feasible, woodrat nests will be protected.

- Within habitat, the cutting of native trees greater than 10 inches DBH will be avoided unless a determination is made that the native tree presents a clear hazard in the event of a fire or cutting is the only option to reduce high fuel loading.
- The fire management officer will arrange for qualified biologists to conduct post-project monitoring to determine short- and long-term effects of fire management actions on activity centers if resources are available.

Tribal Lands

Hoopa Valley Indian Reservation

The Hoopa Valley Indian Reservation is the largest reservation in California encompassing 90,767 acres, and is located in the northeastern corner of Humboldt County. The Hoopa Valley Tribe has recently adopted a revised Forest Management Plan (FMP) covering the period of 2011-2026 (Higley 2012). The annual allowable timber harvest has been determined to be 8.889 million board feet (MBF) net per year of conifer volume and 3.1 MBF net of hardwood volume to be harvested within the Reservation. Northern Spotted Owl habitat losses are expected from implementation of the FMP due to timber harvest, urban development, road construction, and prairie restoration. About 8,980 acres of roosting-foraging and nesting-roosting-foraging habitat are estimated to be lost to timber harvest over the period covered by the FMP. These acres will be temporarily rendered unsuitable to Northern Spotted Owl, although the FMP notes that habitat will "recover eventually to at least foraging dispersal but likely to roosting-foraging habitat…within 30-40 years because of the retention of large structures within all units" (Higley 2012). Implementation of the FMP and associated projects will result in a decline in total suitable habitat by approximately 4.4% by the end of the planning period in 2026. Dispersal habitat will be reduced by approximately 4.9% at the end of 2021 but is expected to rebound to a net reduction of 0.9% by 2026.

The Hoopa Valley Indian Reservation is expected to function as a high quality corridor between late successional reserves to the north, south, and east, and Redwood National Park to the northwest. The reservation will retain sufficient habitat for 50 potential Northern Spotted Owl territories and 20-40 pairs of owls at all times during the planning period. However, the plan notes this number of Northern Spotted Owl will not likely be realized unless Barred Owls are removed from the Reservation. Between 2009 and 2014 over 85% of the historical Northern Spotted Owl sites within the Reservation had Barred Owl detections during regular surveys. During this period, there was steady decline in Northern Spotted Owl occupancy beginning in 2007 in concert with an ongoing increase in Barred Owl detections (Higley 2012, Dugger et al. 2016).

Eight forested management units noted in the FMP will retain Northern Spotted Owl dispersal habitat. None of the forested management units will dip below 50% cover of dispersal or higher quality habitat. The lowest level of owl habitat retention will occur within the Hopkins management unit, which at 72% at the time of the publication of the FMP, was projected to drop to 64% in 2012 and increase to 81% by 2026.

The FMP dictates management actions to mitigate affects to Northern Spotted Owl including land allocation restrictions, requirements for structural retention within timber sale units and hardwood management guidelines, such as:

- The no cut land allocation includes 24,581 acres of which 21,104 acres were forested as of 2011 with stem exclusion or larger size class strata including 10,134 acres of old growth.
- 2,819 acres are allocated as reserved for threatened and endangered species. 73 acres are specifically reserved to protect Northern Spotted Owl nesting core areas.
- Seasonal restrictions will apply to all disturbance activities resulting from logging, site preparation, stand improvement, burning, road construction or reconstruction, and watershed restoration projects, etc. within 0.25 miles of any known Northern Spotted Owl pair, at least until nesting status is determined, from February 1 until July 31. Activities such as logging, which modify suitable nesting and roosting habitat, will be further restricted until September 15 of each year or until the young owls are determined to be capable of moving away from the area or the reproductive attempt has been determined to have failed. For territories that have been surveyed continually and found to be unoccupied for 2 or more years, no restrictions shall be imposed.

Yurok Indian Reservation

The Yurok Indian Reservation is located in Del Norte and Humboldt counties and includes one-mile on each side of a 44 mile stretch of the Klamath River. There are approximately 59,000[1] acres in the entire Yurok Indian Reservation, and of these, approximately 3,320 acres are forested Tribal trust lands (i.e., land that the federal government holds legal title to but the beneficial interest remains with the Tribe), and 2,171 acres are forested allotted lands held in trust (Erler 2012). The remaining lands are fee lands (i.e., land acquired by the Tribe under legal title outside the boundaries of the Reservation, and in this case primarily owned by Green Diamond Resource Company), which are managed intensively for timber products. Total forested Tribal ownership is 36,637 acres.

The Yurok Tribe's FMP (Yurok Forestry Department 2012) includes elements for the management of all Yurok Tribal lands both within and outside of the reservation boundary. The FMP calls for surveys for Threatened and Endangered species (including Northern Spotted Owl) and dedication of no cut areas around all Threatened and Endangered species sites and most traditional species nest/roost/den sites. The management objective for Northern Spotted Owl is to maintain all activity centers as no harvest reserves for the benefit of late-seral cultural, sensitive, and listed species. Northern Spotted Owl activity centers protect owl roost/nest sites and are a minimum of 60 acres of the best existing Spotted Owl

[1] Total acreage in this section may be slightly more due to a recent acquisition of Pecwan, Bear and some of Blue Creeks units from Green Diamond Resource Company.

habitat as determined by a qualified wildlife biologist. Seasonal restrictions may be required on disturbance activities within 0.25 mile of Northern Spotted Owl nest.

Round Valley Indian Reservation

The Round Valley Indian Reservation encompasses about 23,200 acres in Mendocino County. More than two thirds of this area is off-reservation trust land. A total of 2,837 acres are allocated as "Available" under the Round Valley Indian Reserve FMP (Baldwin, Blomstrom, Wilkinson and Associates 2006), which means that programmed timber harvest may be allowed. As of 2006, there were eight known pairs of Northern Spotted Owl either nesting, roosting, or foraging on the Reservation. Approximately 80% of the Reservation could be considered as suitable owl habitat, according to the FMP's Environmental Assessment (2006). The FMP would impact about 13% of the 22,150 acres of suitable habitat on the Reservation. Uneven-aged forest management including single-tree and group selection is the preferred silviculture method, with a 20 year cutting cycle and 100 year rotation, although limited even-aged management is allowed in specific cases. Harvest is expected to be about 3.4 MFB/acre.

Nonfederal Land

Regulatory Background

The California Department of Forestry and Fire Protection (CAL FIRE; http://www.calfire.ca.gov/) enforce the laws that regulate logging on privately-owned lands in California. These laws are found in the 1973 Forest Practice Act which was enacted to ensure that logging is carried out in a manner that will also preserve and protect California's fish, wildlife, forests, and streams. Additional rules enacted by the California Board of Forestry and Fire Protection (BOF) are enacted as state regulations and are collectively referred to as the Forest Practice Rules. The Forest Practice Rules implement the provisions of the Forest Practice Act in a manner consistent with other laws, including the California Environmental Quality Act (CEQA) of 1970, the Timberland Productivity Act of 1982, the Porter Cologne Water Quality Act, and CESA. CAL FIRE ensures that private landowners abide by these laws when harvesting trees. Although there are specific exemptions in some cases, generally all commercial harvesting operations for private landowners from ownerships composed of small parcels to large timber companies with thousands of acres are required to comply with the Forest Practice Act as implemented by the Forest Practice Rules.

A Timber Harvesting Plan (THP) is generally the environmental review document submitted by landowners to CAL FIRE which outlines the timber to be harvested, how it will be harvested, and the steps that will be taken to prevent damage to the environment. THPs are prepared by Registered Professional Foresters (RPF) following the provisions of the Forest Practice Rules. The THP process substitutes for the Environmental Impact Report process under CEQA because the timber harvesting regulatory program has been certified pursuant to Public Resource Code section 21080.5.

A history of timber management on nonfederal lands and the Forest Practice Rules can be found in Appendix 9.

Timber Harvest Management

<u>Timber Harvest Plans</u>

As noted previously, a THP is a document that outlines the level and type of proposed timber harvest, and details steps to be taken to prevent damage to the environment, including measures to avoid take of Northern Spotted Owl. Landowners prepare THPs following the provisions of the Forest Practice Rules, and select options for which to follow (Section 919.9 [939.9], subsections (a) through (g)). The purpose of these options is to avoid unauthorized take of Northern Spotted Owl; each of these seven options for complying with the Forest Practice Rules are described in the previous section of this report.

In order to assess the Forest Practice Rules options that have been used in recent THPs, all THPs submitted to CAL FIRE in 2013 within the Northern Spotted Owl range were reviewed. Forest Practice Rules section 919.9 [939.9], subsections (e) and (g) (hereafter referred to as options (e) and (g)), were used in the majority of THPs to demonstrate that unauthorized take of Northern Spotted Owl was avoided. Other options utilized in THPs submitted in 2013 included Section 919.9 [939.9], subsections (a), (b), and (d). On the coast in Humboldt and Del Norte counties there are two industrial timberland owners with Habitat Conservation Plans that cover Northern Spotted Owl and in 2013 over a third of the THPs submitted on the coast utilized option (d) (plans submitted under an incidental take permit). Habitat Conservation Plans utilizing option (d) and Spotted Owl Resource Plans utilizing option (a) are discussed in separate sections below.

THP Distribution

Within the range of the Northern Spotted Owl in California, a total of 175 THPs were submitted to CAL FIRE in 2013 from 10 counties (Del Norte, Humboldt, Lake, Mendocino, Napa, Shasta, Siskiyou, Sonoma, Tehama, and Trinity counties). Of these, 115 THPs were associated with owl activity centers in seven counties, encompassing approximately 69,226 acres of proposed harvest on private timberland (CAL FIRE 2015). Figure 17 summarizes the number and percent of THPs associated with owl activity centers submitted from each county in the interior and coastal regions. Due to the different habitat retention guidance for interior and coastal THPs, the assessment for interior counties included THPs with activity centers within 1.3 miles of a proposed project, and the assessment for coastal counties included THPs with activity centers within 0.7 mile of a proposed project. Of the 115 THPs associated with owl activity centers, 93 were in coastal counties and 22 were in interior counties.

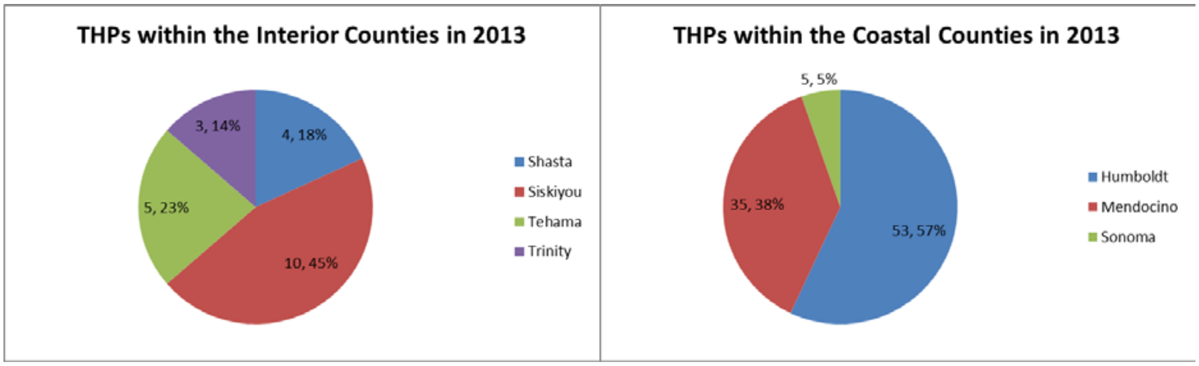

Figure 17: Number and percent of Timber Harvest Plans submitted in the interior and coastal counties during 2013 that were associated with Northern Spotted Owl activity centers in California.

THP Silviculture Methods

Of the 115 THPs associated with owl activity centers, a total of 66 utilized option (e) (60 coastal and six interior), and 9 utilized option (g) (two coastal and seven interior) in 2013. Silvicultural prescription methods and associated acres of proposed harvest from the 66 THPs that applied option (e) in 2013 are summarized in Figure 18. Silvicultural prescription methods and associated acres of proposed harvest from the 9 THPs that applied option (g) in 2013 are summarized in Figure 19. Silvicultural prescription methods are defined in the Forest Practice Rules, and are included in Appendix 1. Variable Retention prescription was the most utilized method for the 66 THPs using option (e), with nearly 28,000 acres of proposed harvest. Alternative, Clear Cut, and Shelterwood prescriptions were the most utilized method for the 9 THPs using option (g), with 1,413, 714, and 657 acres of proposed harvest, respectively. The number of THPs and the total proposed acres for THPs utilizing option (e) surpassed those using option (g) in 2013.

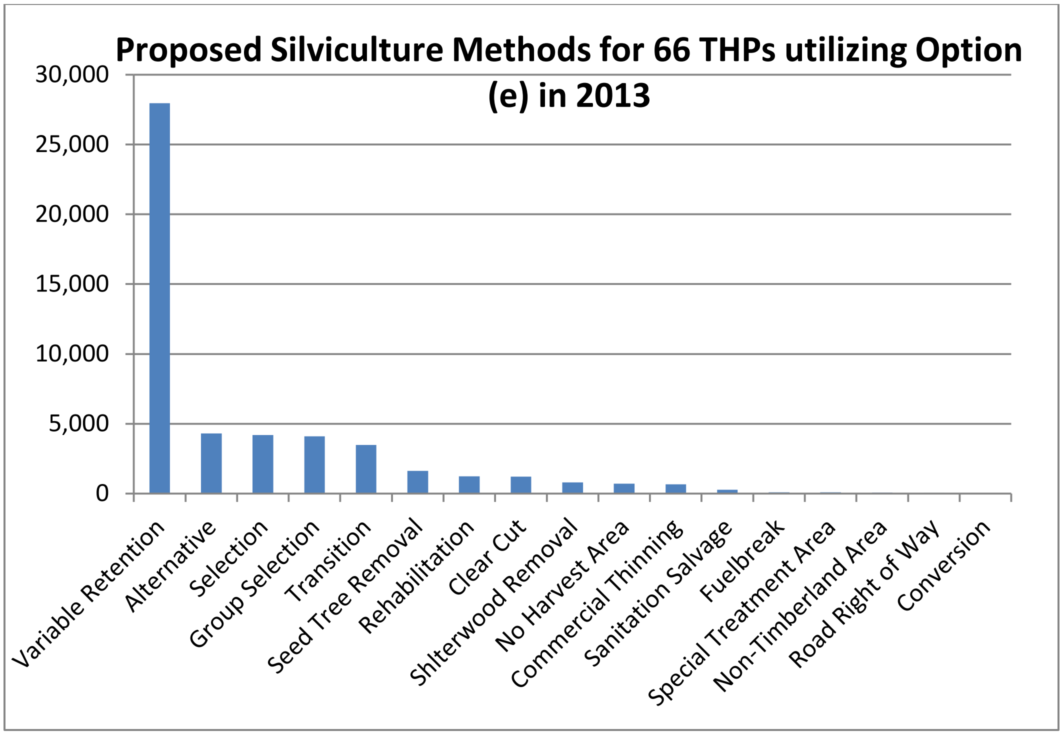

Figure 18: Acreages of silvicultural prescription methods proposed for the 66 THPs (60 coastal and 6 interior) submitted in 2013 that utilized option (e) and were associated with Northern Spotted Owl activity centers.

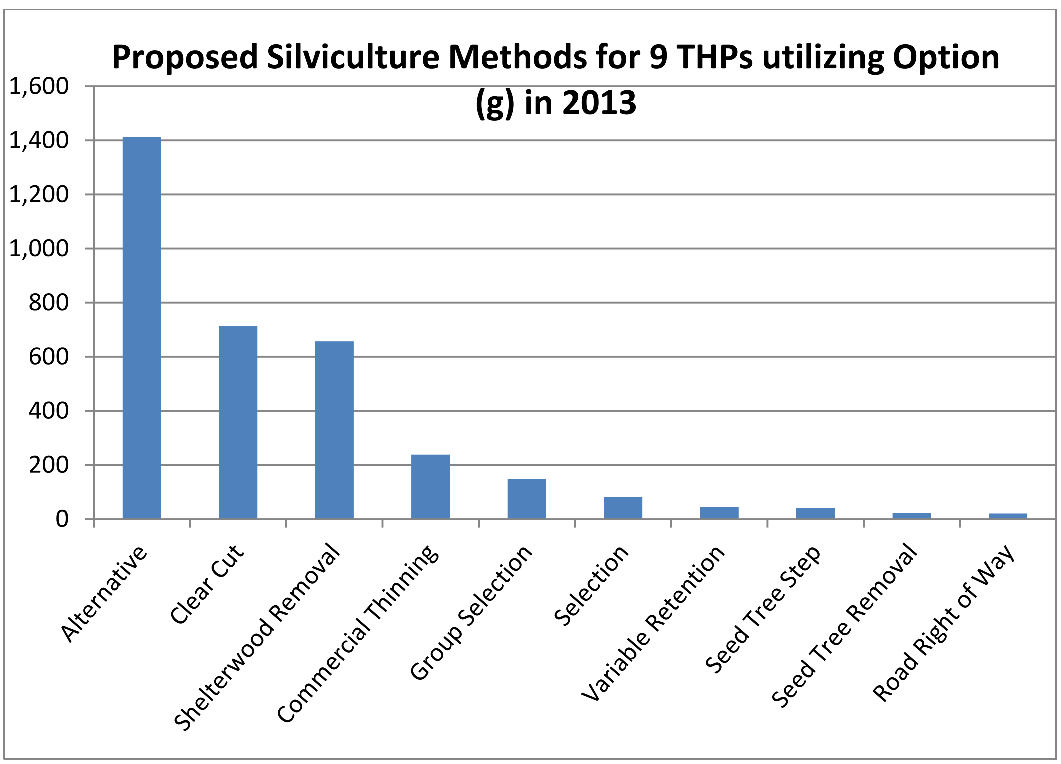

Figure 19: Acreages of silvicultural prescription methods proposed for the 9 THPs (2 coastal and 7 interior) submitted in 2013 that utilized option (g) and were associated with Northern Spotted Owl activity centers.

Proposed silvicultural prescription methods and harvest amounts in the interior and coastal counties differed significantly. The dominant methods and acreages for interior and coastal THPs that used options (e) and (g) in 2013 and that were associated with activity centers are summarized in Table 11. In the interior, the Alternative method was proposed more than any other method, covering 9,798 acres within 1.3 miles of activity centers, and composed more than half of the total acreage. When the Alternative method is used, the plan must include a description of which silvicultural method is most nearly appropriate or feasible, and must also describe how the Alternative method differs from the most similar method. For plans using the Alternative method in the interior, the majority of THPs identify Clear Cut as the silvicultural method most similar to the Alternative method used. The Alternative method as applied differs from Clear Cut in that units typically include a habitat retention area, which can range from 2-10% of the harvest unit. Habitat retention areas usually include hardwoods and/or cavity trees to promote use by wildlife species. On the coast the Variable Retention was used on 28,144 acres within 0.7 miles of activity centers, far more area than all other methods combined. Variable Retention is an approach to harvesting based on the retention of structural elements or biological legacies (trees, snags, logs, etc.) from the pre-harvest stand for integration into the post-harvest stand to achieve various ecological, social and geomorphic objectives (see Appendix 1).

Table 11. The most frequently used silvicultural prescription methods within 1.3 miles of an activity center in interior THPs and within 0.7 miles of an activity center in coastal THPs in 2013.

13 THPs from Interior Counties	Acres	62 THPs from Coastal Counties	Acres
Alternative	9,798	Variable Retention	28,144
Group Selection	2,389	Selection	5,227
Clear Cut	2,257	Group Selection	4,314
Shelterwood Removal	1,574	Transition	3,470
Commercial Thinning	1,335	Seed Tree Removal	1,645
No Harvest Areas	1,015	Clear Cut	1,404

To assess the distribution, extent, and silvicultural practices of THPs over a longer time period, all THPs approved from 1991 to 2014 were evaluated. Within the range of the Northern Spotted Owl in California, a total of 5,567 THPs were submitted from 1991-2014, representing a proposed harvest acreage of 1,471,134 acres (CAL FIRE 2015). An assessment of potential home range disturbance was conducted by evaluating proposed harvest within 1.3 miles of all Northern Spotted Owl activity centers included in the 5,567 THPs. A total of 2,050 activity centers were documented within 1.3 miles of THPs, with combined timber harvest acreage of 880,036 acres within 1.3 miles of all activity centers. The highest amounts of proposed timber harvest acreage were observed in Humboldt (278,543 acres), Mendocino (281,191 acres), and Siskiyou counties (110,446 acres) (Table 12). The most common types of silviculture within the home range of all activity centers were clearcut (183,751 acres), alternative (160,967 acres), and selection (149,569 acres) (Table 12). The average timber harvest acreage per 1.3 mile radius of each activity center was 429 acres, approximately 13% of a hypothetical home range circle of 1.3 mile radius. While providing the average harvest acreage around Northern Spotted Owl territories provides some perspective on potential average impact to territorial owls, the actual harvest amount and distribution at specific activity centers would provide a better assessment of the potential range of impacts to territorial Spotted Owls. Also, this rough assessment includes a large but unknown number of home ranges that are only partially located within THP boundaries, so it is not possible to determine the actual proportion of home ranges that has been proposed for harvest. A detailed analysis of cumulative harvest at individual activity centers was conducted for activity centers located in selected THPs that were submitted in 2013; this analysis is presented below.

Table 12. Acres proposed for harvest under various silvicultural prescriptions for THPs within 1.3 miles of a Northern Spotted Owl activity center, 1991-2014.

County	Clearcut	Alternative	Selection	Group Selection	Seed Tree	Shelter-wood	Other methods	Total
Interior Counties								
Trinity	17,638	24,669	5,911	1,553	6,365	6,570	7,337	**70,043**
Siskiyou	22,885	40,873	6,546	9,843	404	10,280	19,615	**110,446**
Shasta	6,882	10,763	14,870	5,193	113	2,036	12,750	**52,607**
Tehama	215	24,507	2,226	215	707	7,070	2,149	**37,089**
Coastal Counties								
Humboldt	99,303	13,751	43,852	30,282	12,117	10,746	68,492	**278,543**
Mendocino	25,753	41,943	65,439	32,905	35,531	7,208	72,412	**281,191**
Del Norte	8,169	825	827	703	2,855	245	2,267	**15,891**
Lake	66	450	1,196		471	1,031	1,106	**4,320**
Napa	2	97	81	32	20	7	450	**689**
Sonoma	2,410	2,304	8,120	622	2,930	416	3,301	**20,103**
Glenn	428	785	501	454	2,046	4,434	466	**9,114**
Total	**183,751**	**160,967**	**149,569**	**81,802**	**63,559**	**50,043**	**190,345**	**880,036**

Proposed Harvest and Habitat Retention for THPs Associated with Activity Centers

To better understand the level of proposed harvest and habitat retention at owl activity centers, each THP utilizing option (e) and option (g) in 2013 within the interior and coastal region was assessed further. For 13 interior THPs (six using option (e) and seven using option (g)), habitat retention and harvest were assessed at two scales: within 0.5 miles and between 0.5 and 1.3 miles of an activity center. For 62 coastal THPs (60 using option (e) and two using option (g)), habitat retention and harvest was only assessed within 0.7 miles of an activity center. The 0.5 mile and 0.7 mile radii around activity centers is meant to capture the core habitat use of Spotted Owls within their home ranges in the interior and coastal regions, whereas the 1.3 mile radius is meant to capture the broader home range.

The 13 interior THPs and 62 coastal THPs utilizing options (e) and (g) in 2013 were associated with a total of 160 Northern Spotted Owl activity centers (22 interior activity centers, and 138 coastal activity centers). For interior THPs, a pre- and post-harvest habitat analysis was provided in each THP to indicate the amount of suitable owl habitat that would be retained within 0.5 and 1.3 miles of an activity center once timber harvesting had been completed. For each of the 13 interior THPs, four habitat types are assessed: low quality foraging, foraging, nesting/roosting, and high quality nesting/roosting as defined by the USFWS (2009). Each of the 62 coastal THPs included a pre- and post-harvest habitat analysis for each owl activity center within 0.7 mile of a given THP. For the coastal THPs, three habitat types were assessed: foraging, nesting/roosting, and non-habitat.

Table 13 summarizes proposed acres of owl habitat to be retained within the interior and coastal regions for THPs utilizing options (e) and (g) in 2013. The acreages presented are totals for 22 interior activity centers and 138 coastal activity centers. In 2013, activity centers on THPs in the interior portion of the range retained an average of about 200 acres of nesting and roosting habitat and about 410 total acres of habitat in the 500 acre (0.5 mile radius) core area. These activity centers retained an average of about 1,535 acres in the broader home range (1.3 mile radius; 3,400 acres). Activity centers on the coast retained an average of about 360 acres of nesting and roosting habitat and about 760 acres of total habitat in the 985 acre (0.7 mile radius) core area.

Table 13. Proposed acres of habitat retention near activity centers from THPs utilizing options (e) and (g) in 2013. Totals include retention acres for 13 interior THPs and 62 coastal THPs (75 THPs total). Owl habitat is defined as low quality foraging (LQF), foraging (F), nesting/roosting (NR), high quality nesting/roosting (HQNR), and non-habitat (NH).

Habitat type	13 Interior THPs associated with 22 activity centers, options (e) and (g)		62 Coastal THPs associated with 138 activity centers, options (e) and (g)
	Acres retained within 0.5 mile of activity centers	Acres between 0.5 to 1.3 miles of activity centers	Acres retained within 0.7 mile of activity centers
LQF	1,382	7,706	n/a
F	3,149	12,947	54,365
NR	2,875	10,203	50,107
HQNR	1,649	2,940	n/a
NH	n/a	n/a	32,819

Analysis of Cumulative Harvest at Selected Activity Centers

The above assessment of average habitat retention at activity centers was for THPs from a single year (2013). In order to understand the cumulative impact of habitat removal at individual activity centers, the harvest activity must be tracked through time by looking at all THPs that may have affected activity centers. THPs submitted between 1986 and 2013 were evaluated to determine the total amount of habitat proposed for harvest over time on a sample of activity centers (Tables 14 and 15). Appendix 3 includes bar graphs for each activity center within the coast and interior regions, and depicts level of harvest over time within 0.5, 0.7, and 1.3 mile radii from activity centers. The activity centers evaluated over time represent a sample that were selected from those that were associated with THPs submitted in 2013 that utilized options (e) or (g). Activity centers were chosen from all counties with THPs submitted in 2013 to provide results across the range. An approximately even number of activity centers were chosen from each county.

Table 14. Proposed timber harvest (in acres) within interior THPs utilizing option (e) and option (g) over time (range 1997-2013), showing level of harvest within 0.5 miles and between 0.5-1.3 miles of activity centers. The activity centers evaluated are those that were associated with THPs submitted in 2013; these activity centers were evaluated over time by evaluating all THPs associated with these activity centers since 1997.

		Interior, option (e) Acres harvested		Interior, option (g) Acres harvested	
Activity Center	**Range of Harvest Years**	**0.5 miles (~500 acre core area)**	**0.5-1.3 miles (~2,900 acres)**	**0.5 miles (~500 acre core area)**	**0.5-1.3 miles (~2,900 acres)**
SIS0492	2004-2013	0	915		
SIS0554	1998-2004	102	589		
TEH0030	1998-2013	381	2,554		
TEH0037	1998-2013	379	2,221		
TEH0038	1998-2013	151	1,002		
TEH0072	1998-2013	476	1,954		
TEH0075	1997-2004	277	2,530		
TEH0087	1998-2013	291	2,137		
TEH0101	1997-2013	168	2,113		
TEH0114	2002	0	8		
TEH0117	2006-2013	37	1,123		
SHA0024	2003-2005			41	239
SHA0037	1998-2013			0	426
SHA0106	2000-2013			21	160
SIS0319	1997-2013			31	1,505
TRI0169	2000-2013			0	118
TRI0316	1997-2013			251	495

Table 15. Proposed timber harvest (in acres) within coastal THPs utilizing option (e) and option (g) over time (range 1986-2013), showing level of harvest within 0.7 miles of activity centers. The activity centers evaluated are those that were associated with THPs submitted in 2013; these activity centers were evaluated over time by evaluating all THPs associated with these activity centers since 1986.

Activity Center	Range of Harvest Years	Coast, option (e) Acres harvested within 0.7 mile radius (~985 acre core area)	Coast, option (g) Acres harvested within 0.7 mile radius (~985 acre core area)
HUM0058	2011-2013	30	
HUM0400	1990-2013	510	
HUM0622	1993-2013	798	
HUM0791	1999-2013	270	
HUM0986	1997-2013	162	
MEN0146	1994-2013	1,180	
MEN0309	1987-2013	565	
MEN0370	1992-2010	413	
HUM0097	1996-2013		345
HUM0098	2004-2005		67
HUM0308	1996-2013		226
HUM0442	2004-2013		227
MEN0082	1986-2013		1,316
MEN0114	1987-2013		829

At the proposed levels of harvest noted in the THPs, it is apparent that some activity centers have experienced extensive habitat removal or modification over time. Of the 17 activity centers evaluated in the interior, six activity centers have experienced greater than 2,000 acres timber harvest within the 1.3 mile radius (~3,400 acres) home range, and six activity centers have experienced greater than 250 acres timber harvest (as high as 476 acres) within the 0.5 mile radius (~500 acres) core area. Of the 14 activity centers evaluated on the coast, six activity centers experienced harvest of over 500 acres within the 0.7 mile radius (~985 acres) core range, with two of these over 1,000 acres.

It is reasonable to assume that high levels of harvest, such as shown for some activity centers in Tables 14 and 15, can negatively impact Northern Spotted Owls. Because regrowth of forests is slow, particularly within interior forests, this impact may be greater depending on the time frame in which harvest has occurred. For example, the activity center TEH0037 (interior region) experienced proposed harvest of 180 acres within 0.5 mile, and 1,052 acres within 0.5-1.3 miles in 2007 (see Appendix 3). Six years later (2013), this same activity center again experienced 179 acres of proposed harvest within 0.5 miles, and 706 acres within 0.5-1.3 miles. Although no study has been conducted in the northern interior region specifically linking the amount of harvest within the 0.5, 0.7, and 1.3 mile radius of an activity center to impacts on owl fitness (e.g., reproductive rate and survival), several research studies have demonstrated a link between owl fitness and amount of habitat, structural characteristics, and spatial configuration (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005, Irwin et al. 2007), and Diller et al. (2010) evaluated the impact of timber harvest within a 0.5 mile radius of activity centers on the redwood coast. These studies are discussed in more depth above in the Habitat Effects on Demographics section of this report and below in the Habitat Loss and Degradation threat section. Through comparison of Northern Spotted Owl territory loss on private and federal lands, the USFWS (2009) suggests that the Forest Practice Rules have not been entirely effective in preventing cumulative loss of important owl habitat surrounding activity centers associated with repeated harvest. Details regarding the USFWS analysis can be found in the Timber Harvest threat section of this document.

Nonindustrial Timber Management Plans

Background

In 1989, the Legislature added language to the Forest Practice Act creating provisions to include Nonindustrial Timber Management Plans (NTMPs) to promote long term management and planning on forest ownerships of 2,500 acres or less (Pub. Resources Code §4593 et seq.). Private forestlands are generally classified into non-industrial and industrial ownerships based on acreage and association with industrial uses. Non-industrial private forest owners typically have less than 5,000 acres of forestland and do not own a mill. Of the private forestlands in California, non-industrial private forest owners collectively hold about 3.2 million acres (41%), with the balance being held by industrial forest landowners.

The NTMP allows smaller non-industrial private forest owners to prepare a long-term management plan that reduces regulatory time and expense by providing an alternative to submitting individual THPs prior to each harvest. Landowners agree to manage their forests through uneven-aged management and long-term sustained yield, in exchange for a higher degree of regulatory surety. “Sustained yield” means the yield of commercial wood that an area of commercial timberland can produce continuously at a given intensity of management consistent with required environmental protection and which is professionally planned to achieve over time a balance between growth and removal (Pub. Resources Code, § 4593.2, subd. (d); Forest Practice Rules, § 895.1). Timberland owners operating under an NTMP are also protected under provisions of Public Resources Code section §4593, which offers landowners exemption from applying subsequent rule changes to Forest Practice Rules to their project; however, this does not mean that a NTMP will never be subject to new laws or regulations.

Public Resources Code section §4594 subsection (h) requires RPFs to submit a Notice of Operations prior to harvest that will occur under an approved NTMP, which states that the harvest activity will implement best management practices for the protection of water, soil stability, forest productivity, and wildlife, as required by the current rules of the Board of Forestry, or is consistent with the original NTMP and will not result in any significant degradation to the beneficial uses of water, soil stability, forest productivity or wildlife. Landowners submitting a proposed Notice of Operations in accordance with the requirements of Forest Practice Rules, section 919.9 [939.9] subsections (a) through (g), are expected to either contain specific measures that fulfill these requirements or best management practices equivalent to such provisions. These options have resulted in variable and diverse Northern Spotted Owl protection measures within NTMPs; however, options (e) and (g) are the most commonly used options.

As stated previously, option (e) allows landowners to submit a technical assistance letter to the USFWS for approval. Under option (g), the landowner must supply the location of activity centers located within the plan boundary or within 1.3 miles of the boundary and meet minimum habitat retention guidelines.

NTMP Distribution

Within the range of the Northern Spotted Owl in California, a total of 578 NTMPs have been approved from 1991-2014, representing a proposed harvest acreage of 257,536 acres (CAL FIRE 2015). The large majority of these NTMPs occur in coastal counties (524 out of the 578 NTMPs) where there are numerous smaller, nonindustrial landowners, with the remainder in three interior counties (Table 16). About 85% of NTMPs are associated with Northern Spotted Owl activity centers and have proposed harvest of 171,247 acres within 1.3 miles of an activity center. Most NTMPs associated with activity centers also occur in coastal counties; 413 of the total 492 NTMPs associated with activity centers occur in Humboldt and Mendocino counties (Table 16).

Table 16. Number of NTMPs in interior and coastal counties within the range of the Northern Spotted Owl, number of NTMPs that are associated with at least one activity center, and proposed harvest acres within 1.3 miles of activity centers. NTMPs are those approved for years 1991-2014.

County	Number of NTMPs in each county	Number of NTMPs within 1.3 miles of an activity center	Proposed harvest acres within 1.3 miles of activity centers
Interior Counties			
Trinity	23	22	4,736
Siskiyou	19	10	2,219
Shasta	12	4	531
Interior Subtotal	54	36	7,486
Coastal Counties			
Humboldt	226	210	86,632
Mendocino	238	203	59,804
Sonoma	47	35	12,981
Lake	6	2	128
Napa	4	4	2,873
Del Norte	2	1	267
Glenn	1	1	1,076
Coastal Subtotal	524	456	163,761
Total	**578**	**492**	**171,247**

Access to NTMPs and associated Notices of Operations for review has been variable and so a subset was obtained for evaluation of the options used to comply with the Forest Practice Rules. Of 36 NTMPs within 1.3 miles of activity centers from interior counties for years 1991-2014, 23 were evaluated. Most of these used options (e) or (g) with a small number using other options (Table 17). The large majority of NTMPs within 1.3 miles of a Northern Spotted Owl activity center in coastal counties have used option (e) since 2005 (104 of 108; 96%), with the remainder using option (g) (Table 17). It should be noted that the majority of NTMPs on the coast, and within range of Northern Spotted Owl, were submitted prior to 2005 (367 in coastal counties during 1991-2004 versus 157 during 2005-2014). NTMPs evaluated in this report for the coast are from 2005-2014, so represent approaches used to comply with the Forest Practice Rules for the most recent decade. Although the Department had neither the access to, nor the resources available to evaluate all NTMPs approved within 1.3 miles of Northern Spotted Owl activity centers, it is clear that most occurred in coastal counties and used option (e). Because the majority utilized option (e) (i.e., USFWS technical assistance letter) it is implied that the USFWS has been instrumental in providing consultation and guidance to NTMP submitters as it relates to protection measures for Northern Spotted Owl and their habitat.

Table 17. Summary of options used for NTMPs in interior counties for years 1991-2014, and in coastal counties for years 2005-2014. All plans included are within 1.3 miles of an activity center.

County	NTMPs that implemented option (e)	NTMPs that implemented option (g)	NTMPs that used other options
Interior Counties 1991-2014			
Siskiyou	6	7	1
Trinity	2	2	0
Shasta	2	1	0
Tehama	0	0	2
Interior Subtotal	10	10	3
Coastal Counties 2005-2014			
Humboldt	38	2	0
Mendocino	43	2	0
Sonoma	19	0	0
Lake	3	0	0
Napa	1	0	0
Coastal Subtotal	104	4	0
Total	**114**	**14**	**3**

NTMP Silviculture Methods

From 1991-2014, 257,536 acres were proposed for harvest under NTMPs in the range of the Northern Spotted Owl. Of this harvest acreage, 171,247 acres occurred within 1.3 miles of known Northern Spotted Owl activity centers (Table 18). The number of potentially effected activity centers was 724. The majority of this proposed harvest was in coastal counties (163,761 acres; 95%) with the remainder in interior counties. The most common types of silviculture within the home range of all activity centers were selection (98,205 acres), group selection (18,653 acres), and unspecified uneven-aged management (29,689 acres) (Table 18). Uneven-aged was a term used by many plan submitters through the 1990s and until about 2007, and encompasses any silvicultural method that may use Selection, Group Selection, Sanitation Salvage, Variable Retention, or Alternative prescriptions.

Table 18. Acres proposed for harvest under various silvicultural prescriptions for NTMPs within 1.3 miles of a Northern Spotted Owl activity center, 1991-2014.

County	Selection	Group Selection	Uneven-aged Management	Transition	Other methods	Total
Del Norte	267					267
Glenn			1,076			1,076
Humboldt	52,687	11,055	9,667	4,456	8,767	86,632
Lake	100	25			3	128
Mendocino	34,783	3,745	13,670	4,201	3,405	59,804
Napa	2,075	681			117	2,873
Shasta			531			531
Siskiyou	44		1,577		598	2,219
Sonoma	7,108	2,644	1,872	787	570	12,981
Trinity	1,141	503	1,296	1,406	390	4,736
Total	**98,205**	**18,653**	**29,689**	**10,850**	**13,850**	**171,247**

An assessment of potential home range disturbance was conducted by evaluating proposed harvest within 1.3 miles of all Northern Spotted Owl activity centers in the NTMPs presented in Table 16. A total of 724 activity centers were documented within 1.3 miles of NTMPs, with combined timber harvest acreage of 171,247 acres within 1.3 miles of all activity centers. The average timber harvest acreage per 1.3 mile radius of each activity center was about 240 acres, approximately 7% of a hypothetical home range circle of 1.3 mile radius. While providing the average harvest acreage around Northern Spotted Owl territories provides some perspective on potential average impact to territorial owls, the actual harvest amount and distribution at specific activity centers would provide a better assessment of the potential range of impacts to territorial Spotted Owls. Also, this rough assessment includes a large but unknown number of home ranges that are only partially located within NTMP boundaries, so it is not possible to determine the actual proportion of home ranges that has been proposed for harvest. Unfortunately, the limited availability of NTMPs and Notices of Operations made a more detailed analysis of cumulative harvest at individual activity centers (as was done for a sample of THPs) beyond the scope of this review.

The variability in silvicultural methods used and the lack of a detailed analysis of harvest at activity centers makes it difficult to draw conclusions relating to Northern Spotted Owl habitat modification or retention within NTMPs. While reviewing the available NTMP documentation, it became clear that some information was not available to the reviewer due to the nature of the older NTMP narratives, limited public information, and subsequent amendment submissions. Based on the information available to the Department, there does not appear to be an effective way to track cumulative harvest acreage in an analysis going back in time for most NTMPs as was done above for selected THPs. Consistent with the requirement for uneven-aged management under an NTMP, Selection and Group Selection silvicultural methods were most used among NTMPs within the Northern Spotted Owl range. It is likely that some type of owl habitat is retained to some extent through these types of silvicultural methods; however, the Department has not been able to determine the type or quality of habitat retained. For example, the degree of impact to territorial owls depends in part on whether sufficient high quality nesting and roosting habitat has been retained to support high quality habitat in Spotted Owl territories. Greater access to all NTMP documents, including Notices of Operations, would allow for a more robust and in-depth analysis of harvest methods and extent.

Spotted Owl Management Plans

A Spotted Owl Management Plan (SOMP) details measures to avoid take of Northern Spotted Owl as a result of timber harvest operations on privately owned land. SOMPs are developed cooperatively between USFWS and a private land owner, and can be used to streamline the review of THPs. SOMPs follow the procedures in Forest Practice Rules section 939.9 subsection (e) and include:

- a description of the area covered
- protection measures for breeding or nesting Northern Spotted Owls
- habitat definitions, and
- habitat quality and quantity retention requirements

SOMPs contain expiration dates upon which USFWS and land owners meet to review and revise the document as necessary; however, incorporation of new scientific information may occur at any time during the lifetime of the SOMP. SOMPs differ from the standard no-take measures provided in the Forest Practice Rules in that they utilize site-specific information in conjunction with research to develop strategies to avoid take over a period of years. The most notable difference between SOMP no-take requirements and those in the standard Forest Practice Rules section is primarily the survey area required and possibly habitat required post-harvest. Survey areas may be reduced as a result of local information collected over a number of years. Post-harvest habitat requirements may also be greatly reduced or increased based on site specific local information.

Three SOMPs are currently being used in the THP process in California. Two of these were reviewed for this assessment by the Department, totaling 175,700 acres in Siskiyou, Trinity and Shasta counties. The Department has not received a copy of the third SOMP, located in Mendocino County; therefore we are unable to discuss it here. Both documents reviewed included the elements listed above, and were developed with the USFWS considering site-specific information for those properties. Within the SOMPs reviewed, suitable habitat definitions were developed specifically for the ownerships utilizing the SOMPs. These habitat definitions are developed using information from the property and may be different from those suitable habitat definitions in survey protocols or other rules or regulations.

It is not known if the long-term use of SOMPs on private lands in California is affecting Northern Spotted Owl populations, but all operations conducted under a SOMP occur within the known range of Northern Spotted Owl and usually within suitable owl habitat. More information is needed to fully understand the effects of SOMPs on Northern Spotted Owls.

Spotted Owl Resource Plans

A Spotted Owl Resource Plan (SORP) is intended to offer landowners submitting THPs a programmatic approach to avoid take of Northern Spotted Owl. The process for developing a SORP is addressed in Forest Practice Rules section 919.9 subsection (a), and is an approach to prevent take of the Northern

Spotted Owl that necessarily involves more than one timber harvest plan. SORPs do not differ significantly from the required habitat retention guidelines found in the Forest Practice Rules section 919.9 subsection (g), and mainly provide a programmatic method for Northern Spotted Owl protection. A description of the area covered, protection measures for breeding or nesting Northern Spotted Owls, habitat definitions, survey areas and habitat quality and quantity retention requirements are all provided within a SORP. A SORP may be submitted to CAL FIRE for preliminary review, and once approved, can be attached to individual THPs submitted by a landowner under Forest Practice Rules section 919.9 subsection (a). The THP is reviewed by the Department, but not necessarily the SORP.

A total of three SORPs have been approved and are being utilized in the THP process in California, and a fourth SORP is being prepared. The three approved SORPs cover a total of 358,202 acres and use a combination of no-take language from Forest Practice Rules section 939.9, along with site-specific information to develop no-take requirements. No specific habitat definitions were developed for SORPs, and thus, either standard habitat definitions from the Forest Practice Rules or standard habitat definitions from the USFWS are used within the plans. The site-specific information is used mostly for protocol survey areas and noise disturbance buffer distances, and is usually developed from historical survey records and independent noise level studies.

It is not known if the long-term use of SORPs on private lands in California is affecting Northern Spotted Owl populations, but all operations conducted under a SORP occur within the known range of Northern Spotted Owl and usually are within suitable owl habitat.

Habitat Conservation Plans

Under Section 10(a) of the ESA incidental take, defined as take that is incidental to and not the purpose of an otherwise lawful activity, may be authorized for federally threatened and endangered species via a Habitat Conservation Plan (HCP). California's Natural Community Conservation Planning Act of 1991 takes a broader approach than either CESA or ESA. A Natural Community Conservation Plan (NCCP) identifies and provides for the protection of plants, animals, and their habitats, while allowing compatible and appropriate economic activity. HCPs and NCCPs are both long-term landscape level conservation plans that allow harvest of Northern Spotted Owl habitat, which could result in a specified level of incidental take of owls within the plan area. Generally, these plans require historic and occupied Northern Spotted Owl activity centers to be monitored to ensure a healthy and stable population, suitable foraging, and nesting habitat to be maintained or created, and activities to be adjusted accordingly using an adaptive management approach.

Five HCPs that include Northern Spotted Owl as a covered species have been issued in California (Table 19). One plan, on Mendocino Redwood Company land, is in the development process and will be a combination HCP and NCCP. Each of these plans is described in more detail below.

Table 19. Current and planned HCPs/NCCPs in California that include Northern Spotted Owl as a covered species.

Plan Title	Location	Plan Acreage	Date Permit Issued	Term
Green Diamond Resource Company California Timberlands & Northern Spotted Owl HCP	Humboldt and Del Norte Counties	383,100[a]	09/17/1992 (new HCP near completion)	30 years (new plan will be 50 years)
Regali Estates HCP	Humboldt County	480	08/30/1995	20 years
Humboldt Redwood Company HCP	Humboldt County	211,700	03/01/1999	50 years
Terra Springs LLC HCP	Napa County	76	03/03/2004	30 years
Fruit Growers Supply Company HCP	Siskiyou, Shasta, and Trinity Counties	152,178	11/27/2012[b]	50 years
Mendocino Redwood Company HCP/NCCP	Mendocino County	TBD	No permits issued	80 years

[a] Total acreage in this section may be slightly less due to a recent acquisition of Green Diamond Resource Company's Pecwan, Bear and some of Blue Creek units by the Yurok tribe.
[b] A recent court decision in April 2015 determined the Fruit Growers Supply Company HCP to be invalid.

Green Diamond Resource Company Northern Spotted Owl HCP

Green Diamond Resource Company (GDRC) inherited the existing Northern Spotted Owl HCP when the company changed names from Simpson Timber Company (STC 1992). The HCP has a 30-year term, which expires September 17, 2022, and calls for a full review at the end of 10 years of implementation. GDRC currently owns approximately 383,100 acres of forestland in California within the Northern Spotted Owl range, mostly within Del Norte and Humboldt counties and all located within the California Coast Province. Of the 383,100 acres, 86% are conifer forests comprising two dominant species, coastal redwood, and Douglas-fir. Since most of the conifer forests have been harvested over the last several decades, second-growth makes up all but a small fraction. Residual areas of old-growth forests (logged in the early 1940s and 1960s) make up less than 3%, and are concentrated in the more inland portions of GDRC ownership. Forested areas never logged (virgin old-growth) are scattered throughout the land ownership and consist of 150 acres of redwood and 300 acres of Douglas-fir, comprising less than 2% of GDRC land. Hardwood forests (oak species, madrone, alder) comprise 8%, and non-forest (grassland, wetland, rock and river bars) 6%. As of 1991, just prior to issuance of the HCP, 146 activity centers were known to occur on GDRC lands. Density of owls was much higher in the southern portions of land ownership, than the northern portion (1.2 owls/mi^2 and 0.32 owls/mi^2, respectively).

During development, the HCP prepared a 30-year age-class forecast model to determine how much habitat would be available to owls over time, and developed a predictive habitat (nesting mosaic) model to estimate nesting habitat on the GDRC land ownership. The age-class forecast covered 1991 through 2021, and assumed timber harvest would occur at an annual rate of 3,000-6,000 acres. Results indicated that second-growth stands in the 46+ year age-class would more than double, the 31-45 year age-class would increase by approximately 50,000 acres in first 10 years then return to 1991 levels, and the 8-30 year age-class would generally decrease over time. The nesting mosaic model was designed to determine the mosaics of habitat types associated with owl activity centers and utilized the 1991 cover types and age-classes. Results initially indicated 158,477 acres of GDRC land fit the nesting mosaic profile, with the number of activity centers in 2021 roughly the same as the 1991 level.

The level of take (via owl displacement and habitat modification) was estimated at 3 pairs per year over first 10 years through direct habitat modification (habitat removal within owl sites), and 2 owls per year over first 10 years via indirect displacement (habitat removal in adjacent stands to owl sites). Conservation measures were developed to avoid or minimize the likelihood of take, and include:

- Habitat management and nest site protection. Implementation will protect nest sites during breeding and fledging periods, maintain foraging, roosting and nesting habitat, and accelerate growth of replacement stands. Stands to be harvested March through August will be surveyed for Spotted Owls before entering area, as well as a 1,000 ft buffer around the area planned for harvest. Just prior to harvest, up to three more surveys will be conducted. Nest trees will be marked and no timber harvest is to be conducted within a 0.25 mile radius until after young have fledged or the nest fails, and a 500 ft radius after fledging until the young disperse. Valuable land resources for Spotted Owls will be retained on the landscape, such as hardwood/conifer patches, habitat along watercourses, snags, standing live culls, and brush.
- Development of a research program. A research program consists of ongoing owl surveys, banding owls, monitoring reproductive success, identifying important nest site attributes, and assessing abundance and distribution.
- Development of habitat area to be set-aside. Thirty-nine habitat set-asides were identified in which timber harvest would not occur. The total acreage of these set asides is 13,242.5 acres and, as of HCP issuance, 39 owl sites. A 0.25 mile or 500 foot buffers are placed around sites to ensure timber removal or other associated harvest activities adjacent to set-asides to not impact owl sites within. Set-asides were monitored annually.
- Staff training. A program was developed to properly train GDRC employees and contractors to monitor owls and collect data.

The trigger for any course correction required during the HCP term will be if the reproductive rate falls below the rate of the Willow Creek Study Area (WCSA) for three consecutive years. The WCSA was a good comparison at the time due to its proximity to GDRC and its unique long-term Spotted Owl dataset. Since 1993, comparisons of reproductive rates at GDRC and WCSA show that the study area with higher annual reproductive rate often shifts between the two areas. There have not been three consecutive years with statistically significant results showing the reproductive rate at GDRC falling below that at WCSA (GDRC 2015).

In 2006, GDRC submitted an application to the USFWS to amend its 1992 Incidental Take Permit (ITP), and in December 2007, the amended ITP was issued (USFWS 2007). Also in 2007 the USFWS issued an internal biological opinion (BO) which describes the Project, requires the Applicant to comply with terms of the amended BO and its associated incidental take statement (ITS), and incorporates additional measures. In December 2013, GDRC notified the Department that the BO was issued and requested that the Department issue a consistency determination (CD) that the HCP is consistent with CESA pursuant to Fish & Game Code section 2080.1. In January 2014, the Department found that BO, its related ITS and

ITP, and the HCP were consistent with CESA and meet the conditions set forth in Fish and Game Code section 2081 for authorizing incidental take of CESA-Iisted species (CDFW 2014a).

The Department found that the mitigation measures identified in the amended ITP and HCP will minimize and fully mitigate the impacts of take and the continued existence of Northern Spotted Owl will not be compromised. Measures in the amended versions include, but are not limited to:

- Maintaining a 20,310 acres "Special Management Area" in Upper Mad River area where Spotted Owls may not be taken.
- Survey for Spotted Owls in each area where timber harvest is planned, and delay harvest of nest site and primary activity centers in after the breeding season.
- Maintain records of surveys and actual take and notify the USFWS events such as direct harm to owls, catastrophic events that destroy owl sites, shifts in distribution, accidental death, or injury of owls, and the finding of dead or injured owls.
- Continue gathering data on owl behavior and habitat needs, and update GIS database regularly.
- Establish 39 set-asides that represent 13, 252 acres in which timber harvest is not allowed.
- Retain, where feasible, resources values that would provide future owl habitat.
- Comply, where feasible, with "Overall Resource Management" measures specified in the HCP, including retention of canopy cover, ground cover, habitat along streams, and a variety of tree sizes and species within Watercourse and Lake Protection Zones.
- Implement research on habitat overlap and interactions between Spotted Owls and Barred Owls.
- Conduct surveys according to approved Spotted Owl protocol that accounts for occupancy and Barred Owl presence, and contact the USFWS for direction as appropriate.
- Prepare annual report to record actual instances and number of Spotted Owl sites displaced, level of habitat loss within owl sites, actual and estimated levels of displacement of past year, estimated levels of displacement for future year, estimate number of owl sites and amount of owl habitat, pre- and post-harvest estimates of snags and residual trees in THP areas, results of nest and set-aside monitoring, and assess efficacy of measures to date.
- Provide Department with letter to document financial assurances for HCP implementation.

Following the first Northern Spotted Owl surveys of Green Diamond's (formerly Simpson Timber Company) in 1989, it was recognized that the high densities of Spotted Owls on intensively managed timberlands in coastal California represented something potentially unique in Spotted Owl ecology (Thomas et al. 1990). However, the HCP was developed and approved in 1992 based on a single master's thesis of Spotted Owl habitat use in coastal managed timberlands (Folliard 1983, Folliard et al. 2000). Due to the uncertainty related to the HCP's conservation strategy and level of take, a major 10-year review was mandated to address the following:

- A comparison of actual and estimated levels of owl displacement;
- A comparison of actual and estimated distribution of owl habitat;
- A reevaluation of the biological basis for the conservation strategy based on the data collected

through the research program and other sources;

- A detailed analysis of efficacy of and continued need for the set-asides and of the long-term viability of the owl population on Simpson's property; and
- An estimate of annual owl displacement for the remainder of the permit period.

This review was initiated in 2002 in consultation with the USFWS, but due to the extensive amount of data that had been collected as part of the monitoring and research for the HCP and statistically rigorous analyses, the final peer-review and acceptance by the USFWS did not occur until 2010 (Full report in Diller et al. 2010 with summary in Diller et al. 2012). Some of the highlights of the analyses included:

- New spatially explicit definitions of foraging and nesting habitat, and the contribution of habitat quality to owl fitness (i.e., habitat fitness potential following Franklin et al. 2000) with projections of increases in the amount and spatial arrangement of the highest quality habitat (i.e., habitat fitness >1.0) in the future
- Trends in Spotted Owl survival, fecundity and lambda indicating the owl population was stable under the HCP until 2001 when a downward trend began as Barred Owl numbers increased.
- The impact of timber harvest resulting in take of owls, as defined under the ESA, on survival and fecundity of owls. This is the only dataset available to directly estimate the impact of timber harvesting on Spotted Owl demographics and it indicated there was no measurable impact on survival but life-time fecundity was reduced an average of 16.8% for females subjected to take relative to those never taken. Based on an average of three takes per year under the HCP, the impact of take on the owl population within Green Diamond's ownership has been a reduction in fecundity of 2.8%.
- Evidence for an improved Spotted Owl conservation strategy on managed timberlands that will replace protection of static reserve set-aside areas with a dynamic suite of the highest quality core nesting sites that are consistent with the trends of high habitat quality (fitness) tied to the dynamics of habitat heterogeneity. This conservation strategy along with a suite of habitat retention measures are being proposed in the ongoing development of a new 50-year Forest HCP that will cover Northern Spotted Owls, fishers and tree voles.

The USFWS recognized the value of the HCP and the monitoring and research it supported in the Final Critical Habitat Rule by stating: "We have created a close partnership with Green Diamond through development of the HCP, and they have proven to be an invaluable partner in the conservation of the northern spotted owl. Green Diamond has made a significant contribution to our knowledge of the northern spotted owl through their support of continuing research on their lands" (USFWS 2012).

Regali Estates HCP

This HCP covers 480 acres in Humboldt County, southeast of the town of Ferndale, and is located within the California Coast Province (Regali Estate 1995). Its 20-year term expired August 30, 2015. The plan covered two Northern Spotted Owl activity centers, and contains white-fir, Sitka spruce, redwood, young tree plantations, grassland, and agriculture. The harvest of conifer species resulted in the immediate loss of nesting habitat for one pair. Due to its small size, take afforded by the plan was not deemed to impact regional Spotted Owl populations. Measures set for the plan included: (1) Retention of habitat around nest sites; (2) No harvest impact for a portion of the covered area; (3) Retention of foraging habitat in harvested areas; (4) Salvage of only commercially valuable dead and dying trees; (5) Planting of conifer trees in open grassland habitat; (6) Retention of slash piles for prey habitat; (7) Monitoring of owls; and (8) Completion of biannual reports.

Humboldt Redwood Company HCP

The HRC HCP covers 211,700 acres of coast redwood and Douglas-fir forest in Humboldt County, and is located within the California Coast Province (HRC 2014). Currently the Plan Area contains approximately 208 Northern Spotted Owl activity centers. The term is 50 years, which means the plan will expire March 1, 2049. The primary covered activity is timber management (timber harvest and regeneration, site preparation, planting, vegetation management, thinning, and fire suppression) occurring on approximately 203,000 acres. The HCP requires ongoing monitoring and reporting to ensure that the conservation measures being implemented are accomplishing the desired outcomes. Through the adaptive management process, the monitoring results were used to develop an updated HCP on March 31, 2014.

The overall strategy in the Northern Spotted Owl conservation plan, detailed in the HCP, is to (1) minimize disturbance to Northern Spotted Owl activity sites, (2) monitor to determine whether these efforts maintain a high-density and productive population of owls on the ownership, and (3) apply adaptive management techniques when new information on owl biology/ecology is available and to best assess the performance of management objectives. Specific habitat retention requirements are provided to conserve habitat for nesting, roosting, and foraging owls.

Northern Spotted Owl management objective outlined in the plan include:

1. Maintain a minimum of 108 activity centers each year over the life of the HCP.
2. Maintain Northern Spotted Owl pairs on an average of 80 percent (over a five-year period) of the minimum 108 activity centers on the ownership. At least 80 of these sites shall be "Level One" sites, and the balance shall be "Level Two" sites.
3. Maintain an average reproductive rate of at least 0.61 fledged young per pair (over a five-year period) for the minimum of 108 activity centers on the ownership.
4. During the first five years of the HCP, maintain and document the minimum number of activity centers designated in the HCP.

Northern Spotted Owl conservation measures outlined in the plan include:

1. Establish a Northern Spotted Owl Scientific Review Panel to review and make recommendations for monitoring techniques, offer expert review of monitoring results, and make recommendations on habitat retention standards for maintenance and recruitment of activity centers.
2. Conduct a complete annual census (or an approved sampling methodology) to monitor all activity centers on the ownership and to determine numbers of pairs, nesting pairs, and reproductive rates.
3. If activities are initiated before February 21 and are maintained continuously past the onset of the breeding season (March 1 through August 31) the THP and a 1,000 foot buffer is to be surveyed, with timing and number of surveys dependent on when activities are to occur within the breeding season. For site preparation activities initiated between March 1 and May 31, site visits will be conducted based on known activity centers within 1,000 feet of activity. Details on how and when site visits are to occur are site specific. No surveys required if timber operations occur only outside the breeding season.
4. Before June 1 each year, at least 80 activity sites shall be maintained using the habitat retention guidelines detailed in the HCP, referred to as "Level One" habitat retention. Activity sites selected for "Level One" retention must have supported owls in the previous year and must also be active for the year in which the site is selected. If a site is determined to be nesting, no harvesting shall occur during the breeding season within a 1,000-foot radius of the nest tree. Characteristics of suitable nesting habitat, if present, must be maintained within 500 feet of the activity center. Within 500 to 1,000 feet of the activity center, characteristics of suitable roosting habitat, if present, must be retained. Within 0.7 mile of the activity center 500 acres of suitable owl habitat must be provided, if present, and less than 50 percent of this shall be under operation in any one year. If present, 1,336 total acres of suitable owl habitat must be provided, within 1.3 miles of each activity center.
5. Designate additional owl activity sites as "Level Two" habitat retention sites by September 1 of each year to make up the minimum number of activity centers designated by the HCP. "Level Two" habitat retention must be active for the year in which the site is selected. If a site is determined to be nesting, no harvesting shall occur during the breeding season within a 1,000-foot radius of the nest tree. Following the breeding season, 18 acres around the AC shall be maintained as suitable nesting habitat, if present, and a 400 foot radius buffer protecting the AC must the in place. For sites which have been determined to be occupied by a non-nesting pair or single, 18 acres around the activity center shall be maintained as suitable nesting habitat, if present, and a 400 foot radius buffer protecting the activity center must the in place. Harvesting of these sites may occur during the breeding season, in the area adjoining the 18-acre habitat retention area.
6. Activity center that are not needed to meet management objectives above shall receive "Level Three" protection measures. These activity centers shall have a 1,000-foot buffer during the breeding season. Timber harvest associated may occur before March 1 or after August 31.

During the breeding season, for activity centers which have been determined to be occupied by a non-nesting pair or single owl, 18 acres around the activity center shall be maintained as suitable nesting habitat, if present, and have a 400 foot radius buffer. Harvesting may occur during the breeding season in the area adjoining the 18-acre habitat retention area.

7. All nest trees shall be marked and be retained if the activity center is harvested.

The HCP outlines an objective to conserve habitat diversity and structural components within the plan area that would benefit Northern Spotted Owls. The objective will ensure that a mix of vegetation types and seral stages are maintained across the landscape over the permit period, as well as structural components, to contribute to the maintenance of wildlife species covered under the plan, including the Northern Spotted Owl.

Structural components to be retained include:

1. A certain number and size snags that do not pose a human safety hazard.
2. A certain number and size of green replacement trees, if snags are not present, with a priority for trees other than redwood.
3. At least four live cull trees per acre of Class I and II Riparian Management Zones, with a priority given to trees 30 inches DBH and trees with visible defects such as broken tops, deformities, or cavities.
4. All live hardwood trees over 30 inches DBH that do not constitute a safety hazard, to a maximum of two per acre.
5. Two logs per acre greater than 15 inches in diameter and over 20 feet long, with priority given to logs over 30 inches in diameter.

In February 2014, HRC notified the Department that a BO was issued by the USFWS and requested that the Department issue a CD that the HCP is consistent with CESA pursuant to Fish and Game Code section 2080.1. In February 2014, the Department found that BO and its related ITS and ITP, and the HCP are in fact consistent with CESA and meet the conditions set forth in Fish and Game Code section 2081 for authorizing incidental take of CESA-listed species (CDFW 2014b).

The Department found that the mitigation measures identified in the amended ITP and HCP will minimize, will fully mitigate the impacts of take and will not compromise the continued existence of Northern Spotted Owl. Measures in the amended versions include, but are not limited to:

- Sell the Headwaters Forest, Owl Creek Reserve, and Grizzly Creek Reserve to the state and federal governments to ensure their functions as wildlife reserves in perpetuity.
- Set aside, for the life of the HCP, some of the most valuable owl and Marbled Murrelet nesting habitat in a series of Marbled Murrelet Conservation Areas.
- Conduct a combination of night and daytime surveys and stand searches to locate both known, and any new, owl activity centers.

- Comply with the Northern Spotted Owl Conservation Strategy, which relies upon other conservation elements of the HCP for the retention and recruitment of potential foraging, roosting, and nesting habitat in watersheds across the ownership throughout the HCP period.
- Maintain a minimum of 108 activity centers each year over the life of the HCP.
- Maintain an average reproductive rate of at least 0.61 fledged young per pair, over a five-year period, for the minimum of 108 activity centers on the ownership.
- Conduct complete annual censuses to monitor all activity centers on the ownership and to determine numbers of pairs, nesting pairs, and reproductive rates.
- Survey the THP area and a 1,000-foot buffer for new operations, except site preparation, initiated in the period beginning February 21 and ending on or before August 31.
- Starting in 2014, and at five year intervals thereafter, conduct an analysis of owl occupancy and detection probabilities using accumulated survey data.
- Submit annual reports describing the activities undertaken, results of the Operating Conservation Program, and the proposed Operating Conservation Program activities for the next year for all lands covered by the HCP.

Annual reports for Northern Spotted Owl have been developed since the HCP's inception. The most current report (HRC 2015) summarizes the Humboldt Redwood Company's survey effort and whether management objectives were met. The report states,

> "Management objective 1 of the HCP, which requires the maintenance of a minimum of 108 activity sites in the HCP area, was met in 2014 with 136 total occupied activity sites including the 108 core sites. There are currently 215 total activity sites (occupied and unoccupied) on the property. Management objective 2, which calls for maintenance of Spotted Owl pairs on a five year running average of 80% at core activity sites, was met in 2014 with a running average of 82%. The pair occupancy rate for 2013 was also 84% (91 of the 108 cores sites were occupied by a pair of Spotted Owls). Management objective 3 requires the maintenance of a five-year running average reproductive rate of at least 0.61 fledged young per pair for the core sites (for those pairs monitored to determine reproductive output). Nesting activity was verified for 33 of the 91 pairs (of the 108 core sites), and a total of 45 young were fledged, resulting in a reproductive rate of 0.49 in 2014. The five-year running average of the reproductive rate for the fifteenth year of the HCP is 0.42, below the requirements of management objective 3."

Mendocino Redwood Company HCP/NCCP (in planning process; not issued)

The Mendocino Redwood Company (MRC) is in the process of developing a HCP and NCCP with the federal and state agencies. If the permit is issued, the term would be 80 years. The HCP/NCCP will determine how MRC manages threatened and endangered species, rare plants, and natural communities on their land ownership in Mendocino County. The Northern Spotted Owl will be a covered species in the plan. Coverage is proposed for 203,940 acres of approximately 228,800 acres of coast redwood and Douglas-fir forests that comprise the total MRC land ownership which is located within the

California Coast Province. Up to date progress on the HCP/NCCP development can be found on the MRC website (http://www.mrc.com).

Terra Springs LLC HCP

The Terra Springs HCP has been designated as a "Low Effect HCP" due to its limited effects on the Northern Spotted Owl and owl habitat (Butler and Wooster 2003). This HCP covers 76 acres in Napa County west of the city of St. Helena, and is located within the California Coast Province. The plan has a 30 year term that expires March 3, 2034. The plan covers conversion of 22 acres of mature (80-120 year old) Douglas-fir forest to vineyard, as well as any removal of trees from the remainder of the covered lands. One Northern Spotted Owl activity center associated with the plan is located 1.1 miles from the covered lands. Owl habitat within the activity center (large redwood and Douglas-fir trees) is surrounded by vineyards, orchards, grazing lands, and rural residences. The objectives of this low-effect HCP are to maintain 41 acres of suitable roosting and foraging habitat within the covered lands in perpetuity while accomplishing the economic objectives. Measures set for the plan include: (1) Retention of nesting, roosting and foraging (41 acres total); (2) Deed restriction placed on these 41 acres to provide for their management as owl habitat, in perpetuity; (3) Habitat modification limited to removal of small trees, felling hazardous trees, creation of slash piles for prey habitat, selection of appropriate silviculture practices, retention of 60-75% canopy closure throughout the entire operating area, retention of non-hazardous snags, and retention of down logs; (3) Timber operations to cease within a 1000 foot buffer of the owl activity center during the breeding season; (4) Monitoring of the Spotted Owl site to continue for five years subsequent to the timberland conversion; and (5) Annual reporting for the first 5 years of the permit.

Fruit Growers Supply Company HCP

The Fruit Growers Supply Company (FGS) HCP covers commercial timberland owned and managed by FGS in Siskiyou County, totaling 152,178 acres (FGS 2012). The Plan Area is within the California Klamath Province and California Cascades Province. The HCP has a 50 year term that expires November 27, 2062. In February 2014, FGS notified the Department that the federal BO had been issued and requested that the Department issue a CD finding the HCP is consistent with CESA pursuant to Fish and Game Code section 2080.1. In March 2014, after an amendment to the HCP to fully meet mitigation standards, the Department found that BO and its related ITS and ITP, and the HCP were consistent with CESA and met the conditions set forth in Fish and Game Code section 2081 for authorizing incidental take of CESA-listed species (CDFW 2014c).

In April 2015, the United States District Court, Northern District of California, found FGS's HCP to be invalid for the incidental take of two threatened species, the Northern Spotted Owl and the Southern Oregon/Northern California Coast Coho Salmon. The Order on Cross-Motions for Summary Judgment in the case *Klamath-Siskiyou Wildlands Center, Center for Biological Diversity, and Klamath Forest Alliance* vs. *National Oceanic and Atmospheric Administration, National Marine Fisheries, and the United States Fish and Wildlife Service, and Fruit Growers Supply Company* states, "For the reasons explained below, the Court … finds the incidental take permits issued by the Services, the biological opinion issued by

NMFS, and the Final Environmental Impact Statement invalid." The HCP amendment to fully meet mitigation standards was not considered in this case.

Timber management was the primary activity affecting approximately 150,000 acres. FGS land consists of three management units: Klamath River covering 65,340 acres, Scott Valley covering 39,153 acres, and Grass Lake covering 47,685 acres. Klamath River and Scott Valley units are dominated by second-growth mixed evergreen forests that include Douglas-fir, incense-cedar, white fir, ponderosa pine, sugar pine, canyon live oak, Pacific madrone, California black oak, and Oregon white oak. The Grass Lake unit contains three major forest types: Sierran Montane Forest and Upper Montane Forest at higher elevations and Northern Yellow Pine Forest at lower elevations. The Northern Yellow Pine is most common in the Grass Lake unit, and is dominated by ponderosa pine and white fir. The hardwood understory species (e.g., oak species and madrone) are largely absent in this unit. Because most of FGS land has been in commercial timber production since the early 1900s, forests are relatively young (less than 80 years old) with only small, isolated patches of older stands. Less than 1 percent of the forested area in the three management units are in CWHR size class 5 (> 24 inches dbh) and are considered late-seral stage. Most of the forested lands (79-93%) are in WHR size classes 3 and 4 (6-24 inches dbh) and are considered mid-seral.

Covered Activities had the potential to alter forest characteristics, and influence the availability and quality of habitat for Northern Spotted Owls. Northern Spotted Owl surveys on FGS lands and adjoining federal and private lands have shown that many activity centers are located on or have a home range that extends onto the FGS ownership.

<u>Safe Harbor Agreements</u>

The USFWS states (http://www.fws.gov/endangered/landowners/safe-harbor-agreements.html):

> "A Safe Harbor Agreement (SHA) is a voluntary agreement involving private or other non-Federal property owners whose actions contribute to the recovery of species listed as threatened or endangered under the ESA [see section 10(a)(l)(A)]... In exchange for actions that contribute to the recovery of listed species on non- Federal lands, participating property owners receive formal assurances from the Service that if they fulfill the conditions of the SHA, the Service will not require any additional or different management activities by the participants without their consent. In addition, at the end of the agreement period, participants may return the enrolled property to the baseline conditions that existed at the beginning of the SHA."

There are two SHAs covering Northern Spotted Owl in California - Forster-Gill, Inc. and The Fred M. van Eck Forest Foundation.

Forster-Gill, Inc., Safe Harbor Agreement

The Forster-Gill SHA was issued in June 2002 has a 90-year term, and consists of 236 acres in Humboldt County one mile north of the town of Blue Lake (USFWS 2002). The majority of the property (91%) contains young growth coastal redwood (30-35 years old), with 216 acres containing CWHR type 4D (12-

24 inch dbh and 60-100 percent canopy closure). At the time of the SHA issuance two owl activity centers were adjacent to the property, both associated with one pair.

In the SHA, Forster-Gill agrees to enhance and maintain approximately 216 acres of forested Northern Spotted Owl habitat through timber harvest management designed to create uneven-aged stands with large tree components, characteristic of high quality owl habitat. Specifically, the SHA will:

- Maintain 216 acres at the CWHR 4D-level averaged over a 54 acre polygon.
- Retain all snags not posing a hazard risk.
- Conduct annual owl surveys on property and within a 500 foot radius around the property.
- Ensure additional nest sites found are protected by a 300 foot no-cut-buffer.
- Ensure no harvest occurs within 1,000 feet of any active owl nest site.
- Ensure harvest conducted between 300 and 500 foot from active owl nest sites be under single tree selection, retain 80 percent canopy closure of trees at least 12 in DBH, and is reviewed and approved by USFWS.
- Conduct timber stand inventories and provide USFWS with data.
- Allow USFWS or other agreed-upon party access to property for monitoring and management activities.

The Fred M. van Eck Forest Foundation Safe Harbor Agreement

The van Eck Foundation SHA was issued in August 2008 has a 90-year term, and covers management activities on 2,163 acres of land in Humboldt County owned by The Fred M. van Eck Forest Foundation (USFWS 2008a). Four management units are identified, of which three (Lindsay Creek, Squaw Creek and Fieldbrook) are located in the Lindsay Creek watershed about one mile of the town of Fieldbrook. The fourth unit, Moonstone, is located in the about ½ mile east of the community of Westhaven. The main forest types found include redwood, Douglas-fir, grand fir, western hemlock, and Sitka spruce. Approximately 80% of the land contains nesting and roosting habitat, with dense canopy cover, and trees over 16 inch dbh. At the time of SHA issuance, no Spotted Owl nesting was documented, however a roosting pair was located on Lindsay Creek.

The SHA incorporates the terms of the conservation easement granted to Pacific Forest Trust in 2001. The conservation easement includes performance goals and restrictions that create forest components recognized as high quality owl habitat. The lands enrolled in this SHA are also currently managed under an NTMP.

In the SHA, van Eck Foundation agrees to limit harvesting to single-tree selection or group selection with a target of retaining native species and trees that grow vigorously, and nesting/roosting habitat will be expanded and maintained to 1,947 acres (90% of area) for the remainder of the permit term. Exceptions will be made for trees that have been identified for snag or wildlife tree retention. Canopy cover will remain above 80% (averaged across the stand) upon completion of harvesting activities. Specifically, the SHA will:

- Comply with the conservation strategy, including management performance goals, restrictions on harvest, and road construction and maintenance conditions.
- Retain all snags not posing a safety hazard.
- Conduct protocol-level surveys and determine reproductive status on property and within 500 foot radius off property, with annual surveys at Lindsay Creek, Squaw Creek, and Fieldbrook units, and one year prior to harvesting activities at Moonstone unit.
- Implement the following protection measures for up to five activity centers, any additional activity centers on covered lands may be managed in a manner that results in no take. A 300 foot no harvest buffer will be maintained around no more than two activity centers, and a 100 foot no harvest buffer and a 100 to 300 foot partial harvest buffer will be maintained around no more than three activity centers. The activity center currently existing at van Eck and one additional future activity center will receive the 300 foot no harvest buffer (6.5 acres) around their activity centers.
- Refrain from conducting harvest operations within 1,000 feet of any activity center during the breeding season, and forego harvest of any known owl nest trees.
- Cooperate with USFWS on Barred Owl control measures.
- Submit timber inventory reports according to management units
- Allow the USFWS or other agreed-upon party, access to property.
- Conduct annual protocol-level surveys and determine reproductive status and success at owl nest sites found for a minimum of three years post-harvest.

<u>Exemption Harvest</u>

Exemption harvest is meant to assist private landowners wanting/needing to remove trees and may allow the removal to be exempt from the THP process. The different types of exemptions available include:

- Forest Fire Prevention Exemption
- Christmas Tree, Dead, Dying or Diseased Fuel wood or Split Products Exemption
- Less Than Three Acre Conversion Exemption
- Substantially Damaged Timberland, Unmerchantable as Sawlog Exemption
- Public Agency, Public and Private Utility Right of Way Exemption
- Woody Debris and Slash Removal Exemption
- Removal of Fire Hazard Tree within 150 feet of a Structure Exemption
- Drought Mortality Amendment Exemption 2015
- Protection of Habitable Structures Exemption 2015

Any of the above mentioned exemptions may impact Northern Spotted Owls either directly through habitat removal or indirectly through noise or visual disturbance, depending on the location and on the yearly timing of operations

Exemption harvest operations must comply with all aspects of the Forest Practice Rules and various restrictions regarding the operations under the various emergency conditions. In exemption harvest actions, no known sites of rare, threatened or endangered plants or animals are to be disturbed, threatened or damaged. However, Northern Spotted Owl protocol-level surveys and habitat assessments are not generally required by the Forest Practice Rules to operate under an exemption.

Not all exemptions require an RPF certification. Those that do not require the certification are: Christmas Tree, Dead, Dying or Diseased Fuel wood or Split Products Exemption, the Public Agency, Public and Private Utility Right of Way Exemption, Drought Mortality Amendment Exemption and the Removal of Fire Hazard Trees within 150 feet of a Structure Exemption.

The Christmas Tree/Dead, Dying or Diseased Fuel wood or Split Products Exemption has been available during the entire time period in which the Northern Spotted Owl has been listed as threatened by the USFWS. Tree removal is limited to less than 10 percent of the average volume per acre and can be applied to an entire ownership on any size.

The Forest Fire Prevention Exemption allows the harvest of green merchantable trees, but the logging area is limited to 300 acres in size and a statement of the postharvest stand stocking level is required as required in 1038(i) in the Forest Practice Rules.

The Less Than Three Acre Conversion Exemption is applicable to a conversion of timberland to a non-timber use of less than 3 acres in one contiguous ownership, whether or not it is a portion of a larger land parcel, and shall be not part of a THP. Within one month of the completion of timber operations, including slash disposal, the timberland owner shall submit a work completion report to CAL FIRE.

The Substantially Damaged Timberland, Unmerchantable as Sawlog Exemption is not limited to 10% of the volume per acre and the landowner must notify CAL FIRE of the completion of timber operations within 30 days of their cessation.

The Public Agency, Public and Private Utility Right of Way Exemption , working with Public Resources Code section 4628 and Forest Practice Rules section 1104.1(b) exempts public agencies from the requirement to file an application for timberland conversion or a THP when they construct or maintain rights of way on their own property or that of another public agency. This exemption extends to easements over lands owned in fee by private parties. This exemption is not available for rights of way granted from one private landowner to another.

The Woody Debris and Slash Removal Exemption allows the removal of woody debris and slash that is: (1) located outside the Watercourse and Lake Protection Zone, (2) within the reach of loading equipment operating on existing roads and landings, (3) developed during timber operations, (4) delivered as combustion fuel for the production on energy, and (5) in compliance with the conditions of Forest Practice Rules section 1038 subsection (b) paragraphs (3),(4),(6),(7),(8) and (10).

The Removal of Fire Hazard Trees within 150 feet of a Structure Exemption allows only trees within 150 feet of an approved and legally permitted structure that complies with the California Building Code (includes only structures designed for human occupancy, garages, barns, stables and structures used to enclose fuel tanks) may be harvested under this Notice of Exemption.

The Drought Mortality Exemption was adopted in 2015 by the Board of Forestry due to the prolonged drought and supersedes the provisions of any other exemption in the same harvest footprint (harvesting of dead and dying trees). Trees that are dead or trees with fifty percent or more of foliage-bearing crown that is dead or fading in color are eligible for removal. Under this exemption, it is required to retain an average for the harvest area of not less than one decadent and deformed tree of value to wildlife, snag or dying tree per acre that is greater than sixteen inches diameter breast height and twenty feet tall. This provision does not apply within 100 feet of habitable structures, roads, fire suppression ridges and infrastructure facilities such as transmission lines and towers or water conveyance and storage facilities. This exemption requires an RPF signature when timber operations on a cumulative harvest area exceed twenty acres per total ownership.

The Protection of Habitable Structures Exemption was adopted in 2015 by the Board of Forestry due to the prolonged drought and allows trees to be cut and removed that are located 150 feet up to 300 feet from any point of an habitable structure that complies with California Building Code for the purpose of reducing flammable materials and maintaining a fuel break. The post-harvest stand shall be primarily comprised of healthy and vigorous dominant and co-dominant trees well distributed throughout the treated area and meet the stocking standards consistent with Forest Practice Rules sections 913.2, 933.2, 953.2. The quadratic mean diameter of trees greater than eight inches in the pre-harvest project area shall be increased in the post-harvest stand.

During the time in which the Northern Spotted Owl has been listed as threatened by the USFWS, approximately 41,767,250 acres (1992 to 2013) have been included in a tally of lands exempted for harvest in counties within the range of Northern Spotted Owl (CAL FIRE 2014). These acres do not represent operational acres (actual acres harvested) but only notification acres (possible intended acres harvested). Operational acre reporting is not required; therefore there is no data representing the precise amounts or locations of areas harvested under an exemption. The approximately 41.8 million acres represents over five times the total acreage of forested lands in private ownership within the range of the Northern Spotted Owl in California. This is due to redundancy in reporting, and some of these acres are most likely outside the known range of the Northern Spotted Owl. In addition, some landowners prepare notifications for their entire ownership yearly; yet may only operate on any part of the ownership or only a small area, thereby compounding this acreage total.

Volume of timber removed under an exemption is reported to the Board of Equalization (BOE), and is another way to assess levels of exemption harvest. With the precise location and yearly timing of the volume reported unknown, specific impact assessments cannot be developed. However, the total volume harvested, average volume amounts by each county and total percentage of harvest volume may be enough to determine that more information is needed. Yearly exemption harvest volume from the counties within the known Northern Spotted Owl range date back to 1990 and average approximately 49,456 MBF (1 MBF = 1,000 board-feet) and represent approximately 4.87% of total volume harvested. The highest total amount harvested occurred in 1994 totaling 164,232 MBF, accounting for 15% of the total volume harvested that year. The total exemption volume harvested during the time that Northern Spotted Owl has been listed as threatened by the USFWS is 1,186,954 MBF. The largest amount of exemption volume recorded is from Shasta in 1994 totaling 79,993 MBF, with the largest percentage of total volume coming from Napa (1994), Marin (1996), Glenn (2003), and Lake (2005), where 100% of the total volume harvested was exemption volume (BOE 2014). These volume amounts do not include all volume as the BOE reporting requirements only require volume reporting when $3000.00 is obtained. The BOE does not track the volume that is less than $3000.00 in value (A. Tenneson, personal communication, November 18, 2015).

It is not known if the long-term exemption harvesting on private lands in California is affecting Northern Spotted Owl populations, but exemption harvesting may reduce well defined/ critical habitat elements over time. The current exemption harvest process does not require owl habitat analysis or surveys and may directly impact Northern Spotted Owl, and therefore more information is needed to fully assess the impacts from exemption harvest.

Emergency Harvest

Private landowners may cut or remove timber under an emergency basis if "emergency conditions" exist pursuant to Forest Practice Rules section 895.1. Emergency conditions are defined as, "… those conditions that will cause waste or loss of timber resources to the timber owner that may be minimized by immediate harvesting of infected, infested or damaged timber or salvaging down timber; or those conditions that will cause appreciable financial loss to the timber owner that may be minimized by immediate harvesting of timber."

Types of emergency conditions include:

- Dead or dying trees as a result of insects, disease, parasites, or animal damage.
- Fallen, damaged, dead, or dying trees as a result of wind, snow, freezing weather, fire, flood, landslide, or earthquake.
- Dead or dying trees as a result of air or water pollution.
- Cutting or removing trees required for emergency construction or repair of roads.
- Cutting and removal of hazardous fuels.
- Treatments to eradicate an infestation of Sudden Oak Death.

There is some overlap with types of emergency conditions between Exemption and Emergency harvests. Exemption Harvest allows only 10% of volume of "dead and dying trees" to be removed, while under an Emergency Harvest the minimum stocking standards need to be met and does not allow the harvest of merchantable sawlogs. In addition, Emergency Harvests allow removal of dead trees or trees instituting an obvious large scale economic loss, whereas Exemption Harvest does not.

Emergency Harvest operations must comply with all aspects of the Forest Practice Rules specific to emergency operations (Forest Practice Rules § 1052 subd. (a)). Before cutting or removing timber on an emergency basis, an RPF on behalf of a timber owner or operator must submit a Notice of Emergency Timber Operations. In Emergency Harvest, no known sites of rare, threatened or endangered plants or animals are to be disturbed, threatened or damaged. However, Northern Spotted Owl protocol-level surveys and habitat assessments are not generally required to operate during emergency conditions.

During the time in which the Northern Spotted Owl has been listed as threatened by the USFWS, between 1992 and 2013 approximately 344,542 acres (CAL FIRE 2014) have been notified for emergency harvest in counties within the owl's range. These acres may not represent operational acres (actual acres harvested) but only notification acres (intended acres harvested). Depending on the emergency condition and stocking requirement, operational acre reporting may not be required; therefore there is no acreage data or mapping data representing the precise amounts or locations for all emergency operational areas.

Emergency harvest operations mostly occur in areas where forest stand conditions are dead or fallen, forest habitat conditions not meeting the definitions of suitable habitat for Northern Spotted Owl under the Forest Practice Rules, however indirect impacts may occur as a result of the emergency operation. The emergency notification data is compiled yearly by county, therefore Northern Spotted Owl range-specific data is not available. Of the total notification acres between 1992 and 2013, some are most likely outside the known range of the Northern Spotted Owl as the known range line does not include all of the county area within this acreage data set.

It is not known if the long-term emergency harvesting on private lands in California is affecting Northern Spotted Owl populations, however, there is some evidence that salvage logging effects use of burned areas by Spotted Owls. See the discussion of wildfire in the Threats section for additional discussion on this type of emergency harvest. Some indirect impacts, such as noise disturbance, may be occurring as a result of emergency operations but level and extent of this potential impact is not well documented. More information is needed to fully assess the impacts to Northern Spotted Owl from emergency harvesting.

Other Management Actions

Forest Certification Programs

Some private landowners in California have voluntarily worked with organizations to achieve certification for their forest landholdings and forestry practices. There are numerous organizations that certify forest products, with Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI) being two of the largest. In order for a landowner to attain certification, they must achieve certain conservation requirements and initiate specific management activities to meet these requirements. For example, a landowner may be required to increase retention in even-aged units, and to achieve this 10-30% of the pre-harvest basal area might be retained in a clumped or dispersed fashion. Another example that could benefit Northern Spotted Owl would be protection of old-growth and legacy trees through the creation of policy and planning documents that ensure their identification and protection (T. Bolton, personal communication, September 5, 2014).

The FSC conducts audits to ensure compliance with FSC certification. In addition, the FSC certification has geographic-specific indicators for the US and Pacific Coast region (FSC 2010a, S. Chinnici, personal communication, September 3, 2014) and has developed a draft framework for assessing "High Conservation Value Forests" to help land managers identify lands with high conservation value (FSC 2010b). Lands determined to be of high conservation value have extra requirements for monitoring. Conserving these lands enables landowners to get credit for conservation while being able to manage other parts of their land for timber products (FSC 2010a).

The Department does not have an accounting of the number of acres of timberland covered by a forest certification program, nor the quality of the management activities required to meet certification. Therefore, there is not enough information available to suggest what kind of impact, if any, forest certification has had on Northern Spotted Owl populations. However, certification programs may have a positive effect on Northern Spotted Owl in cases where more foraging, nesting, or roosting habitat is maintained than that called for in the Forest Practice Rules.

Conservation Easements

Most of the conservation easements in forested environments within the Northern Spotted Owl range allow for some sort of timber harvest. The Department is involved in only a portion of easement/title projects, and of these projects, the Department is typically not a landowner, title-holder, or manager of these lands. While working with landowners and managers on the easement/title conditions, the Department Lands Program staff suggests conditions conducive to the protection and conservation of wildlife and their habitats.

Due to the variability of landowner needs, the conditions agreed upon for easements constitute a wide range of habitat protection. Thus, it is difficult to draw conclusions as to how easements/titles are contributing to Northern Spotted Owl conservation. Additionally, these areas are not rigorously studied specific to the Northern Spotted Owl.

State Forests

CAL FIRE operates eight Demonstration State Forests in California, totaling about 71,000 acres. A majority of these forests are actively managed as timberlands and annually produce on average about 30 million board feet of wood. About 53,145 actively-managed acres of State Forest lands occur within the range of the Northern Spotted Owl; this includes Ellen Pickett State Forest (158 acres), Las Posadas State Forest (843 acres), Boggs Mountain Demonstration State Forest (3,425 acres), and Jackson Demonstration State Forest (48,719 acres). State Forests are intended to be used for experimentation and demonstration of various silvicultural methods for their economic and environmental/scientific value. The State Forests have management plans that are periodically reviewed by BOF and all timber harvesting activities on State Forests must comply with the Forest Practice Act and the Forest Practice Rules, including the measures to avoid take of Northern Spotted Owl found in Forest Practice Rules sections 919.9 and 919.10.

Jackson Demonstration State Forest (JDSF) is the largest of the eight forests (49,000 acres) and represents nearly 70% of the total State Forest acreage in California. This forest has been managed and harvested since 1862 and was acquired by the State in 1947. Located in central Mendocino County, the forest consists primarily of coast redwood and Douglas-fir, with some old-growth coast redwood remaining. Forest stands on JDSF have been managed on an even-aged and uneven-aged basis under various silvicultural systems; however, special restrictions are put on even-aged management and clear-cutting (CDF 2008, CDF 2014).

The JDSF Management Plan (CDF 2008) contains a Northern Spotted Owl Conservation Strategy, with the goal to “maintain or increase the number and productivity of nesting owl pairs through forest management practices that enhance nesting and roosting opportunities and availability of a suitable prey base.” CAL FIRE monitors certain Northern Spotted Owl activity centers on JDSF and the Management Plan conditions are nearly identical to the Forest Practice Rules.

State Parks

The California Department of Parks and Recreation (CA State Parks) manages 280 park units in California; 64 of these park units are within the range of the Northern Spotted Owl, totaling 214,286 acres. CA State Parks’ mission, in addition to preserving biodiversity, includes protecting cultural resources and creating recreation opportunities. CA State Parks does not have a management plan for the Northern Spotted Owl and management for species occurs at the park unit scale. Each park unit prepares a general plan that describes the range of activities occurring within the park unit and resource protection that the park unit enables.

The largest State Park (SP) in the Northern Spotted Owl range, Redwood National and State Parks, is jointly managed by the NPS and CA State Parks and includes: Redwood National Park, Jedediah Smith Redwoods SP, Del Norte Coast Redwoods SP, and Prairie Creek Redwoods SP. RNSP does not have specific Northern Spotted Owl management actions in its General Management Plan/General Plan, but does have vegetation management actions for old-growth, second-growth, prairie and fires. Old-growth forests are protected, managed, and restored to provide habitat for species and to reduce fire hazards. Second-growth forests are managed through silvicultural methods (thinning, replanting, and burning) to reduce the time needed to attain a mature forest. Additionally, conifer encroachment into oak woodlands and prairies is managed through tree removal and burning. Nine management zones within the RNSP delineate the degree of human influence and development on that can occur on the landscape (NPS 2000a).

Similar to Redwood National and State Parks, the second largest park unit within the Northern Spotted Owl range, Humboldt Redwoods State Park, does not engage in specific management activities for Northern Spotted Owl, but protects and manages for old-growth stands to be sustained over time (CDPR 2001).

California State Parks do not engage in regular surveys for Northern Spotted Owl within State Parks, though surveys sometimes occur before park projects are started. However, adjacent timberland owners routinely survey Northern Spotted Owl activity centers within State Parks (T. Fuller, personal communications, September 2, 2014).

University of California Natural Reserves

Comprised of more than 756,000 acres across 39 sites and representing most major California ecosystems, the UC Natural Reserve System (UCNRS) is the largest university-administered reserve system in the world. By supporting university-level teaching, research, and public service, the UCNRS contributes to the understanding of and wise stewardship of California's natural resources. Five UCNRS sites (totaling 4,625 acres) across California occur within the range of the Northern Spotted Owl, though there are no management plans or Northern Spotted Owl data for individual reserves (UC 2014). Angelo Coast Range Reserve has had three Northern Spotted Owl territories since the late-1980s, but since Barred Owls were detected in the area starting in 1999 Spotted Owls have not been detected at any of the three sites (A. Franklin, personal communication, March 23, 2015).

Department Ecological Reserves

Authorized by the California Legislature in 1968 and administered by the Department, the ecological reserve system is designed to conserve areas for the protection of rare plants, animals, and habitats, and to provide areas for education and scientific research. The system now encompasses 119 properties totaling nearly 129,000 acres. Sixteen Department Ecological Reserves (totaling 16,753 acres) occur within the range of the Northern Spotted Owl; however there are no management plans for the system or individual reserves and the status of Northern Spotted Owl on these lands is unknown. One exception is the Headwaters Forest Ecological Reserve, a 7,515 acre Department Conservation Easement owned by BLM, which manages for late seral habitat benefiting Spotted Owls.

Fisheries Restoration Grant Program

As part of the Fisheries Restoration Grant Program (FRGP), certain measures for protection of Northern Spotted Owls and their habitat are required for each project funded. The purpose of FGRP is to support restoration projects along watersheds to enhance salmon and steelhead habitat. Applicants must provide a detailed proposal that thoroughly addresses all criteria of the FGRP, one of which is avoidance and minimization measures for Northern Spotted Owls if a project proposes to conduct work in owl habitat. The geographic area covered by FGRP almost completely overlaps with the Northern Spotted Owl range in California, therefore the potential for a project be in owl habitat is high. Once a project is approved, the proponent must obtain a Lake or Streambed Alteration Agreement (LSAA) from the Department to comply with the CEQA. The LSAA will include conditions for the protection of wildlife and habitat, and must be followed during project activities.

To avoid potential impacts to Northern Spotted Owls FRGP projects must adhere to the following, as noted in the LSAA:

- Work with heavy equipment at any site within 0.25 miles of suitable habitat for the Northern Spotted Owl shall not occur from November 1 to July 9.
- The work window at individual work sites may be advanced prior to July 31, if protocol surveys determine that suitable habitat is unoccupied.

- If these mitigation measures cannot be implemented or the project actions proposed at a specific work site cannot be modified to prevent or avoid potential impacts to Northern Spotted Owls or their habitat, then activity at that work site will be discontinued and the project proponent must obtain incidental take authorization from the USFWS.
- For projects contained within streams and watersheds included in a USFWS Habitat Conservation Plan the mitigation measures contained within those Habitat Conservation Plans shall be followed.

The grant program funds numerous projects each year. In fiscal year 2013/2014 alone, FRGP funded approximately $16.5 million dollars in 56 projects, of which 44 projects were located within the range of the Northern Spotted Owl.

Threats (Factors Affecting Ability to Survive and Reproduce)

Historical Habitat Loss and Degradation

Historical Habitat Loss

The revised recovery plan includes ongoing loss of habitat as a result of timber harvest, wildfire, and other disturbances, and historical loss of habitat from past activities, as the most important threats to the Northern Spotted Owl, along with competition from Barred Owl (USFWS 2011). Estimates of the pre-logging extent of old-growth forest in western Washington and Oregon have ranged from 60-72% of the landscape (Courtney et al. 2004). Strittholt et al. (2006) estimated more than 16 million hectares (>40 million acres) of old-growth within the Pacific Northwest region of Washington, Oregon, and California (excluding much of the California Coast Province) prior to European settlement, representing about two-thirds of the total land area. In 1990, the USFWS estimated that Northern Spotted Owl habitat had declined 60-88% since the early 1800s and losses were largely attributed to timber harvest and land conversion activities, with natural disturbance regimes (e.g., wildfire) less of a factor (USFWS 1990, 2011). Strittholt et al. (2006) evaluated loss of old-growth forests across the Pacific Northwest and estimated a decline of 72% since European settlement. Losses of Northern Spotted Owl habitat were concentrated at lower elevations and in the Coast Ranges (USFWS 2011). This pattern of historical habitat loss is apparent in the current distribution of suitable habitat, with large areas of coastal and low-lying areas that no longer support suitable nesting and roosting habitat (see Figure 5).

Prior to 1990, the annual rate of removal of Northern Spotted Owl habitat on national forests as a result of logging had been about 1% per year in California and 1.5% per year in Oregon and Washington (USFWS 1990, 2011). At the time, it was projected that ongoing rates of habitat removal would eliminate all nesting and roosting habitat on non-protected BLM lands in Oregon, with the exception of the Medford District, by the year 2016 (USFWS 1990). Estimates from the decades before 1990 indicate that harvest rates on private industrial lands were consistently about twice the average rate of harvest on public land (Cohen et al. 2002). Bigley and Franklin (2004) estimated harvest rates in the late 1980s and early 1990s for private industrial land of 2.4% per year, and harvest rates on non-industrial lands increased from 0.2% in the 1970s to a rate similar to that of the private industrial lands by the early 1990s.

Habitat Loss under the Northwest Forest Plan

To address ongoing decline of Northern Spotted Owl habitat across the range, the NWFP established reserved lands including late-seral reserves, adaptive management reserves, congressionally reserved lands, managed late-successional areas, and larger blocks of administratively withdrawn lands (USDA and USDI 1994) (see Figure 16). These reserve lands are described fully in the Federal Lands section of this report. It was assumed that habitat in reserves would improve over time as successional processes led to more mature forests, however, this is a slow process and so recruitment of habitat conditions on reserves was expected to take many decades (Lint et al. 1999). It was also assumed that habitat outside of reserves would continue to decline due to timber harvest and other disturbances but that dispersal habitat would be maintained in order to facilitate movement between reserve lands (Lint et al. 1999). Given the continued declines in the Northern Spotted Owl population and the increasing threat of the Barred Owl, the revised recovery plan recommended conserving occupied sites and unoccupied, high-value Spotted Owl habitat on state and private lands wherever possible (USFWS 2011).

In order to understand the degree to which the NWFP conserves Northern Spotted Owl habitat, the range-wide trends in habitat are regularly assessed. To date, assessments have been performed at the 10-year, 15-year and 20-year time points (Davis and Lint 2005, Davis et al. 2011, Davis et al. 2015). The most recent assessment (Davis et al. 2015) estimated range-wide habitat changes on federal and nonfederal lands from 1993 through 2012 by comparing vegetation maps for the two bookend time periods. In addition to range-wide changes, trends for each physiographic province and for each state are also reported. The assessment tracks changes in Northern Spotted Owl nesting and roosting habitat, and also tracks changes in dispersal habitat within and between the reserves; whereas foraging habitat is not assessed. Nesting and roosting habitat maps were produced through habitat suitability modeling using several forest structure variables (e.g., percent conifer cover, average conifer dbh, average stand height) and a forest age variable (Davis et al. 2015). Vegetation stands were placed in one of four categories (highly suitable, suitable, marginal, and unsuitable), with highly suitable and suitable categories assumed to represent nesting and roosting habitat (Davis et al. 2015). To assess change, an area was considered to have lost nesting and roosting habitat if its condition moved from suitable or highly suitable to marginal or unsuitable.

Although federal lands contain less than half of the total forest land within the entire range of the Northern Spotted Owl (Mouer et al. 2011), Northern Spotted Owl habitat is concentrated on federally administered lands (Davis et al. 2015). Range-wide, nesting and roosting habitat loss was estimated at 12.9% (1,611,000 acres), with 7.2% (650,200 acres) loss of habitat on federal lands, and the remainder of the loss on nonfederal lands (Davis et al. 2015). On federal lands, most of the nesting and roosting habitat loss (73%) was due to wildfire, and these losses were larger on federal reserved land (388,500 acres) than on nonreserved land (85,900 acres). This pattern of loss to wildfire is likely in part attributable to the fact that federal land is predominately distributed in the drier portions of the Northern Spotted Owl range (Healey et al. 2008). The rate of Northern Spotted Owl habitat loss due to timber harvest on federal lands has declined since the listing of the species in 1990 and the implementation of the NWFP in 1994. On nonfederal lands most of the range-wide nesting and roosting habitat loss was due to timber harvest (94% of losses on nonfederal land), whereas a relatively small amount of nesting and roosting habitat on nonfederal lands was lost to wildfire and insects (Davis et al. 2015). Timber harvest accounted for 63% of the nesting and roosting habitat loss range-wide (Davis et al. 2015).

Habitat recruitment estimates in Davis et al. (2015) have a higher level of uncertainty than estimates of habitat loss because structural changes associated with forest succession may not be reliably captured by satellite sensors, whereas abrupt changes brought about by removal or reduction of vegetation are easier to discern (Davis et al. 2011). Nevertheless, estimates of gains and losses were used to assess net changes in Northern Spotted Owl habitat. Since 1993, there was a net decrease of nesting and roosting habitat range-wide on all federal lands of 1.5%, with a net decrease on reserved lands of 4% and a net increase on nonreserved lands of 4.3% (Davis et al. 2015). There was a net decrease in nesting and roosting habitat range-wide on all federal and nonfederal lands of 3.4%. The observed habitat recruitment is thought to be the result of changes in species composition (e.g., understory development) that moved forest stands from unsuitable to suitable classifications, and to younger forests transitioning into suitable habitat through forest succession.

In California, relative rates of nesting and roosting habitat loss on federal vs. nonfederal lands follow the range-wide pattern. Nesting and roosting habitat loss in California was estimated at 11.9% (413,700 acres), with 10.8% (234,400 acres) loss of habitat on federal lands in California, and the remainder of the loss on nonfederal lands (Davis et al. 2015). Consistent with the entire subspecies range, more nesting and roosting habitat on federal land was lost to wildfire (208,800 acres) in California than any other cause, with about 93% of the total wildfire loss occurring on federal land (Table 20; Figure 20; Davis et al. 2015). Most of the loss due to wildfire occurred in the California Klamath Province; 199,800 acres on federal land and 8,300 acres on nonfederal land (Davis et al. 2015). Harvest rate of nesting and roosting habitat on federal lands in California was relatively low (17,800 acres) (Davis et al. 2015). Timber harvest on nonfederal land in California was much higher than on federal land, and about 42% of the explained losses in nesting and roosting habitat in California were due to harvest (Davis et al. 2015). From 1994-2007, 5.8% of nesting and roosting habitat on nonfederal lands in California was removed by timber harvest (Davis et al. 2011). Since 1993, there was a net decrease of nesting and roosting habitat on federal lands in California of 3.6% (Davis et al. 2015), with the California Klamath and Cascades provinces experiencing net losses of nesting and roosting habitat (Davis et al. 2015). However, due to large estimates of habitat recruitment in the California Coast Province where habitat development through forest succession can occur relatively quickly (Thome et al. 1999, Diller et al. 2010), estimates for net change of nesting and roosting habitat in this province are positive (Davis et al. 2015).

Table 20. Estimated acreage and net change (in acres) of Northern Spotted Owl nesting and roosting habitat from 1993 to 2012 in California, and assigned causes of loss. See Davis et al. 2015, Tables 4-7.

	Acres of Nesting and Roosting Habitat and Net Change 1993 to 2012			Causes of Habitat Loss (acres)[a]			
Nonreserved Federal	**1993**	**2012**	**Net Change**	**Harvest**	**Wildfire**	**Insect**	**Other**
CA Coast Range	7,300	10,000	2,700	-	100	-	0
CA Klamath	615,100	621,800	6,700	8,200	41,800	1,100	0
CA Cascade	84,000	89,300	5,300	6,100	2,300	800	0
Reserved Federal							
CA Coast Range	106,100	113,800	7,700	100	1,700	-	500
CA Klamath	1,245,700	1,142,900	(102,800)	2,200	158,000	2,200	2,600
CA Cascade	117,400	120,000	2,600	1,000	4,900	300	300
All Federal Lands							
CA Coast Range	113,300	123,800	10,500	200	1,800	-	500
CA Klamath	1,860,800	1,764,700	(96,100)	10,400	199,800	3,300	2,600
CA Cascade	201,300	209,300	8,000	7,200	7,200	1,100	300
All Federal and Nonfederal Lands							
CA Coast Range	970,700	1,198,500	227,800	79,500	5,600	2,900	500
CA Klamath	2,148,500	2,063,400	(85,100)	50,100	208,100	5,600	2,600
CA Cascade	368,500	362,500	(6,000)	44,700	10,500	3,300	300

[a] The total acres for causes of habitat loss do not necessarily represent total habitat loss, but rather are estimates of loss for acres that could be assigned to a specific cause of habitat loss.

Trends in dispersal habitat from 1993 to 2012 were analyzed within and between federal reserved lands, and the distribution of "dispersal-capable" habitat was mapped by combining results of the mapped dispersal habitat with estimates of maximum dispersal distance from Forsman et al. (2002) (Davis et al. 2015). This estimate of dispersal-capable habitat on the landscape allowed for a measure of the ability of owls to disperse between habitat reserves, which is a goal of the NWFP and an important functional measure of habitat beyond a simple acreage estimate of total dispersal habitat.

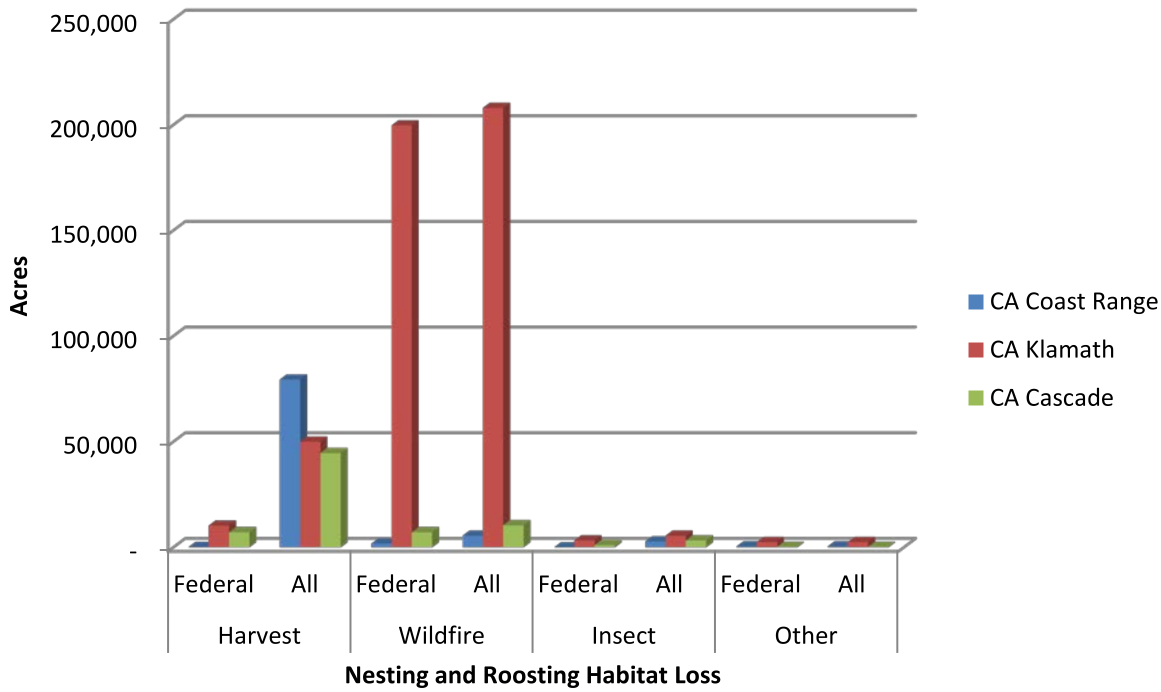

Figure 20. Assigned causes of Northern Spotted Owl nesting and roosting habitat loss (acres) in California from 1993 to 2012 (data from Davis et al. 2015).

Range-wide, dispersal habitat on federal lands experienced a gross loss of 789,500 acres of which 79% was due to wildfire (621,900 acres) (Davis et al. 2015). On federal land, most of the loss due to wildfire occurred on reserved land (511,500 acres). Timber harvest accounted for 15% (116,800 acres) of dispersal habitat loss on federal lands, most being on nonreserved land (85,200 acres). However, losses were offset by gains of dispersal habitat on federal land, for a net gain of 2.2% due to forest succession. Cumulatively, all lands (both federal and nonfederal) experienced 681,100 acres of dispersal habitat loss due to wildfire and 2,945,100 acres loss due to harvest, for a net decline in dispersal habitat across the range of 2.3%. The estimates for dispersal-capable habitat, which take into account the dispersal distance of Spotted Owls, revealed a net decline of 5% since 1993. Losses of dispersal-capable habitat were concentrated on nonfederal lands around the periphery of federal forests, where losses of dispersal habitat to harvest outpaced gains due to forest succession (Figure 21; Davis et al. 2015).

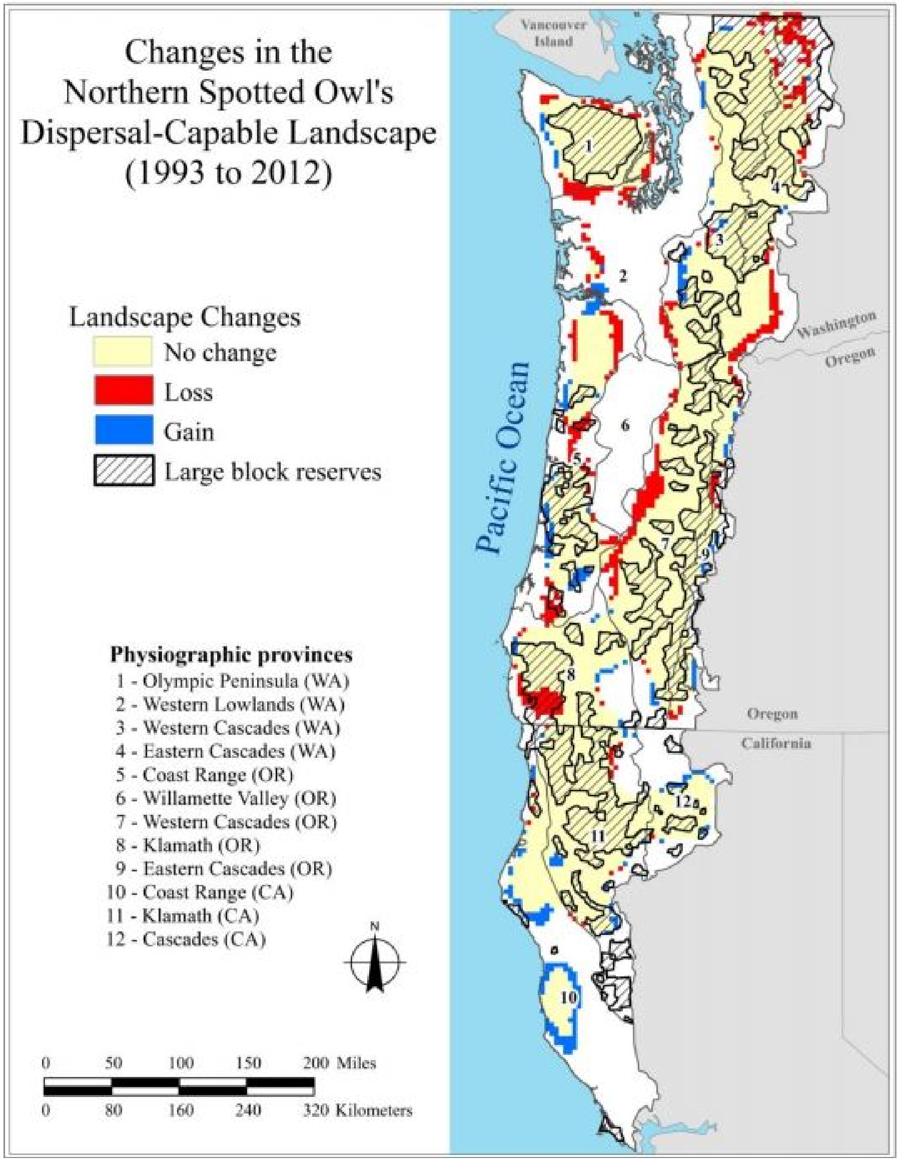

Figure 21. Changes in dispersal-capable landscapes across the Northern Spotted Owl's range (Figure 9, Davis et al. 2015).

In California, there was little net change of dispersal habitat since 1993, with only the California Klamath Province experiencing net declines in dispersal habitat (net decline of 59,600 acres on federal land and of 35,500 acres province-wide) (Table 21, Figure 22; Davis et al. 2015). Loss of dispersal habitat within the Klamath Province was largely due to wildfires (208,500 acres; Davis et al. 2015). Rapid growth of redwood forests along the coastal region resulted in a large net increase of dispersal habitat in the California Coast Province (Davis et al. 2015).

Table 21. Estimated acreage and net change of Northern Spotted Owl dispersal habitat from 1993 to 2012 in California, and assigned causes of loss. See Davis et al. 2015, Tables 9-12.

	Acres of Dispersal Habitat and Net Change 1993 to 2012			Causes of Habitat Loss (acres)[a]			
Nonreserved Federal	**1993**	**2012**	**Net Change**	**Harvest**	**Wildfire**	**Insect**	**Other**
CA Coast Range	20,500	26,000	5,500	200	400	-	-
CA Klamath	898,100	938,100	40,000	8,700	45,000	1,100	-
CA Cascade	311,600	335,800	24,200	8,900	3,200	1,900	-
Reserved Federal							
CA Coast Range	160,300	176,600	16,300	200	2,900	-	300
CA Klamath	1,851,500	1,751,900	(99,600)	1,800	163,500	1,300	2,300
CA Cascade	255,300	265,200	9,900	900	4,700	600	500
All Federal Lands							
CA Coast Range	180,800	199,600	18,800	400	3,300	-	300
CA Klamath	2,749,600	2,690,000	(59,600)	10,500	208,500	2,400	2,300
CA Cascade	566,900	600,900	34,000	9,800	7,800	2,400	500
All Federal and Nonfederal Lands							
CA Coast Range	1,848,200	2,192,600	344,400	54,300	9,200	2,300	300
CA Klamath	3,285,300	3,249,800	(35,500)	62,600	221,000	5,800	2,300
CA Cascade	1,004,700	1,029,000	24,300	61,400	13,600	6,400	500

[a] The total acres for causes of habitat loss do not necessarily represent total habitat loss, but rather are estimates of loss for acres that could be assigned to a specific cause of habitat loss.

The network of large federal reserves across the range of the Northern Spotted Owl is fairly well connected, although there are exceptions in the Olympic Peninsula, the eastern Washington Cascades, and in the southern end of the range in California. The Marin County population is poorly connected to other federal reserves, and large portions of the California Coast physiographic province are mapped as having poor dispersal-capability. However, the definition of minimum dispersal habitat in Thomas et al. (1990) and used to map trends in the NWFP may not capture the full range of dispersal habitat conditions in Northern California, where Northern Spotted Owls use younger forests (USFWS 2011).

In summary, the rate at which nesting and roosting habitat is being lost has declined since the implementation of the NWFP (Figure 23). Range-wide net loss of nesting and roosting habitat on federal lands was estimated at 1.5% over 20 years, whereas the loss on federal lands in California was estimated at 3.6%. Within reserved land, nesting and roosting habitat has declined range-wide by 4% since 1993, primarily due to wildfires, and the California Klamath Province experienced the largest amount of loss to wildfire (Davis et al. 2015). Gains in nesting and roosting habitat were mostly within the moist portions of the range (i.e., coastal regions) but not enough time has passed since implementation of the NWFP to allow for significant recruitment (Davis et al. 2015). There was a net gain in dispersal habitat of 2.2% range-wide on federal lands, but losses on adjacent non-federal land resulted in a net loss of 2.3% on all lands.

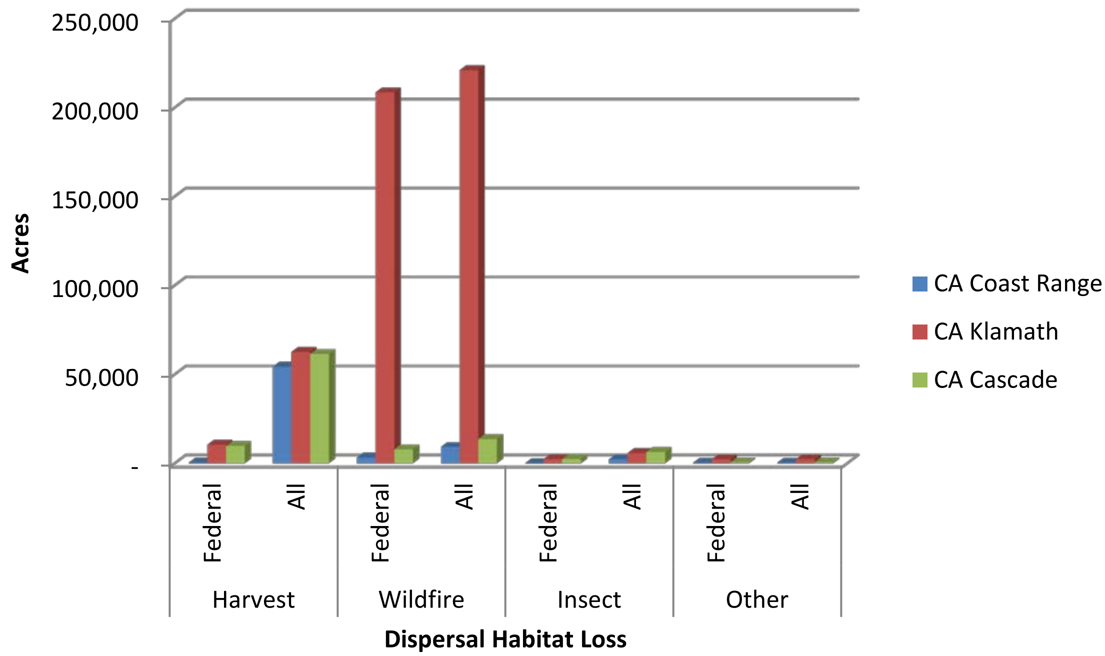

Figure 22. Assigned causes of Northern Spotted Owl dispersal habitat loss (acres) in California from 1993 to 2012 (data from Davis et al. 2015).

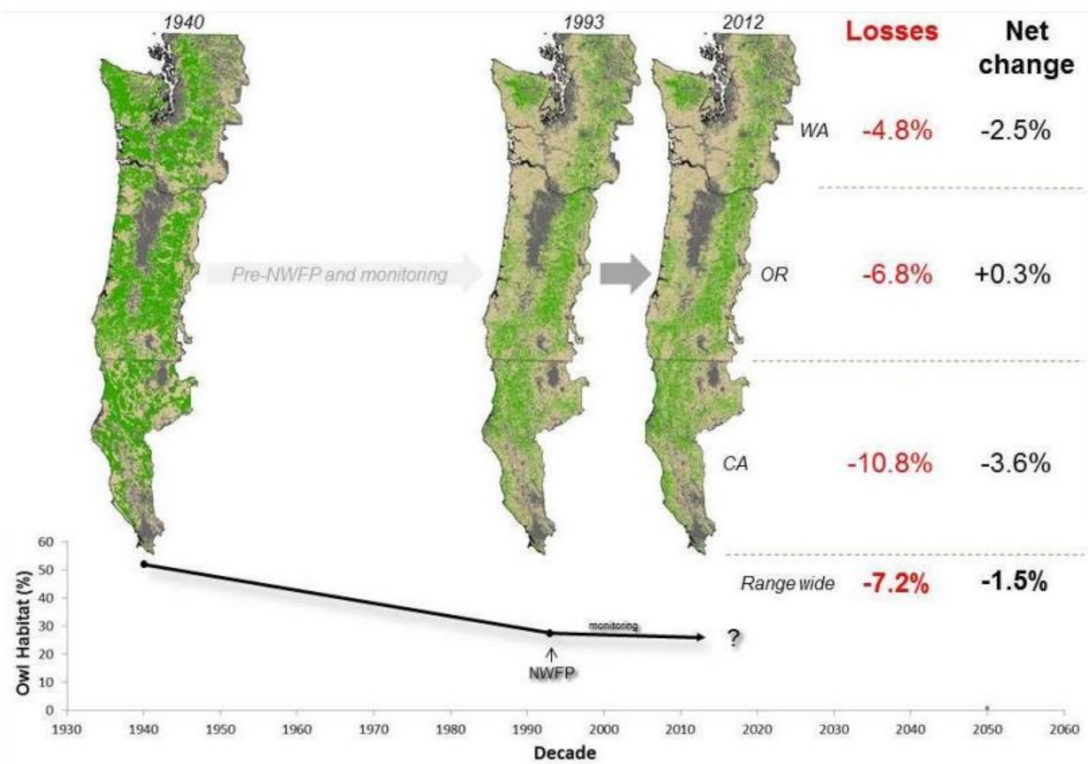

Figure 23. Gross losses and net change on federal land (by state) in Northern Spotted Owl nesting and roosting habitat from 1940, to the implementation of the NWFP in 1993, through 2012 (Figure 10 in Davis et al. 2015).

Two decades into implementation of the NWFP, Northern Spotted Owl habitat is still declining overall. However, habitat recruitment in portions of the range is beginning to offset some losses. Davis et al. (2015) predicts that significant habitat recruitment may not be seen until the middle part of this century, but this prediction is complicated by a changing climate and potential increases in the frequency and severity of wildfires on the landscape (Davis et al. 2015).

Timber Harvest

Timber Harvest and Regulatory Mechanisms on Private Land

The Northern Spotted Owl was federally listed as Threatened in 1990 largely due to extensive habitat loss from timber harvest activities on federal and nonfederal land (USFWS 1990). As described in the Existing Management section of this report, timber harvest on nonfederal land in California must comply with the Forest Practice Rules, including sections 919.9 [939.9] and 919.10 [939.10] which describe options that can be used in THPs to avoid take of Northern Spotted Owl or to proceed under incidental take authorization. Compliance with the Forest Practice Rules applies to all commercial timber harvesting operations for private landowners (excluding specific exemptions discussed in the Timber Harvest Management section of this report) from small parcel operations to large timber operations. THPs are plans submitted by the landowners that serve as the environmental review document. They outline the amount and characteristics (e.g., stand composition, size, age) of timber to be harvested, how it will be harvested, and the steps that will be taken to prevent damage to the environment, including impacts to Northern Spotted Owl activity centers.

Changes in nesting and roosting habitat and dispersal habitat conducted for the NWFP and discussed above have provided an assessment of broad landscape changes across the range of the Northern Spotted Owl, including changes specific to physiographic regions within California. As has been demonstrated at territory-based studies of demographics in California and southern Oregon, Northern Spotted Owl habitat is often composed of a mosaic of mature forests intermixed with younger forest types within the home ranges of individual owls (e.g., Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005, Irwin et al. 2007, Diller et al. 2010), with both the amount and spatial configuration of different habitat types at a territory contributing to levels of survival and productivity in the resident owls. Because some of the forest types included in high quality Northern Spotted Owl home ranges are younger forests considered to be foraging habitat, they were not assessed for change in the recent review of the NWFP. Detection of changes in habitat quality at the smaller scale of Northern Spotted Owl home ranges require an assessment of management practices at this scale, and can be accomplished by evaluating timber harvest practices around known Northern Spotted Owl activity centers.

When the Northern Spotted Owl guidelines were added to the Forest Practice Rules in 1992, the intent was to protect Northern Spotted Owls and suitable habitat used for nesting, roosting and foraging activities. Based on existing knowledge of Northern Spotted Owl biology and ecology, criteria were established for retention of habitat around known nest sites, in core use areas, and in the broader home range. Criteria in the Forest Practice Rules Section 919.9 subsection (g) are summarized in Table 22.

Definitions of owl habitat referred to in Forest Practice Rules Section 919.9(g) can be found in Appendix 2.

Table 22. Criteria for minimum quantities of habitat to be retained to avoid incidental take of Northern Spotted Owls on private timberlands according to Forest Practice Rules Section 919.9(g).

Forest Practice Rules Subsection	Proximity to Activity Center (acreage)	Criteria Description
919.9(g)(1)	Within 500 feet of the activity center (~18 acres)	Characteristics of functional nesting habitat must be retained.
919.9(g)(2)	Within 500-1000 feet of the activity center (1,000 foot radius circle is ~72 acres)	Retain sufficient functional characteristics to support roosting and provide protection from predation and storms.
919.9(g)(3)	Within a 0.7 mile radius of the activity center (~985 acre core area)	Provide 500 acres of owl habitat. The 500 acres includes the habitat retained in subsections 919.9(g)(1) and (2) and should be as contiguous as possible.
919.9(g)(4)	Within 1.3 miles of each activity center (~3,400 acre home range)	Provide 1,336 total acres of owl habitat. The 1,336 acres includes the habitat retained within subsections 919.9(g)(1)-(3).
919.9(g)(5)	Shape of habitat retention	Areas established shall be adjusted to conform to natural landscape attributes such as draws and stream courses while retaining the total area required within subsections 919.9(g)(1) and (2).

The USFWS has expressed concern that the guidelines for habitat retention in the Forest Practice Rules may be insufficient to avoid take of Northern Spotted Owl (USFWS 2009). The definition of take under federal ESA includes actions that would significantly modify or degrade habitat. The USFWS found that the cumulative effects of repeated harvest entries within many Northern Spotted Owl home ranges had reduced habitat quality to a degree causing reduced occupancy rates and frequent site abandonment (USFWS 2009). An analysis of occupancy declines from 1978-2007 at sites that were known to have supported a pair of owls was conducted by the USFWS (2009), and compared territory loss on private timber lands in the north interior region to USFS lands. Of 44 sites evaluated on private timber lands, 54% of sites occupied by a pair of Northern Spotted Owls became unoccupied by 2007, and 23% of sites declined from pair status to single owl status. Conversely, on USFS lands 80% of the sites remained occupied by pairs (i.e., original occupancy status did not change) (USFWS 2009). A lack of owl responses and a lack of suitable habitat to support continued occupancy and survival was noted in USFWS technical assistance letters issued regarding THPs and NTMPs in the early 2000s (USFWS 2009). Because of these concerns and the growing body of literature linking habitat characteristics to owl fitness, the USFWS provided revised guidance for avoiding take of Northern Spotted Owl, including habitat retention recommendations (USFWS 2008b). The USFWS (2008b, 2009) guidelines for the northern coastal (coast redwood ecotype) and northern interior regions are summarized in Tables 23 and 24.

Table 23. USFWS guidelines criteria for minimum quantities of habitat to be retained to avoid incidental take of Northern Spotted Owls on private timberlands, and selected stand structural parameters used to classify nesting/roosting and foraging habitat for Northern Spotted Owls in the northern coastal region (coast redwood ecotype) of California (USFWS 2008b).

Habitat Type	Acre Retention in Core Area (within 0.7 mile; ~985 acres)[1]	Acre Retention in Outer Ring (between 0.7-1.3 mile)[1]	Acre Retention in Home Range (total up to 1.3 mile; ~3,400 acres))	DBH	Percent Canopy Cover	Basal Area
Nesting/Roosting	200 acres	NA	200 acres	≥ 11 inch	≥ 60%	≥ 100 ft^2/acre
Foraging	≥ 300 acres	NA	≥ 300 acres	≥ 11 inch	≥ 40%	≥ 75 ft^2/acre
Suitable Habitat[2]	NA	≥ 836 acres	≥ 836 acres			

[1] No more than 1/3 of the remaining suitable habitat may be harvested within the core area and outer ring during the life of the plan.

[2] Suitable Habitat is defined as habitat that meets either Nesting/Roosting or Foraging definitions, or a combination of Nesting/Roosting and Foraging habitat.

Table 24. USFWS guidelines criteria for minimum quantities of habitat to be retained to avoid incidental take of Northern Spotted Owls on private timberlands, and selected stand structural parameters used to classify nesting/roosting and foraging habitat for Northern Spotted Owls in the northern interior region of California (USFWS 2008b and 2009).

Habitat Type	Within 1,000 feet of Activity Center	Acre Retention in Core Area (within 0.5 mile; ~500 acres) [1]	Acre Retention in Outer Ring (between 0.5-1.3 mile; ~2,900 acres) [1]	Acre Retention in Home Range (total up to 1.3 mile; ~3,400 acres)	Basal Area Parameter	Quadratic Mean Diameter Parameter	Large trees/acre Parameter	Canopy Closure Parameter
High Quality Nesting/Roosting	No timber operations are allowed other than use of existing roads.	100 acres	NA	100 acres	≥ 210 ft^2/acre	≥ 15 inch	≥ 8	≥ 60%
Nesting/Roosting		150 acres	NA	150 acres	Mix, ranging from 150 to ≥ 180 ft^2/acre	≥ 15 inch	≥ 8	≥ 60%
Foraging		100 acres	655 acres	755 acres	Mix, ranging from 120 to ≥ 180 ft^2/acre	≥ 13 inch	≥ 5	≥ 40%
Low-quality Foraging		50 acres	280 acres	330 acres	Mix, ranging from 80 to ≥ 120 ft^2/acre	≥ 11 inch	NA	≥ 40%

[1] No more than 1/3 of the remaining suitable habitat may be harvested within the core area and outer ring during the life of the plan.

The USFWS guidelines differ somewhat from the Forest Practice Rules. The Forest Practice Rules require a total of 40% of the 1.3 mile radius area (1,336 acres of the 3,400 acre area) be retained as habitat and that about 50% of the 0.7 mile core area (500 of 985 acres) be retained. The total acreage to be retained according to the USFWS guidelines for the interior is similar, at 1,335 acres. However, the USFWS guidelines require greater concentration of habitat near the activity center than the Forest Practice Rules. This concentration occurs through: (1) a decrease in the size of the core area from 0.7 to 0.5 mile radius; and (2) a requirement that part of the total amount of foraging habitat in the home range be retained within the core area (USFWS 2009). These changes are supported by results of demography studies that show that habitat fitness potential is greatest in Northern Spotted Owl territories with at least 50% old forest in a core area, intermixed with other forest and nonforest vegetation types (Franklin et al. 2000, Dugger et al. 2005, Diller et al. 2010). See the Habitat Effects on Demographics section of this report for discussion of these studies. A decrease in size of the core area is supported by studies that have documented a more concentrated and frequent use of habitat features surrounding the activity center (e.g., Carey and Peeler 1995, Hunter et al. 1995, Bingham and Noon 1997, Meyer et al. 1998, Zabel et al. 2003, USFWS 2009). The USFWS used the results of demography studies and additional studies on habitat selection by Northern Spotted Owl (e.g., Solis and Gutiérrez 1990, Zabel et al. 1993, Irwin et al. 2007), to develop the harvest management guidelines (USFWS 2008b, 2009). The purpose of the USFWS guidelines was to enable CAL FIRE to more effectively and appropriately evaluate THPs and NTMPs to ensure timber harvest activities do not result in take of Northern Spotted Owls.

Among the recommendations in the USFWS guidance to CAL FIRE (USFWS 2008b), minimum amounts of nesting, roosting, and foraging habitat are described for both 0.5 mile (502 acres; interior forests) and 0.7 mile (985 acres; coastal redwood forests) radii surrounding the activity center, representing the core habitat use, and for an outer ring of habitat from 0.5 to 1.3 miles radius (2,908 acres; interior forests) surrounding the activity center, representing the broader home range. The USFWS determined that within the interior forests in California, a 0.5 mile radius, rather than the 0.7 mile radius noted in the Forest Practice Rules, more effectively captured actual core habitat use of Northern Spotted Owls (USFWS 2009). The 2008 USFWS guidelines also revised the definitions of nesting, roosting, and foraging habitat for the interior, and included differentiation between high quality and low quality habitat (USFWS 2008b and USFWS 2009).

In order to evaluate the potential cumulative effect of timber harvest on Northern Spotted Owl, the Department evaluated the proposed timber harvest history at a sample of activity centers, and assessed whether harvest history around the activity centers complied with the habitat retention guidelines in the Forest Practice Rules and the revised guidance provided by the USFWS. As detailed in the Timber Harvest Management section of this report, all THPs submitted in 2013 were evaluated, and a subset of Northern Spotted Owl activity centers (17 interior and 14 coastal activity centers) from plans utilizing options (e) or (g) (the most commonly used options from Forest Practice Rules 919.9 [939.9]) were tracked back in time to summarize cumulative harvest activities at owl sites between 1986 and 2013. Of the 17 activity centers evaluated in the interior, six activity centers have experienced greater than 2,000 acres timber harvest within the 1.3 mile radius (~3,400 acres) home range, and six activity centers have experienced greater than 250 acres timber harvest within the 0.5 mile radius (~500 acres) core area. Of the 14 activity centers evaluated on the coast, six activity centers experienced harvest of over 500 acres within the 0.7 mile radius (~985 acres) core range, with two of these over 1,000 acres (see Tables 14 and 15 and Appendix 3). At some of the activity centers evaluated for harvest history, cumulative harvest exceeded the habitat retention guidance provided in the Forest Practice Rules and by the USFWS.

A similar activity center analysis was not possible for NTMPs due to lack of access to timber harvest documents, particularly in older plans, and with limited staff time. Considering the types of silviculture practiced in NTMPs (uneven-aged management), we can infer that owl habitat is retained to some extent; however, we cannot determine the type or quality of habitat retained. For instance, high quality nesting and roosting habitat may be harvested more frequently, thereby reducing owl fitness.

Types of silvicultural practices vary on the landscape and may impact Northern Spotted Owls differently depending on a variety of factors surrounding type and extent of habitat removed. For example, clearcut harvesting (removal of an entire stand in one harvest), depending on how it is applied on the landscape, has the potential to negatively impact Northern Spotted Owls because owls have been shown to avoid nonforested areas (e.g., recent clearcuts) and very early forest successional stages for foraging (USFWS 2011a, Irwin et al. 2013). However, this same form of timber harvesting in the redwood region has been documented to create the greatest abundance of dusky-footed woodrats in even-aged stands following 5-20 years forest regrowth post-harvest, while forest stand thinning did not create habitat for this key prey species (Hamm and Diller 2009). Implementation of other frequently used silvicultural methods (e.g., Selection, Variable Retention, Group Selection, Uneven-aged) have less obvious impacts to Northern Spotted Owl foraging, nesting, and roosting habitat. Some harvest methods may serve to reduce habitat quality by removing key components of owl habitat near Northern Spotted Owls activity centers. For example, thinning has been shown to decrease the abundance of northern flying squirrels and red tree voles, two important prey species for Northern Spotted Owls (Wilson and Forsman 2013). Alternatively, applied at appropriate scales, some methods may in fact serve to enhance owl habitat, for example, by increasing foraging opportunities for certain prey types (i.e., woodrats). Given the potential of both negative and positive impacts to the Northern Spotted Owl, more thorough documentation and monitoring of Spotted Owl response to harvest type and actual harvest levels of foraging, nesting, and roosting habitat within harvest plans are needed. In addition, research is needed to provide a clearer understanding of the effects of silvicultural practices on important prey species habitat, including regrowth potential, and on Northern Spotted Owl occupancy and fitness.

In addition to the cumulative harvest at activity centers, differences between the habitat definitions and retention requirements in the Forest Practice Rules (Appendix 2 and Table 22) and the revised take avoidance guidance provided by the USFWS (2009; summarized in Table 24) reveal that implementation of the Forest Practice Rules, as written, may result in degradation of habitat quality around Northern Spotted Owl activity centers in the interior portion of the range. The definition of functional nesting habitat under the Forest Practice Rules might be adequate to provide suitable nesting or roosting habitat for Spotted Owls, although the average stem diameter is less than that recommended by the USFWS. However, the functional roosting habitat under Forest Practice Rules does not meet the requirements of roosting habitat under the USFWS recommendation; and instead would be considered low-quality foraging habitat under the USFWS recommendations. Functional foraging habitat as defined under Forest Practice Rules might meet the requirements for low-quality foraging habitat as defined by USFWS, but does not meet the requirements of foraging habitat.

As a result of differences in habitat definitions, the Forest Practice Rules' minimum retention requirements would retain nesting or roosting habitat (meeting the USFWS definition) only within 500 feet of a nest (~18 acres). The habitat retained within 1,000 feet (~72 acres) would be defined as low-quality foraging habitat in the USFWS guidance. Because the 500 acres of spotted owl habitat to be retained within 0.7 miles of an activity center and the total of 1,336 acres to be retained within 1.3 miles of an activity center can be composed of functional foraging habitat (according to Forest Practice Rules and USFWS habitat definitions), there is no requirement in the Forest Practice Rules for the majority of retained habitat to include nesting or roosting habitat. Also, using the revised habitat definitions provided by USFWS (2009), much of the retained foraging habitat could be of low quality. Although similar acreage of habitat is retained under the Forest Practice Rules and the USFWS recommendations, it does not appear that implementation of minimum requirements in the Forest Practice Rules would meet all requirements of the Northern Spotted Owl. Consequently, depending on how the rules are implemented, management could result in a reduction in habitat quality around Northern Spotted Owl sites and could lead to declines in survival, productivity, and overall fitness. Post-harvest habitat retention associated with approved timber harvest plans should be regularly assessed to better track actual harvest levels over time, and to ensure levels of harvest meet retention guidelines for the protection of Northern Spotted Owls.

Our evaluation of the long-term impact of harvest at a sample of activity centers, and the differences between the current Forest Practice Rules and the USFWS recommendations for habitat retention reveal a potential for negative effects on Northern Spotted Owl. Given what we know about Northern Spotted Owl habitat and fitness, it is reasonable to conclude that some level of harvesting could be beneficial, but high levels of harvest, such as levels documented for some activity centers in the harvest analysis described above, can negatively impact Northern Spotted Owls. In some cases, the existing regulations appear to have been insufficient to protect Northern Spotted Owl habitat. Section 919.10 [939.10] of the Forest Practice Rules requires CAL FIRE to make a finding as to whether or not the proposed timber operations in a timber harvest plan will avoid Northern Spotted Owl take. If CAL FIRE concludes take would occur, they must provide reasons why the determination was made according to criteria presented in section 919.10 [939.10], and recommend changes to the proposed THP to avoid take. In 2012, CAL FIRE reported that application of option (g) had involved using the standards contained in the Forest Practice Rules but also often included additional measures derived from the 2009 USFWS-recommended take avoidance guidelines (CAL FIRE 2012). A broader assessment of harvest history at sites across the Northern Spotted Owl range would be required to assess the implementation of the Forest Practice Rules and the degree to which Northern Spotted Owls have been impacted by timber harvest.

Harvest of Hardwood Forests

The economic value of tree species growing on timberlands differs, with conifers being generally more valuable than hardwoods. The low value of hardwoods historically discouraged their harvest and removal from timberlands during commercial harvesting (Merenlender et al. 1996). The differential retention of hardwoods coupled with aggressive growth of tanoak during early successional processes lead many north coast timberlands to be heavily dominated by hardwoods.

To counter this history, the Forest Practice Rules (Section 912.7, 932.7, and 952.7) provide timber resource conservation standards that require that the percentage of site occupancy by Group A (generally conifers) species not be reduced relative to Group B species (generally hardwoods) as a result of harvest. The Forest Practice Rules specifically require retention of trees of each native commercial species including Group B hardwoods where present at the time of harvest in a limited number of silvicultural situations: during the seed step of shelterwood (Section 913.1, 933.1, 953.1 (d)(2)(F)) and seed tree (Section 913.1, 933.1, 953.1 (c)(1)(F)) silvicultural systems, and only when applied in the absence of a Sustained Yield Plan. The purpose of this retention is to maintain and improve tree species diversity, genetic material and seed production, and is achieved by requiring the trees retained to be of the best phenotypes available, a determination of which is not defined and presumably left to professional judgement. However, in the initial steps of the two silvicultural systems mentioned above, these trees need not be retained during the final removal step. Otherwise, the Forest Practice Rules relegate hardwood retention during timber harvest to standards developed during plan development and agency review; for example, hardwood must be retained at such a level as to “Maintain functional wildlife habitat in sufficient condition for continued use by the existing wildlife community within the planning watershed” (Section 897(b)(B)), and as per the “Hardwood Cover” evaluation requirements of the Cumulative Impacts Technical Rule Addendum #2 (Section 912.9, , 932.9, 952.9 (c)(4)(e)).

Outside of the timber harvest regulatory arena, some landowners are using techniques such as hack and squirt to actively suppress hardwood competition with the more economically valuable conifers. In these situations, the Department has no authority or permit mechanism to identify or mitigate impacts by recommending retention standards. Some landowners have developed internal standards that they apply during and outside timber harvest operations. While these may assure some specimens are retained, presumably providing some level of hardwood function on timberlands, the Department is unaware of the empirical support for the efficacy of these levels to provide Northern Spotted Owl habitat and to support Spotted Owl forage base (e.g., woodrats).

As mentioned in the Habitat Requirement section of this report, hardwoods are an important habitat component for Northern Spotted Owls in California (Solis & Gutiérrez 1990) because they typically support healthy woodrat populations, a key prey species in the California portion of the owl’s range. Therefore, appropriate management of hardwoods on the landscape is essential to maintaining foraging habitat for owls, possibly just as essential as maintaining conifer habitat for nesting and roosting activities. The limited protection of hardwood harvest within the Forest Practice Rules and the subjective nature of determining appropriate hardwood components within the timber harvest regulatory arena, along with unregulated hardwood suppression, are likely unfavorable to conserving valuable foraging habitat within the range of the Northern Spotted Owl.

Habitat Loss from Marijuana Cultivation

Large-scale marijuana cultivation in remote forests throughout California has increased since the mid-1990s, coinciding with the passage of the "Compassionate Use Act" in 1996 (Proposition 215) that allows the legal use and growth of marijuana for certain medical purposes (Bauer et al. 2015). Within the range of the Northern Spotted Owl, Shasta, Tehama, Humboldt, Mendocino, and Trinity counties comprise the areas known for the most marijuana cultivation in California due to the remote and rugged nature of the land, making cultivation difficult to detect (National Drug Intelligence Center 2007, Bauer et al. 2015). Illegal marijuana cultivation grows on public and private land are widespread in California (Gabriel et al. 2013, Thompson et al. 2013, Office of National Drug Control Policy 2015), and may also negatively impact owl habitat through degradation and removal of habitat, as well as exposure to toxins used in cultivation (see Contaminant section of this report), though data on the extent of this impact is not well known. The Office of National Drug Control Policy (2015) reported that in 2012 3.6 million plants were eradicated from 5,000 illegal outdoor marijuana grow sites in the United States, of which 43% were removed from public and tribal lands. Additionally, the USFS reported that 83% of the plants removed were from California (Office of National Drug Control Policy 2015).

As discussed previously, for typical timber harvest activities, land owners are bound by the Forest Practice Rules and would therefore need to submit a THP, Spotted Owl Management Plan, Spotted Owl Resource Plan or exemption notification to the appropriate governing agencies. However, small scale timber removal in association with legal marijuana cultivation on private land does not require review or approval from state or federal governments as long as the timber is not sold. Habitat alteration also occurs in association with illegal marijuana grow sites, but the extent is not well known due to the secretive nature of these activities. Therefore, loss of timber and other habitat components important to Northern Spotted Owls (e.g., timber removal, riparian habitat alterations) for the cultivation of marijuana for such purposes is largely unregulated and unknown.

In an effort to assess potential environmental impacts to aquatic ecosystems from legal marijuana cultivation, Bauer et al. (2015) delineated cultivation sites (outdoor plantations and greenhouse locations), using Google Earth satellite imagery from 2011 and 2012, within four watersheds (hereafter referred to as the study area): Upper Redwood Creek, Redwood Creek South, and Salmon Creek, located in Humboldt County; and Outlet Creek, located in Mendocino County. In addition to the Bauer et al. (2015) study area, cultivation sites in the Mad River Creek watershed, in Mendocino and Trinity counties, were also delineated due to interest in identifying potential impacts to aquatic species and water quality in that area. Cumulatively, these 5 watersheds represent approximately 4% of the Northern Spotted Owl range in California (Table 25). Within these watersheds, marijuana cultivation sites varied in size from 0.002 to 2.9 acres and comprised a total of 362 acres - a relatively small portion of the watersheds assessed.

Table 25. The number of marijuana cultivation sites within each watershed, and area (acres) associated with each. Watersheds assessed are within Humboldt, Mendocino, and Trinity counties.

Watershed Name	Area (acres)	Number of Cultivation Sites	Total area (acres) of Cultivation Sites
Upper Redwood Creek	155,338	253	43
Redwood Creek South	16,653	369	53
Salmon Creek	23,489	515	42
Outlet Creek	103,554	795	90
Mad River Creek	321,972	416	134

Areas with higher prevalence of marijuana cultivation may also contain high numbers of Northern Spotted Owl activity centers (see Figure 3), especially in areas where riparian habitat exists. To date, there has been no study that analyzes the impact of marijuana cultivation sites on Northern Spotted Owl habitat or fitness. However, there is a potential for negative impacts of sites placed on private and public land within the owl's range. The level of impact would likely depend on density of cultivation sites in proximity to owl activity centers, and whether sites are placed within suitable owl habitat.

Using the data within the watersheds mentioned in Table 25, the Department assessed potential impacts to Northern Spotted Owls habitat by evaluating proximity of marijuana cultivation locations to owl activity centers (Figure 24). We found that no Northern Spotted Owl activity centers were within delineated cultivation sites; however, 10 activity centers are within 0.5 miles of the cultivation sites, and 96 within 1.3 miles. Depending on the size of the site and how much suitable owl habitat is removed, impacts to owls may vary. For the cultivation sites delineated in 2011 and 2012, much of the habitat removed was unsuitable for Northern Spotted Owls, with the exception of Mad River Creek watershed; here, 12.45 acres of highly suitable, 6.89 acres of suitable, and 22.91 acres of marginal owl habitat was removed (Table 26).

Table 26. Acres of Spotted Owl habitat removed in each watershed associated with cultivation sites delineated in 2011 and 2012.

Watershed Name	Highly Suitable (acres)	Suitable (acres)	Marginal (acres)	Unsuitable (acres)
Upper Redwood Creek	2.67	3.56	22.91	8.9
Redwood Creek South	1.11	1.33	14.90	32.47
Salmon Creek	0.00	0.89	12.23	20.68
Outlet Creek	3.56	5.56	15.35	38.25
Mad River Creek	12.45	6.89	22.91	8.90

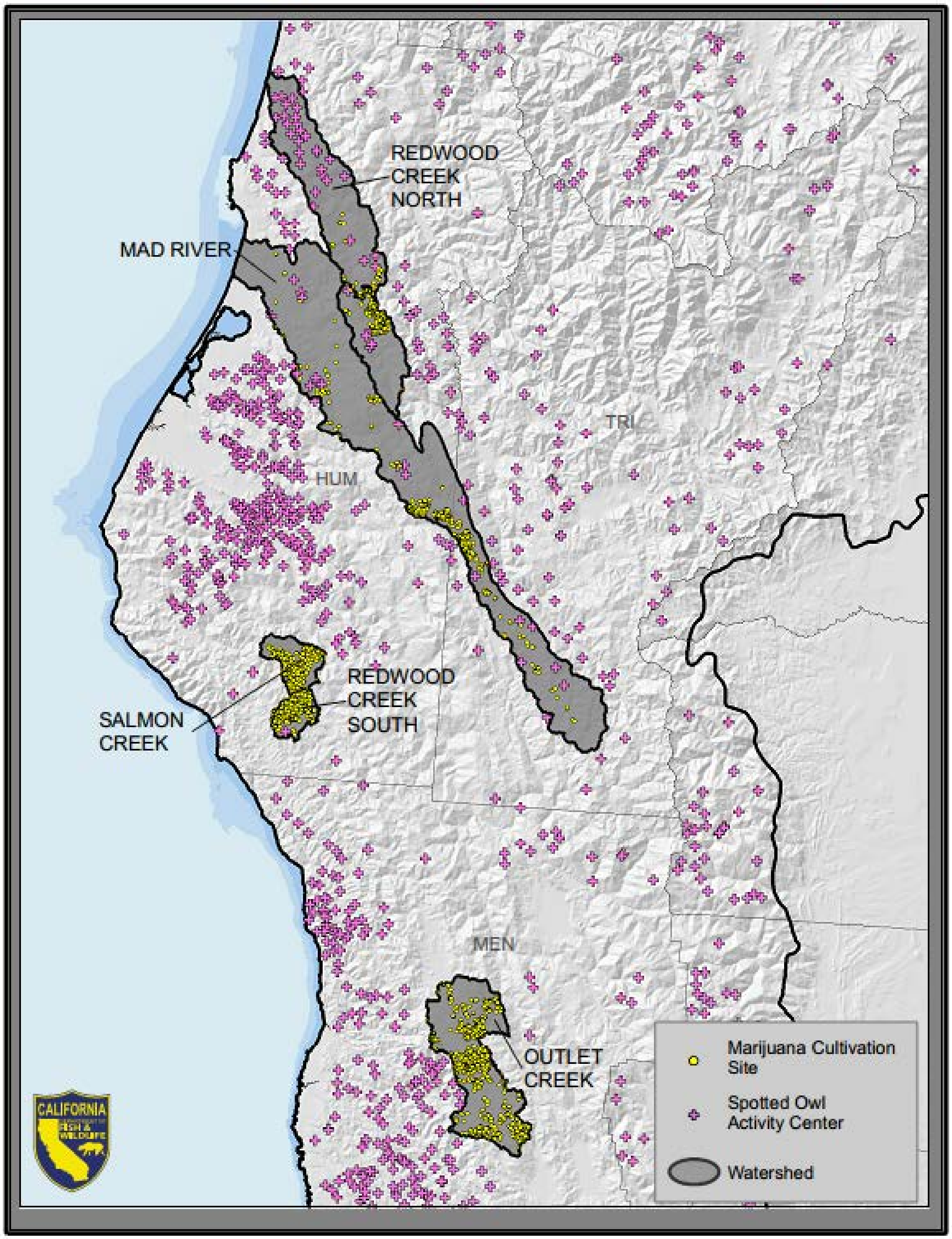

Figure 24. Marijuana cultivation locations from 2011 and 2012 within the watersheds of Upper Redwood Creek, Redwood Creek South, Salmon Creek, Outlet Creek and Mad River Creek in Humboldt, Trinity, and Mendocino counties, overlaid with owl activity center locations.

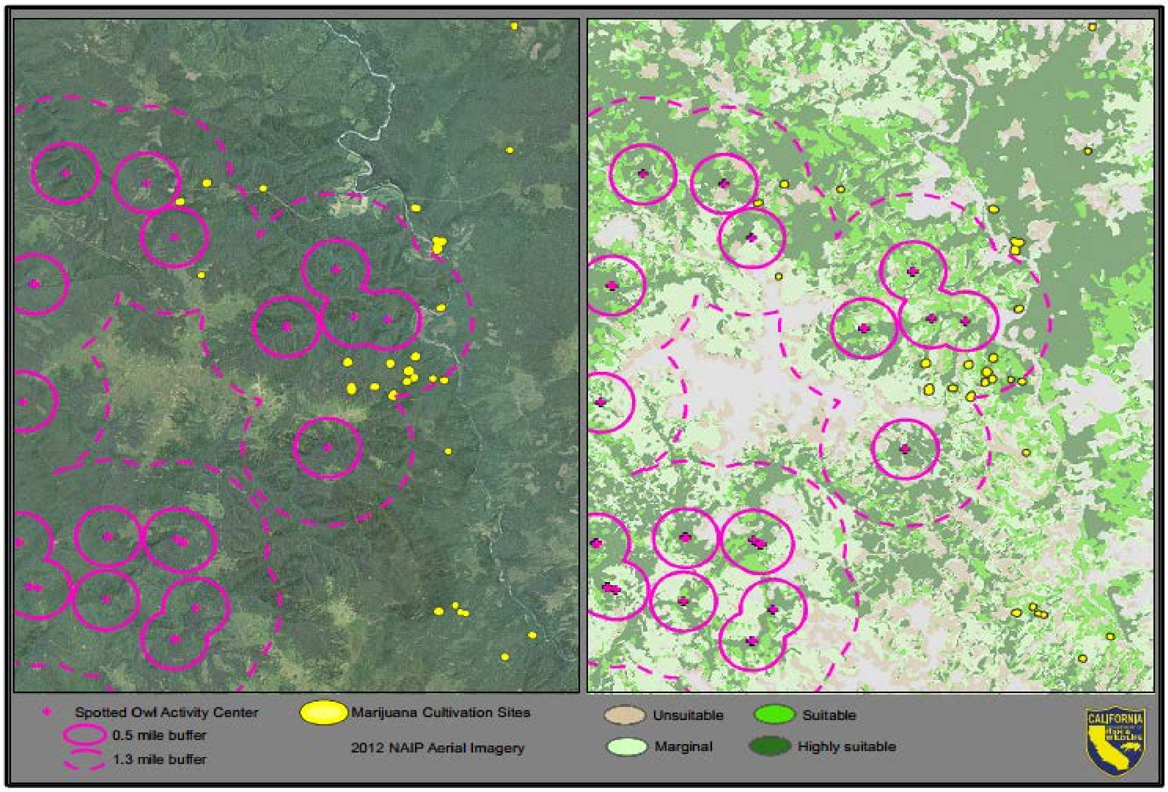

Figure 25. Area in Humboldt County where marijuana cultivation sites overlap the home range for several activity centers. Scale is 1:110,181 or 1 inch = 2 miles.

As described elsewhere in this report, habitat removal, fragmentation, and degradation can all have varying degrees of impacts on Northern Spotted Owls depending on how much suitable habitat is removed within their core range (e.g., represented by the 0.5 mile buffer surrounding the activity center) and within their home range (e.g., represented by the 1.3 mile buffer surrounding the activity center). Of the 362 acres of forestland or riparian habitat removed for marijuana cultivation, approximately 20 acres are within highly suitable Northern Spotted Owl habitat, 18 acres are in suitable habitat, and 97 acres are in marginal habitat. As an example of potential impacts to Northern Spotted Owl activity centers, Figure 25 shows an area in Humboldt County (1:110,181 or 1 inch = 2 miles) where marijuana cultivation sites overlap the home range for several activity centers. One activity center displayed in Figure 25 experienced removal of 4.45 acres of highly suitable habitat, 0.67 acres of suitable, 4.45 acres of marginal, and 0.89 acres of unsuitable habitat within the 1.3 mile buffer.

The data used for this analysis comes with certain limitations when assessing impacts to the Northern Spotted Owl. First, the dataset is a snapshot in time during 2011 and 2012 and does not represent expansion of cultivation sites since the data were collected. The data also only covers 4% of the Northern Spotted Owl range and is therefore only representing a small area of potential impact.

Marijuana cultivation is occurring outside of the area assessed. To more fully consider impacts of marijuana cultivation throughout the Northern Spotted Owl range in California, a broader habitat analysis (similar to the watershed analysis) would have to be done. In addition, not all marijuana grow site locations are reported as required by law, and smaller clearings (less than 10 mi^2) are likely not captured in the dataset due to difficulties identifying and delineating smaller sites using aerial imagery . Sites likely have not been captured for other reasons as well; for example, some sites are intentionally placed in areas where they are harder to detect (e.g., sites with higher canopy closure). Law enforcement efforts and ground surveys helped fill in the gaps for the data collected in 2011 and 2012, but the number of sites unaccounted for is unknown. Lastly, there may be other activities associated with the cultivation sites not captured using this data that can also have an impact on Spotted Owls, such as placement of roads and vehicular traffic, other sources of noise disturbance during the breeding season, or the use of pesticides to increase crop yield (see the Contaminants section of this report).

Given above uncertainties regarding the dataset used in this analysis, it is plausible to assume that the density of cultivation sites is likely higher than represented in the dataset. In addition, given the density of cultivation sites within Humboldt, Trinity and Mendocino counties represented in this analysis, and the fact that the watersheds analyzed comprise only 4% of the Northern Spotted Owl range, it is also very plausible to assume that marijuana cultivation sites are impacting Spotted Owl habitat to some unknown extent, thereby impacting fitness to some extent. While indirect impacts to Northern Spotted Owls through modification or loss of habitat is unknown and may be minimal, the potential direct impacts from anticoagulant rodenticide use associated with marijuana cultivation may be much more serious (see Contaminants section of this report below).

Wildfire

Wildfire is a natural process in California's forests, and in much of its range the Northern Spotted Owl has evolved in a landscape of frequent wildfire. Despite this, fire is often considered a primary threat to Northern Spotted Owl habitat due the owl's preference for older forests and the capacity of fire to rapidly remove or degrade habitat. The mature forests preferred by owls for nesting and roosting can take decades to centuries to develop following removal, depending on location, forest type and fire severity. The USFWS revised recovery plan (USFWS 2011) considered fire to be a primary threat to the Northern Spotted Owl in some fire-prone physiographic provinces, along with ongoing losses to timber harvest and competition with the Barred Owl.

Fire has become the primary cause of nesting and roosting habitat loss on federal lands since implementation of the NWFP, only surpassed by range-wide losses due to timber harvest, which have been concentrated on nonfederal land (Davis et al. 2015). Most of the nesting and roosting habitat loss from wildfires on federal lands in the NWFP area between 1993 and 2012 has been lost in the five relatively dry physiographic provinces (eastern Washington Cascades, eastern Oregon Cascades, California Cascades, Oregon Klamath, and California Klamath; Figure 26); with about 86% (164,221 hectares, or 405,800 acres) of the total wildfire-related habitat loss in the NWFP area occurring in these provinces, and nearly 70% of that loss from the Oregon and California Klamath provinces alone (Davis et al. 2015). These dry provinces contain only about 45% of the total nesting and roosting habitat acreage on federal lands range-wide. Degradation of nesting and roosting habitat from fire was also estimated, with most of the degradation occurring in the western Cascades (Davis et al. 2015). See the Habitat Loss under the Northwest Forest Plan section above for further discussion on habitat loss due to wildfire.

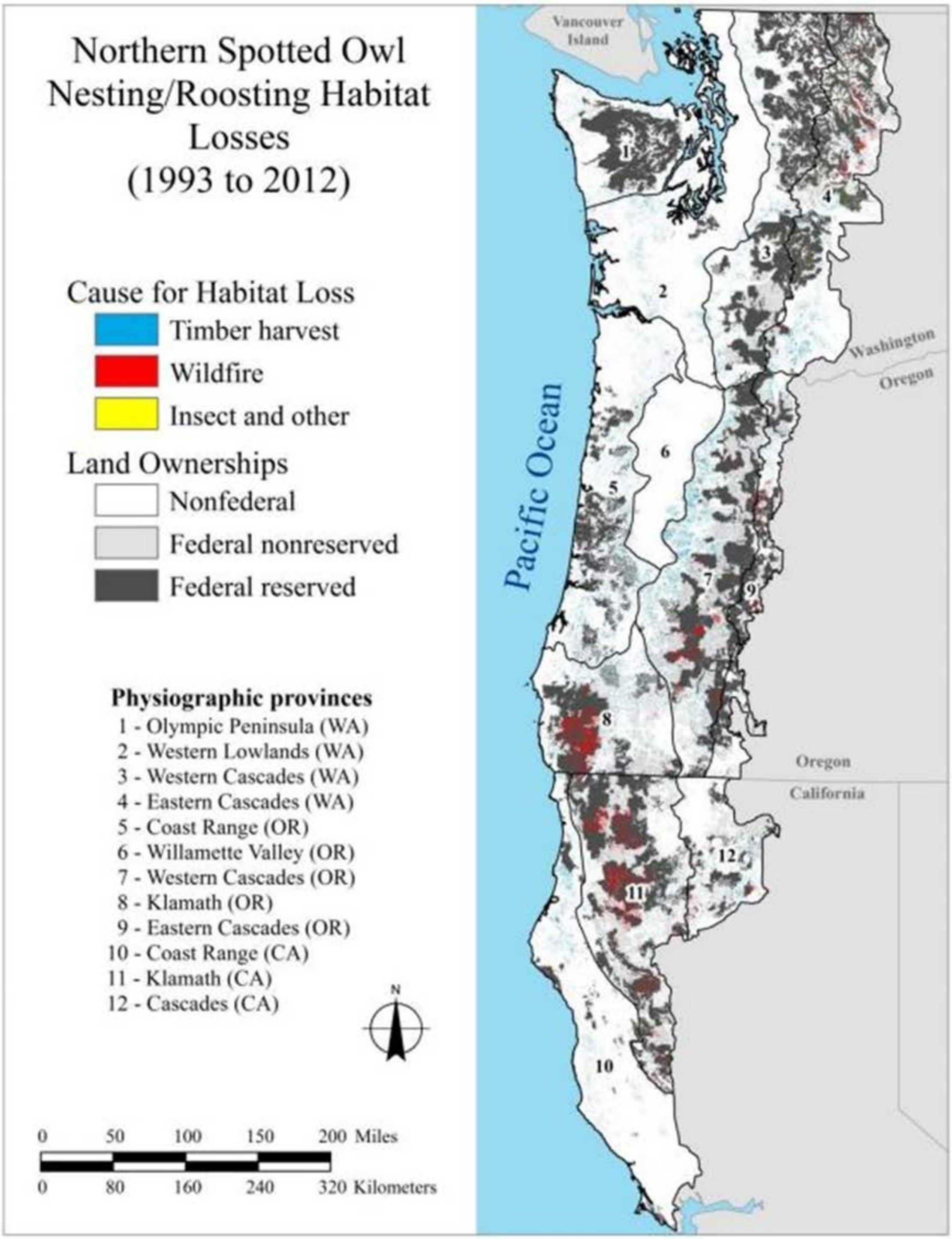

Figure 26. Northern Spotted Owl nesting and roosting habitat losses by cause from 1993 to 2012 (Figure 7 in Davis et al. 2015).

Fire Regime in the Northern Spotted Owl Range

When the USFWS subdivided the range of the Northern Spotted Owl into 12 physiographic provinces, information on fire disturbance regimes was used to inform boundaries (USFWS 1992). Efforts to map the fire-prone portion of the Northern Spotted Owl range since then have generally followed physiographic province boundaries, with the drier provinces of the eastern and California cascades and the Oregon and California Klamath provinces generally considered more fire-prone (e.g., see Rapp 2005, Spies et al. 2006, and Healey et al. 2008). As part of an evaluation of the NWFP, a recent effort to model fire-prone areas used fire history and environmental predictor variables to map the likelihood of large wildfire occurrence throughout the range (Davis et al. 2011). Although this approach did not use existing physiographic province boundaries or other lines used to delineate fire-regimes across the Northern Spotted Owl range to inform the model, results were generally similar to previous efforts based on broad geographic regions and identified the California Klamath and Cascade regions as the most fire prone (Figure 27(a)).

Regardless of methodology used, all attempts to map fire-prone areas consistently include large portions of the Northern Spotted Owl range in California, with much of the California Klamath and California Cascades identified as highly prone to fire disturbance. By overlaying the modeling results for fire-prone areas with the Northern Spotted Owl habitat suitability map, Davis et al. (2011) showed that the physiographic province with the most owl nesting and roosting habitat in fire-prone landscapes is the California Klamath Province. This is evident when looking at the actual fire history from 1950 to 2014 (Figure 27(b)). Over the last several decades, large acreage fires have been prevalent on the landscape within the Klamath Province.

Within the fire-prone regions of California, fire regimes vary depending on a number of factors, with broad differences noted between the mixed conifer/mixed hardwood forests characteristic of the Klamath Province and the ponderosa pine forests that dominate some portions of the Cascade Province and eastern Klamath Province. The following discussion of historical and current fire regimes in California focuses on these two provinces, as these are the two regions where fire is most likely to have an impact on the Northern Spotted Owl.

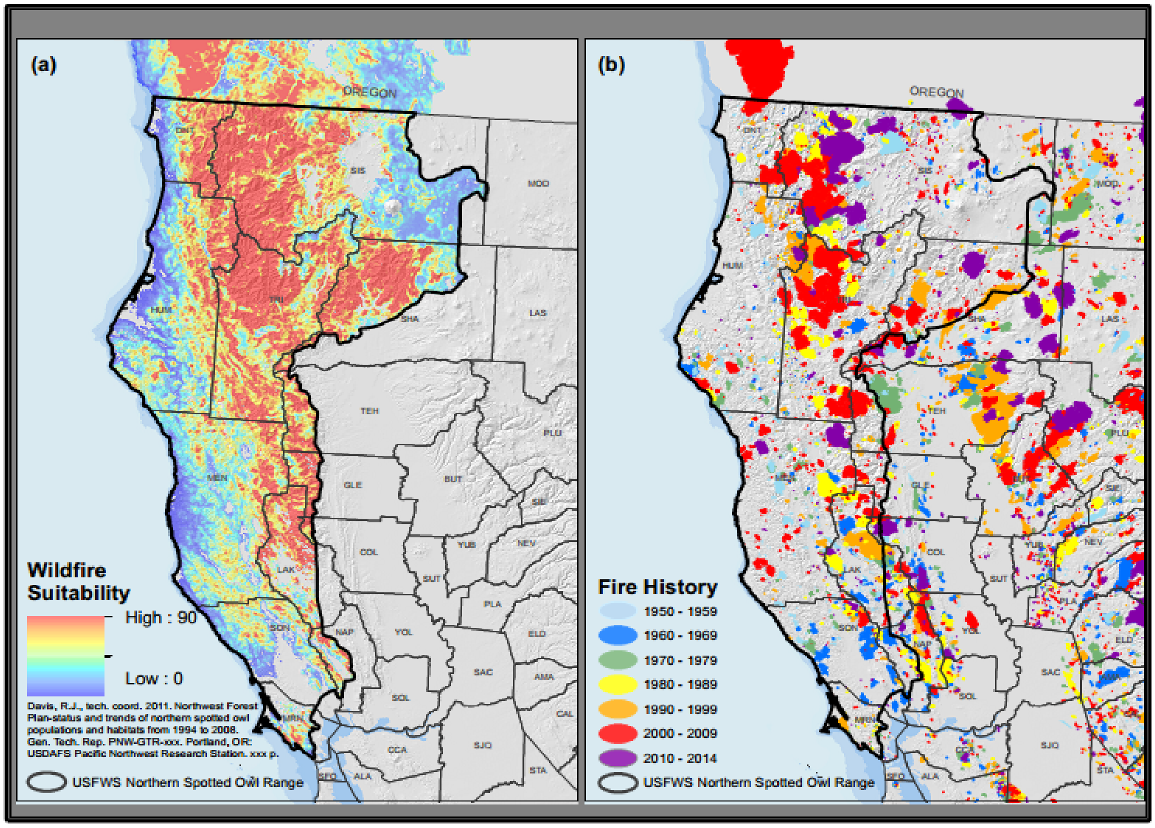

Figure 27. Map (a) shows fire suitability modeling results within the Northern Spotted Owl range (Davis et al. 2011). Map (b) shows actual fires history during 1950-2014.

<u>Historical Fire Regime in the Klamath Province</u>

As described in the Habitat section of this report, the Klamath Province is an area with extremely high floristic diversity and heterogeneity. This diversity arises from complex patterns in topography, soils, and climate throughout the region, which results in complex vegetation and contributes to a diverse fire regime. The occurrence of diverse hardwoods in coniferous forests of the Klamath region may reduce fire severity, and following fire may lead to more rapid recovery by sprouting (Odion et al. 2004, Spies et al. 2006). Throughout the Klamath Mountains in the pre-settlement period, most forest stands experienced at least several fires each century, suggesting a mixed fire regime of frequent low- to moderate-intensity fires (Skinner et al. 2006), with low-severity fire composing the largest portion of burned area, and high-severity fire the smallest portion (Agee 1993). Low-severity fire has been defined as those which kill less than 20% of the basal area; high-severity fire causes high tree mortality, with mortality of 70% and above (Agee 1993, Hessburg et al. 2005). Variation within the mixed-severity fires of the Klamath region has been strongly influenced by topography in both the pre-settlement and contemporary periods (Taylor and Skinner 1998). As described by Skinner et al. (2006),

> "Generally, the upper third of slopes and the ridgetops, especially on south- and west-facing aspects, experience the highest proportion of high-severity burn…The lower third of slopes and north- and east-facing aspects experience mainly low-severity fires. Thus, more extensive stands of multi-aged conifers with higher densities of old trees are found in these lower slope positions. Middle slope positions are intermediate between lower and upper slopes in severity pattern."

This topographically-controlled fire regime is the most widespread regime in the Klamath Mountains and is controlled by greater heating and drying on certain portions of mountain slopes and climatic variables in deep canyons (Skinner et al. 2006). Temperature inversions that often occur while fires are burning enhance this topographic pattern of fire intensity (Skinner et al. 2006). Historical fires were patchy and relatively small, although fires of up to several thousand acres were relatively common, and the majority of burned areas experienced low and moderate severity fire (Spies et al. 2006). The frequent occurrence of mixed-severity fires created a diverse landscape of older forest with variable openings of younger forest and nonforested areas, with the relative composition of these forest types varying depending on slope position.

Historical Fire Regime in the Cascades Province

South of the latitude of Mount Shasta in the California Cascades, the vegetation composition and species dominance of lower and mid-montane forests is similar to that of the northern Sierra Nevada, and upper montane forests are more similar to the Klamath Mountains (Skinner and Taylor 2006). As in the Klamath Mountains, fire-severity in the California Cascades is associated with topographic position, with the high-severity portion of burns more likely to occur on upper slopes and the low-severity burns occurring predominately on lower slopes. This pattern is less pronounced in the Cascades than in the more extreme terrain of the Klamath Mountains (Skinner and Taylor 2006).

The portion of the Northern Spotted Owl range which is dominated by yellow pines (ponderosa pine and Jeffrey pine) is relatively uncommon and is distributed in a narrow band on the east side of the Cascades and in limited areas in southwestern Oregon and northern California (Spies et al. 2006). Jeffrey pine-dominated forests occupy the lower elevations on south-, east-, and west-facing slopes in eastside environments (Skinner and Taylor 2006). These forests occur in the driest portions of the Northern Spotted Owl range. Ponderosa and Jeffrey pine dominated forests have a distinctly different structure and historical fire regime in comparison to the mixed-conifer forests of the rest of the Klamath and Cascade provinces.

Historically, frequent low-severity burns in yellow pine forests resulted in low and variable tree densities, with low, patchily developed understory, and reduced fuel loads (Hessburg et al. 2005). Frequent burns favored fire-tolerant tree species, such as ponderosa pine, and maintained fire-tolerant forests by elevating tree crowns and consuming many small and medium sized trees (Hessburg et al. 2005). The forest structure and composition in these yellow pine forests that resulted from frequent fires reinforced the occurrence of low-severity fires by limiting the conditions that could support high-severity fires (Hessburg et al. 2005). Historical open yellow pine forests would not have provided all necessary habitat conditions for the Northern Spotted Owl, but local areas of high density and complex structure likely provided requirements for nesting and roosting (Davis et al. 2011) among a landscape of mixed forest types and nonforest areas.

Recent Changes in Fire Regimes and Possible Causes

Multiple potential causes have been implicated in increasing fire activity over the last several decades. The success of fire suppression and exclusion has advanced secondary succession in forests and changed forest composition by increasing tree density, decreasing prevalence of fire-tolerant tree species (e.g., ponderosa pine and Jeffrey pine), and contributing to homogenization of forest structure (Hessburg et al. 2005). In some cases, timber harvest has directly advanced secondary succession through the selective removal of the largest trees. Post-harvest tree plantations have created homogeneous forests dominated by even-aged, smaller diameter trees that in some cases are less resistance to fire (Hessburg et al. 2005). In addition, climate variables, including temperature and precipitation, have produced conditions that promote increased amounts of fire activity (Miller et al. 2012, Westerling and Bryant 2008). Most fires in the Klamath region continue to burn under historical mixed regimes that can contribute to a heterogeneous forest landscape (Odion et al. 2004). However, recent large fires are cause for concern for the future stability of forest conditions in the region, especially considering the high percentage of remaining suitable owl nesting and roosting habitat experiencing high-severity burns.

Forest Management and Fire Suppression

Beginning in the early 1900s in accessible areas and in the mid-1900s in remote areas, fire suppression caused a dramatic decline in fire occurrence in the Klamath province (Skinner et al. 2006). The result was a series of decades, beginning in the early 1900s, with dramatically reduced fire extent over most of the Klamath region (Taylor and Skinner 1998, 2003; see Figure 28 for example). During this period, the fire rotation (the length of time necessary to burn an area equal to the area of interest, vs. fire return interval which is the length of time between successive fires at a given point) increased to an estimated 974 years in the early 1980s (Miller et al. 2012) compared to a historical estimate for fire rotation of only 20 years (Taylor and Skinner 2003). In the Cascade Province the fire suppression period began in the early 1900s. The gentler slopes of the Cascade Province, relative to the Klamath region, lead to successful fire suppression efforts. This success resulted in a dramatic change in fire frequency from high frequency low-severity fires to a period of minimal fire occurrence in the California Cascades.

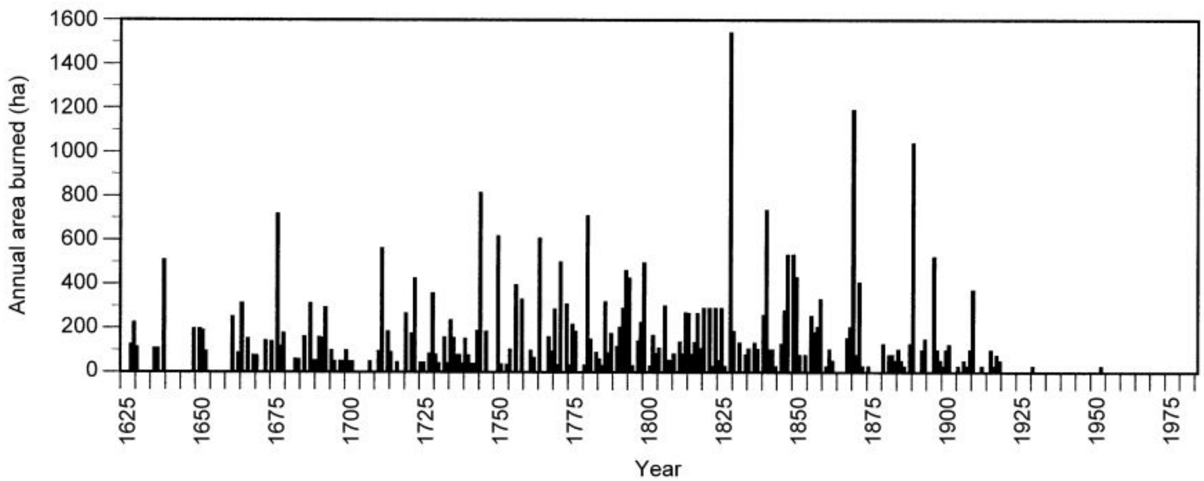

Figure 28. Annual burned area between 1628-1995 in the Hayfork Study Area, Shasta-Trinity National Forest, California (Figure 2 in Taylor and Skinner 2003).

Following several decades of reduced extent and frequency of fire as a result of fire suppression efforts, the average fire size has increased in recent decades across the western United States beginning in the 1980's (Schwind 2008, Westerling et al. 2006), including the area comprising the Northern Spotted Owl range in California (Odion et al. 2004, Miller et al. 2012). The area burned annually within the entire range of the Northern Spotted Owl (Davis et al. 2011) and within the California portion of the range (Miller et al. 2012) also increased dramatically during this time and the regional fire rotation declined from a high of 974 years in the early 1980s to 95 years by 2008. As noted in Figure 29, the years between 1970 and 2009 in which the most area burned per year in the California portion of the Northern Spotted Owl range have all occurred since 1987 (Davis et al. 2011, Miller et al. 2012).

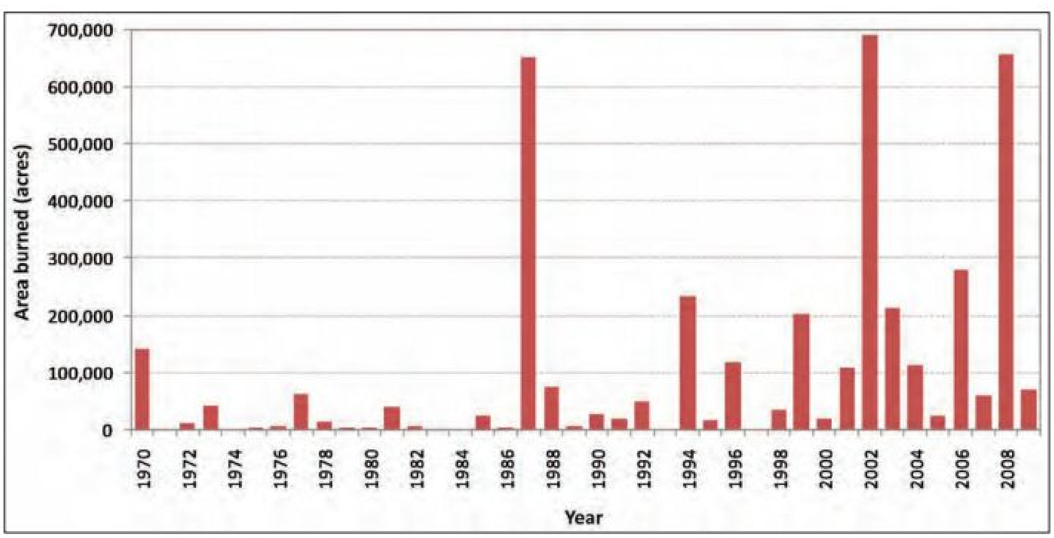

Figure 29. Frequency histogram of acres burned by wildfires within the range of the Northern Spotted Owl between 1970 and 2009 (Figure 4-2 in Davis et al. 2011).

Fire suppression and exclusion in ponderosa pine forests has been successful at reducing the frequency of fire which allowed for the development of shade-tolerant trees and understory vegetation in the previously open forests, and resulted in an increase in stand density (Taylor 2000). Increased stand density results in competition between trees for sunlight, soil, and water and can result in stress on the trees. Resource-stressed stands are more susceptible to insects and disease which results in an increase in weakened or dead trees and heavy fuel loadings (Hessburg et al. 2005, Davis et al. 2011). This has led to fuel characteristics in ponderosa pine forests that can support larger and more severe wildfires (Hessburg et al. 2005). Large, severe fires in the dry eastern Cascades of Oregon and Washington have occurred in recent years (Davis et al. 2011), and the potential remains for the loss of large amounts of nesting and roosting habitat.

Although there is evidence that the increase in fire size in recent years has corresponded with an increase in fire severity in the western U.S., including the Sierra Nevada (Hessburg et al. 2005, Schwind 2008, Miller et al. 2009), trends in burn severity have been less conclusive than trends in fire size and total area burned (Schwind 2008). Miller et al. (2012) conducted a broad assessment of patterns in the extent of high-severity fire in four national forests of northwestern California. Their study covered all fires larger than 100 acres during the years 1910 to 2008 in a 5.8 million acre area including the northern California Coast Range and the Klamath Mountains, as well as a portion of the southern Cascade Range. This study area covers most of the range of the Northern Spotted Owl on federal land in California. The authors observed significant increases in both fire size and total annual area burned from 1910 to 2008, although they found no temporal trend in the percentage of high-severity fire in recent years. Conversely, Steel et al. (2015) showed that the proportion of fires burning at high severity has increased for fuel-limited forest types (i.e., dry, east side forests) using data on fire severity for 660 fires that occurred on USFS land in California (within and outside of the northern spotted owl range), between 1984 and 2011. This increase in severity was correlated to indicators of fire suppression for much of California; however, the Klamath bioregion did not show this relationship.

Despite Miller et al.'s (2012) failure to detect an increasing trend in fire severity in northwestern California, at least one recent fire, the Biscuit Fire of 2002, has occurred in the Klamath province that was not only large but was of uncharacteristic high-severity (Skinner et al. 2006). The Biscuit Fire burned about 500,000 acres in southern Oregon and northern California. Almost 224,000 acres (49%) burned at high severity, with 75-100% canopy tree mortality, and an additional 14% of the burn area experienced 50-75% mortality (USFS 2003). Under stable atmospheric conditions, current fires tend to follow a mixed fire regime similar to historical patterns (Taylor and Skinner 1998, Odion et al. 2004). However, this large high-severity burn was associated with weather conditions that are conducive to fire (i.e., high winds and low humidity). Conversely, in the years when the highest acreage has burned in the Klamath province of California since the 1980s, fires have primarily been caused by region-wide lightning events associated with more moderate meteorological conditions. Overall fire severities were relatively low in these years due to the long duration of fires, weather conditions, and strong inversion events (Miller et al. 2012).

Past management practices that have established more homogeneous even-aged forests (e.g., fire suppression, livestock grazing, and timber harvest practices) may provide forest conditions that are conducive to high-severity fires in forests with fire regimes that were historically fuel-limited (Hessburg et al. 2005). Extensive areas of young even-aged forests that have resulted from a combination of past fire and past timber harvest practices may amplify conditions for repeated high-severity fires compared to heterogeneous forests that were created by historical patterns of mixed-severity fires (Spies et al. 2006). A positive feedback resulting from past timber management and fire suppression practices, existence of more even-aged stands in the forest matrix, and future high-severity fire has the potential to support a new forest matrix with stable or increasing amounts of even-aged forest and decreased heterogeneity (Skinner et al. 2006).

Climate Change Effects on Wildfire

In addition to land-use history over the last century, climate variables (e.g., precipitation, temperature) have been evaluated as potential causes of recent increases in large wildfires. Several studies have determined a strong link between changes in fire extent, severity and season, with climatic variables such as low precipitation and high temperatures. While changes in forests brought about by land-use history may be reversible through management actions such as forest thinning and prescribed fire; reversing trends in climate warming are unlikely in the near future (Westerling et al. 2006, Littell et al. 2009).

Under various climate change scenarios (as discussed below in the Climate Change section of this report), fire seasons have been predicted to be longer and fire sizes larger (McKenzie et al. 2004, Westerling and Bryant 2008, Littell et al. 2009, Miller et al. 2009, Westerling et al. 2011). For example, McKenzie et al. (2004) found that extreme fire weather (e.g., hot dry summers) in western America will influence the severity and the total area burned, with the duration of the fire season lengthened with more fires occurring early and later in the typical fire season. Fires have been more frequent during dry years (Cook et al. 1996) and extreme weather events influence the occurrence of large, landscape-scale fires (Miller and Urban 2000). Westerling et al. (2006) found that periods with large fire occurrences corresponded with a shift toward warm springs and longer summer dry seasons, and suggested that both land use and climate have contributed to increased fire risk, but that broad-scale increases across the western U.S. were driven primarily by recent trends in climate.

Compared to pre-European settlement, Miller et al. (2009) found that high severity fires in low- to mid-elevation forests are increasing of California and western Nevada. Miller et al. (2009) suggested that snow water deficits, earlier snowmelt, lengthening of the fire season, worsening drought conditions, low fuel moisture, and increase of forest fuel availability all play a role in how forests are in a position to burn more often and at higher severity. In this study, the types of forested land most impacted by high severity fires include those on National Forest land, those experiencing high resource extraction and rapid human population growth, and those supporting old growth dependent species (Miller et al. 2009).

Another study in the western United States supported the theory that climate is a driving factor influencing fire extent in the 20th century. Littell et al. (2009) found that fire regimes will vary dependent on fuel energy and water deficits. Low precipitation and high evapotranspiration in mountainous regions of the western United States lead to low fuel moisture conditions; thus, creating a system at higher risk to combustion and fire spreading. Similar to Miller et al.'s (2009) findings, Littell et al. (2009) suggest that low precipitation, warmer winters, reduced snowpack, and drought effects lead to an increased area of burned forest. In areas where fire regime is fuel-limited (e.g., dry eastern Cascades forests), wildfire impacts could be lessened through fuel reduction prescriptions; however in areas where fire regime is climate-limited (e.g., wetter portions of the Klamath province), this may prove less effective as large, severe wildfires in these areas are largely driven by extreme weather conditions (Littell et al. 2009).

With future climate change, the continued occurrence of large, uncharacteristically severe fires may become increasingly common. These changes may in turn impact the habitat, distribution and abundance of sensitive species such as the Northern Spotted Owl.

Effects of Wildfire on Spotted Owls

Wildfire Effects on Spotted Owl Habitat

As discussed above, wildfire has been the leading cause of nesting and roosting habitat loss on federal lands in recent decades. The degree to which wildfires impact Northern Spotted Owl habitat depends on a number of factors including: amount and arrangement of remaining habitat, fire management history, logging history, forest type, historical fire regime, and weather patterns. In addition, interpreting the observed impacts of wildfires on Northern Spotted Owls can be complicated by the occurrence of post-fire salvage logging (Clark et al. 2013). The majority of Northern Spotted Owl nesting and roosting habitat lost on federal lands since implementation of the NWFP is attributed to wildfire (a 5.2% reduction of suitable nesting and roosting habitat; for comparison, 1.3% has been lost to timber harvest) with the majority being lost in a few very large fires (e.g., the Biscuit Fire of 2002) (Davis et al. 2015). If recent trends in wildfire extent and severity continue in the future, much more habitat will be lost.

There has been disagreement on the level of risk that fire poses in the dry portions of the Northern Spotted Owl range. Hanson et al. (2009) contend that the risk of fire to Northern Spotted Owl habitat in the dry provinces had been overestimated in the 2008 Recovery Plan, which included ongoing loss of habitat as a result of timber harvest and fire as threats to the Spotted Owl (USFWS 2008a). Hanson et al.'s (2009) claim was made based on calculated estimates of hectares of old-forest recruitment that exceeded the hectares of old-forest burned in high severity fire. However, Spies et al. (2010) criticized the findings of Hanson et al. (2009), stating that an incorrect threshold for defining high-severity fire was used resulting in a significantly reduced estimate of the extent of high-severity fire; and that an incorrect depiction of error was used to support selection of the threshold. Spies et al. (2010) also believe the assumptions used by Hanson et al. (2009) to estimate the rate of recruitment of old- forests owl habitat were not justified.

The degree to which wildfire threatens the Northern Spotted Owl has important management implications. If recent and projected changes in fire size or severity continue to remove large amounts of nesting and roosting habitat, fuel treatments (e.g., thinning and prescribed fire) to reduce fire risk may have long-term benefits to owls by encouraging the development and maintenance of older forest patches while limiting the risk of stand-replacing fires. However, if recent large high severity fires are an anomaly and recruitment of old forest outpaces losses to high severity fire, natural processes can be incorporated into management plans to shape Spotted Owl habitat on the dry province landscape. Risks are not likely to be uniform across the range, with ponderosa pine forests likely having a different response to past management than mixed-conifer forests of the Klamath.

The effect of wildfires on Northern Spotted Owl habitat is highly variable, depending on fire size, location, and severity. Variation in fire severity has an important influence on forest structural diversity because low-severity fires kill few trees while high-severity fires may kill all trees in a stand (Taylor and Skinner 2003). High-severity fires tend to result in even-aged stands while lower severity fires result in more structurally diverse forests with multiple age classes. Prior to fire suppression, the frequent occurrence of mixed-severity fires in large portions of the Klamath and Cascade ranges, along with the resulting complex landscape (e.g., older forests with openings of other forest types intermixed with non-forested areas) was prominent throughout the region. The historical mixed fire regime in the Klamath region may have benefited Northern Spotted Owl habitat by maintaining areas of older forests with dense canopies and complex structure, while also providing a heterogeneous landscape composed of multiple forest ages and structure. This pattern could have supported high quality habitat mosaics of nesting and roosting habitat and diverse foraging habitat which lead to high survival and reproductive success (Franklin et al. 2000).

Wildfire Effects on Occupancy and Use

Research on the effect of wildfire on Spotted Owl habitat use and selection, occupancy, and survival has been conducted in eastern Washington and southern Oregon for the Northern subspecies, in the Sierra Nevada mountains for the California Spotted Owl, and in Arizona and New Mexico for the Mexican Spotted Owl (e.g., Gaines et al. 1997, Bond et al. 2002, Jenness et al. 2004, Bond et al. 2009, Clark et al. 2011, 2013). Studies have generally been performed opportunistically and retrospectively due to the difficulties associated with experimental fire research in a natural setting; thus, much uncertainty remains on the effect of wildfire on Spotted Owl habitat use and demographics. Conclusions regarding the effect of fire on occupancy rates of Spotted Owls have been somewhat equivocal, in some cases showing that stand replacing wildfire has a negative impact on occupancy (e.g., Gaines et al.'s 1997 and Clark et al.'s 2013 studies of Northern Spotted Owls), and in other cases showing no adverse impact of wildfire on Spotted Owl occupancy (e.g., Jenness et al.'s 2004 study of Mexican Spotted Owls, Lee and Bond's 2015 study of California Spotted Owls). Here we focus on the relatively extensive studies from the Sierra Nevada Mountains in the range of the California Spotted Owl (Bond et al. 2009, Lee et al. 2012, Lee and Bond 2015) and from southwestern Oregon in the range of the Northern Spotted Owl (Clark et al. 2011, 2013), as these areas more closely represent the forest types within the fire-prone interior range of the Northern Spotted Owl in California and are relatively well studied.

In the southern Sierra Nevada, in areas with a mosaic of burned and unburned forests, California Spotted Owls have been shown to use multiple forest types that have experienced a full range of burn severities to meet nesting, roosting, and foraging needs. Bond et al. (2009) found that moderate to high severity fire may impact preferred nesting and roosting habitat while providing foraging habitat. In an area that had experienced a mixed-severity wildfire, most California Spotted Owl roost sites (85%) occurred in unburned and low-severity burn areas, and owls avoided roosting in moderately and severely burned areas (Bond et al. 2009). Conversely, California Spotted Owls selected foraging sites represented by all severities of burned forest, yet avoided unburned forest (Bond et al. 2009).This study occurred four years after a mixed-severity wildfire, resulting in owl territories with a mosaic of all burn classes, ranging from unburned forests (31% of the forest area) to high-severity burn areas with most of the overstory removed by mortality of dominant vegetation (13% of the forest area).

The owls that were tracked in the burned areas of the southern Sierra Nevada by Bond et al. (2009) were shown to have a diet composed of predominately pocket gophers (Bond et al. 2013), whereas the diet of California Spotted Owls in unburned forests was dominated by woodrats and northern flying squirrels, depending on location. California Spotted Owls also selected for foraging sites that included edge between burned and unburned forests and between burn areas of different severity classes (Bond et al. 2009). Bond et al. (2009) concluded that the most likely explanation for high probability of use by foraging California Spotted Owls of forest patches that experienced high severity burns was increased prey promulgated by enhanced habitat conditions, including increased shrub and herbaceous cover and number of snags. They provided the following discussion on the importance of snags to Spotted Owl prey:

> "Snags provide shelters for prey species like woodrats and flying squirrels. In the southern Sierra Nevada, dusky-footed woodrat nests are common where shrubs encircle rock outcrops or snags (Lawrence 1966). Bushy-tailed woodrat (*N. cinerea*) densities in dry forests of eastern Washington, USA, were strongly correlated with arboreal and terrestrial cover in the form of large snags, mistletoe, and large soft logs (Lehmkuhl et al. 2006). Northern flying squirrel population densities in Oregon, USA, were correlated with the occurrence of suitable nesting cavities in trees and early decay-stage snags with diameters >50 cm (Volz 1986)."

Breeding home range sizes were similar for owls occupying burned and unburned areas (Bond et al. 2013). The apparent shift to an alternative prey source in the post-fire landscape of the Sierra Nevada may have allowed California Spotted Owls to effectively utilize high-severity burn areas and to maintain similar home range sizes.

In contrast to the findings of Bond et al. (2009), recent work on the impact of fire on foraging site selection by California Spotted Owls in Yosemite National Park showed that owls selected for areas of low-severity burns but avoided areas of high-severity burns (Eyes 2014). Lee and Bond (2015) found that the history of nesting success at a site is an important factor in interpreting the response of California Spotted Owls to wildfire and salvage logging. They found that wildfire and salvage logging had a strong negative impact on occupancy and reproduction at sites where owls did not successfully reproduce the previous year, but only a slight negative impact where owls successfully reproduced the previous year (Lee and Bond 2015).

In a study of post-fire occupancy at six fire locations across the range of the California Spotted Owl in the Sierra Nevada, Lee et al. (2012) found no difference in site occupancy rates between burned and unburned sites. As with Bond et al.'s (2009) study on post-fire habitat selection, this study included fires with a range of burn severities, which is typical of fires in the Sierra Nevada (Odion and Hanson 2006). An average of 32% of each owl site (defined as a 200 hectare circular area around a collection of points where a territorial owl or owl pair had been detected, including roost and nest locations) was burned at high-severity. A subset of burned sites included in the study (9 of 41) burned at higher severity (>50% of site's suitable vegetation burned at high severity). Owls were detected at five of these nine sites post-fire (Lee et al. 2012), suggesting that sites that were exposed to higher amounts of high-severity fire might have experienced reductions in occupancy, but this was not modeled. Lee et al. (2012) found that post-fire salvage logging appeared to adversely affect occupancy of burned sites but the sample size was too small for the effect to be modeled. Salvage logging was known to occur on eight burned sites post-fire and California Spotted Owls initially occupied seven of the eight sites after the fire, however, following the salvage logging none of the sites remained occupied.

An additional study in the Sierra Nevada compared occupancy rates at 10 unburned sites to 9 sites that burned at low to moderate severity in Yosemite National Park and found no difference in occupancy rates between burned and unburned sites (Roberts et al. 2011). However, the study area was restricted to areas with ≥40% canopy cover, occupancy was positively correlated with total tree basal area and canopy closure, and this study did not address effects of high-severity fire, nor post-fire salvage logging (Roberts et al. 2011).

It is not known how well the results of studies of California Spotted Owls in the Sierra Nevada translate to Northern Spotted Owls, due to differences in fire regimes, vegetative communities, and prey communities. In the range of the Northern Spotted Owl, the most extensive evaluation of the effect of fire on owls has been conducted on a group of three fires in the Klamath and Western Cascades physiographic provinces of southwest Oregon (Clark 2007, Clark et al. 2011, 2013). By tracking radio-marked owls with territories inside and adjacent to burned areas, Clark et al. (2011) were able to estimate the effects of fire on occupancy and survival of Northern Spotted Owls. The occurrence of a demographic study area (South Cascades) in proximity to the fires allowed for comparison of unburned areas to pre- and post- fire rates within the fire footprints. On one of the fire study areas (Timbered Rock fire), 22 territories had been surveyed for ten years pre-fire which allowed for a comparison of pre- and post- fire occupancy. Occupancy at this site was compared to the nearby South Cascades study area and the two areas were shown to have similar trends in occupancy rates prior to the Timbered Rock fire in 2002. However, extinction rates in the Timbered Rock fire area increased after the fire, resulting in declines in occupancy (Clark 2007, Clark et al. 2013). Only 20% of territories at the Timbered Rock fire were occupied by a pair of owls by the end of the study period in 2006 (four years post fire), where >50% of territories had been occupied in all years pre-fire. These declines were not observed at the unburned South Cascades study area. Data collected at all three fires from 2003-2006 was used to model post-fire rates and suggested that high extinction rates and low colonization rates led to declines in post-fire occupancy (Clark 2007).

Using the telemetry data collected by Clark in southwest Oregon, Comfort (2013) evaluated selection of habitats relative to availability following mixed-severity fire disturbance. The strongest predictor of Spotted Owl presence was habitat suitability (as defined in Davis and Lint 2005). Northern Spotted Owls avoided large, contiguous patches of high-severity disturbance and preferentially used areas of lower severity disturbance. At small spatial scales (<0.8 hectare; ~2 acres), Spotted Owls did select for areas with hard edge created by high severity fire, but at larger spatial scales, hard edges were avoided (Comfort 2013, Comfort et al. 2016). This suggests that at the scale of a home range, owls selected for large patches of contiguous high suitability habitat interspersed with small patches (<0.8 hectare) of high severity fire or salvage logging; however, use of hard edge by Spotted Owls quickly declined as the amount of edge within 3.2 hectares increased (Comfort et al. 2016). Because post-fire salvage logging occurred in the study area on private industry land, the analysis by Comfort (2013) did not distinguish between areas of high-severity burns and those that were salvage logged, but instead used the combined disturbance of fire and logging to evaluate owl use of different components of the landscape.

The number and size of standing dead trees (snags) following a wildfire may be an important predictor of Spotted Owl occupancy. Lee et al. (2012) argued that snags play an important role in suitable California Spotted Owl habitat in burned areas. This was based on observations that occupancy decreased when ≥20 hectares (~49 acres) of mature conifer forest was logged within a 400 hectare (~988 acres) circle surrounding a California Spotted Owl site (Seamans and Gutiérrez 2007), whereas when an average of 32% of suitable habitat within a 400 hectare circle burned at high severity no negative effect on occupancy is observed. In southern Oregon, Clark et al. (2013) modeled the effects of fire severity, post-fire salvage logging, and pre-fire habitat characteristics on occupancy by Northern Spotted Owls. They found that extinction probabilities increased as the combined area of pre-fire harvest, high-severity burn, or salvage logging increased, resulting in reduced occupancy of nesting territories by Northern Spotted Owls; however, they were unable to distinguish the effect of salvage logging from the effects of pre-fire timber harvest or from the effects of burn severity.

Post-fire declines in occupancy in southern Oregon contrast with most results for the California Spotted Owl in the Sierra Nevada. As mentioned above, two of three burn areas in southern Oregon underwent fairly extensive salvage logging post-fire. The studies conducted in the Sierra Nevada included some sites that were salvage logged, but sample sizes were too small to model the perceived effect of logging on occupancy. Several authors have suggested that salvage logging after a fire or occurrence of extensive high severity burns likely have contributed to a decline in habitat use, occupancy, or survival of Northern Spotted Owls (Bond et al. 2009, Roberts et al. 2011, Clark et al. 2011, 2013, Lee et al. 2012). With the exception of low severity burns, burned areas have generally not supported nesting habitat but have been shown in some cases to create foraging habitat. The presence of snags has been suggested as an important component of prey habitat and as perch sites for foraging Spotted Owls. We do not know of any research conducted on Northern Spotted Owl prey abundance in burned vs. unburned forests, but early successional forests have been shown to support abundant woodrat populations in the southern portion of the range (see discussion of prey in Life History section) and so burned areas may provide high quality prey habitat once vegetation regrowth produces an understory.

Overall, observational studies and occupancy modeling conducted to date suggest that post-fire landscapes that are salvage logged experience declines in Spotted Owl occupancy. However, other factors such as history of nesting success, initial habitat conditions (e.g., area of pre-fire harvest), the amount and distribution of high-severity fire, regional differences in forest composition and fire history, and differential subspecies response may also influence occupancy. Bond et al. (2009) recommended that burned forests within 1.5 km of nests or roosts of California Spotted Owls not be salvage logged and Clark et al. recommended restricting salvage logging after fires within 2.2 km of Spotted Owl territories in the range of the Northern Spotted Owl in southern Oregon. Results of studies assessing post-fire salvage logging on Spotted Owls suggest a negative impact; however, more research is needed to determine if no-salvage buffers are needed to mitigate the impacts to owls, and if so, to what extent.

Wildfire Effects on Demographics

Bond et al. (2002) evaluated short-term survival of Spotted Owls following wildfire by tracking color-banded owls which occurred on territories that later burned in a wildfire during a period from 1985-2001. Because of the opportunistic nature of observations for this study, only 11 territories were included in the study and they were distributed across the range of the species from California, Arizona, and New Mexico, and represented all three subspecies of the Spotted Owl. Twenty-one color-banded owls had occurred on the eleven territories pre-fire and 18 were re-sighted the year following fire (Bond et al. 2002). Most territories in this study burned at low to moderate severity and no post-fire salvage logging had occurred between time of fire and the following year when re-sighting attempts occurred. From this data a simple annual survival estimate of 86% was derived, which is similar to reported estimates of survival in unburned areas. The short-term covered by the study (one year post-fire) and the small sample size limit the utility of the study for extrapolating to a general effect of fire on Northern Spotted Owls (of which four territories were included), but the study does at least demonstrate that some wildfires have little impact on Spotted Owl survival, at least for the first year following fire. (Bond et al. 2002).

On two of the burned areas studied by Clark et al. (2007, 2011, 2013) in southwest Oregon (Timbered Rock and Quartz fires), 23 radio-marked Northern Spotted Owls were tracked over a one year period in order to estimate survival rates of owls within and adjacent to burns. Mean annual survival rates of owls displaced by wildfire (0.66 ± 0.14) or occupying territories within the burned area (0.69 ± 0.12) were lower than those for owls outside of burned areas (0.85 ± 0.06) (Clark et al. 2011). Survival rates of owls outside of burned areas were similar to rates at the nearby unburned demographic study area (South Cascades; 0.85 ± 0.01) (Anthony et al. 2006). The two fires included in the survival study each burned about 50% of the owl habitat at mixed severities from low to high. Of the 24 owls tracked, 5 died during the study. Necropsies were performed on 4 of these owls and showed that all were severely emaciated and likely died due to starvation (Clark et al. 2011). This, and the fact that owls in the study maintained larger home ranges post-fire (Clark 2007), suggest that food limitation might have played a role in reduced survival rates. Also, the documented dispersal of several adult Northern Spotted Owls out of the burn area at the Timbered Rock fire 1-2 years post-fire suggests that insufficient habitat remained at abandoned territories to support an owl pair (Clark et al. 2013). Both of the fire areas in this study were salvaged logged post-fire complicating the interpretation of the study’s results, with about 20% of the area logged in each fire.

In conclusion, there is a broad scale trend of increasing wildfire size and annual extent in western forests. Some evidence suggests there is also an increasing trend in fire severity, although trends vary between ecoregions and are not clear in the Klamath Mountains. The effects of wildfire on Northern Spotted Owl habitat are variable, depending at least in part on burn severity and the function of the habitat (i.e., foraging, roosting, or nesting). Multiple studies (Clark et al. 2007, 2011, 2013) indicate that Northern Spotted Owl occupancy and survival rates can be negatively impacted by large, severe wildfires; however the relative impacts of fire and salvage logging are difficult to separate.

Climate Change

According to global and regional climate scenarios, wildlife species are, and will continue to be exposed to changes in temperature, precipitation, and vegetative structure resulting from global and local climate change. Species will need to adjust to these changes through behavioral changes, spatial shifts, or adaptation, or face eminent declines or extirpation. The degree of threat varies based on species and region. Climate change scenarios have been modeled across the range of the Northern Spotted Owl, including in California. Several studies have been conducted to assess the threat to Northern Spotted Owl specifically. In California, several climate change studies have been conducted with a resulting common theme that suggests temperature will generally increase, but changes in precipitation vary by location across the state (Pierce et al. 2012). Generally, most studies agree that California will retain its Mediterranean climate of cool, wet winters and hot, dry summers, yet the degree of wetness/dryness will likely be amplified (Lenihan et al. 2003, Cayan et al. 2012).

Climate Change Projection Modeling

The projected climate model simulations from Cayan et al. (2012) exhibit warming over California, with a mid-century rise of approximately 1°C to 3°C (1.8°F to 5.4°F), and 2°C to 5°C (3.6°F to 9°F) rise by end-of-twenty-first century. Pierce et al. (2012) showed an average annual increase in temperature over California of 2.4°C (4.3°F) by the 2060s, with coastal areas showing less warming (1.9°C (3.4°F)) than interior areas (2.6°C (4.7°F)). Westerling and Bryant (2008) predicted an average increase of 4.3°C (7.7°F) in California by 2070–2099. Seasonally, the summer and fall months exhibit greater warming than winter and spring months (Cayan et al. 2012, Pierce et al. 2012), with the degree of warming increasing as one moves from the coast to the interior of the state (Cayan et al. 2012). Extreme temperature events (i.e., frequency of extremely hot days) will become more commonplace and may take place earlier in the season (Cayan et al. 2012).

Climate projection modeling conducted by Cayan et al. (2012) show a high degree of variability between month-to-month and year-to-year precipitation with slight drying tendencies in some areas of California, this suggests that California will remain at risk to drought and flooding events, with more prominent changes in the southern portion of the state than the northern portion. Modeled seasonal changes in precipitation included a somewhat contracted wet season, with less precipitation during late winter and spring than during the core winter months (Cayan et al. 2012). Pierce et al. (2012) found precipitation is likely to decrease overall in the southern portion of California by the 2060s, but remain unchanged from historical levels in the northern portion of the state. Seasonally, winters in the northern portion of the state are expected to become wetter and be offset by drier conditions the rest of the year by the 2060s.

The southern part of the state showed moderate decreases in fall, winter, and spring but stronger increases in summer (Pierce et al. 2012).

Climate Change Impacts to Forests

In the Pacific Northwest, including California, changes in precipitation and temperature may impact forest distribution, growth, and structure (Lenihan et al. 2003, Dalton et al. 2013, Vose et al. 2012, McIntyre et al. 2015). Most climate projection models indicate upward elevational shift and a northward latitudinal shift in forest habitats (Vose et al. 2012). In climate projection scenarios specific to California, the most notable predicted response to increased temperature was a shift from conifer-dominated forests to mixed conifer-hardwood forests in the northern half of the state (e.g., the replacement of Douglas fir-white fir forest by Douglas fir-tan oak forest in the northwest), and an expansion of conifer forests into the northeast portion of the state (e.g., Modoc Plateau) by the 21st century (Lenihan et al. 2003). A comparison of current forest structure and composition in the last decade to historic data (1930's) suggests these predicted shifts are already occurring across the entire latitudinal extent of forests in California (McIntyre et al. 2015). Currently, forests in California are exhibiting an increased dominance of oaks (Quercus spp.) at the expense of pines (Pinus spp.), and across a 120,000km2 (46,332mi2) study area a demographic shift from large trees to small trees has been detected and overall tree density has increased since the early 1900s (McIntyre et al. 2015). Understanding the causes of shifts in structure and species composition is complex, but may be partially attributed to water deficits within California forests (e.g., drought), along with other contributing factors such as logging and fire suppression (McIntyre et al. 2015). Conifer-dominated forests (e.g., redwood and closed-cone pine forests) along the north-central coast of California (Crescent City south to Monterey) are projected to advance, resulting in redwood forests shifting inland, replacing current Douglas-fir-tan oak forests (Lenihan et al. 2003). In general, large areas of the Pacific Northwest will likely become climatically unsuitable for Douglas-fir forests in the 21st century (Dalton et al. 2013). Using vegetation and climate variables, Carroll (2010) modeled a predicted initial northward expansion of high quality owl habitat in the NWFP area, followed by a habitat contraction as climate variables intensify over time. Tree productivity along California's north-central coastal and at high elevation forests has increased in response to increased growing season temperatures (Lenihan et al. 2003); however, the impacts of fog on productivity has mixed results (Lenihan et al. 2003, Sillet 2013). Johnstone and Dawson (2010) inferred a 33% reduction in the frequency of fog over northwestern California redwood forests over the 20th century. Lenihan et al. (2003) suggests that tree productivity along the coast can only occur if coastal summer fog persists. Whereas, Sillet (2013) found that over the last 100 years redwood growth rate has increased, possibly due to increase sun exposure in areas experiencing less fog. If summer fog were to continue to decrease in conjunction with increased temperatures, it is uncertain how productivity of redwood forests along the coast would be impacted, if at all..

Vulnerability to disturbance, such as wildfire, disease and insect outbreaks, is expected to increase in most forests in the Northwest in the 21st century, and may change forest composition and structure depending on changes to climate (Dalton et al. 2012, Vose et al. 2012). One of the objectives of US Forest Service is to develop projections for wildfire regimes and habitat shifts due to changing climate and increased threats from wildfire, disease and insect outbreaks (Davis et al. 2011). The projected nationwide effects of climate driven disturbance over the 21st century can be summarized as follows (Vose et al. 2012):

- Frequency and extent of wildfire will likely increase.
- The area affected by insect infestations (e.g., bark beetle in the western US) will expand.
- Invasive species will likely become more widespread, especially in areas with increased disturbance and in dry forests.
- Increased flooding, erosion and sediment transport will increase due to increased precipitation, increased size of wildfire burn areas, and increased rain-on-snow ratios.
- Increased occurrence of drought will exacerbate other disturbances (e.g., fire, insect outbreaks, invasive species), leading to higher tree mortality, decreased regeneration in some tree species, and alteration of tree species composition and structure.

Climate modeling studies agree that forest wildfire occurrence and severity will increase due to warmer spring/summer temperatures, reduced precipitation, reduced snowpack, earlier spring snowmelts, and longer drier summers (Swetnam 1993, National Assessment Synthesis Team 2000, Houghten et al. 2001, Lenihan et al. 2003, Westerling et al. 2006, Westerling and Bryant 2008, McKenzie and Littell 2011, Vose et al. 2012). Spracklen et al. (2009) projected that forests of the Pacific Northwest forests will experience increases in mean annual area burned, with a projected increase of 175% by 2050 compared to the area areas burned between 1996 and 2005. This increase will likely negatively impact old-growth forests and the species that inhabit them (Dalton et al. 2012, Vose et al. 2012). By evaluating fire history and climatic data in forested areas across the western United States over a 34-year period, Westerling et al. (2006) tested the contributions of land use and climate conditions on occurrence of large fires. Over this study period, the frequency and size of wildfires showed a marked increase in the mid-1980s; a large portion of this increase occurred in the range of the Spotted Owl in California (Sierra Nevada, southern Cascades, and Coast Ranges of northern California). The period of increase in large fire occurrence corresponded with a shift toward warm springs and longer summer dry seasons (Westerling et al. 2006). The authors concluded that both land use and climate have contributed to increased fire risk; however , but that broad-scale increases across the western U.S. were driven primarily by recent trends in climate (Westerling et al. 2006). For California as a whole, by the end of the 21st century, risk of large fire frequency will increase between 12 and 53 percent compared to observed fire regimes between 1980 and 1999, and for northern and southern California, large fires fire frequency will increase 15 to 90 percent and -29 to 28 percent, respectively (Westerling and Bryant 2008). See the Wildfire section above for more detailed discussion on wildfire impacts to forest systems.

Effects of Climate Change on Spotted Owls

A species' vulnerability to climate change impacts depends on the magnitude of the change, the species' and its habitat's sensitivity to the change, and the species' ability to cope with change through its adaptive capacity. Adaptive capacity is a function of the species' ability to move (from small movements to new microhabitats within its range, to substantial movements beyond its historic range), to make behavioral adjustments, and its genetic capacity to adapt and evolve (Beever et al. 2015). Several traits of Northern Spotted Owls suggest they have capacity to adjust to climate change: mobility, adaptation to a variety of different forests types, and demonstrated behavioral adaptation to heat stress. Conversely, the habitats they occupy in Northern California have been, and will continue to be affected by substantial changes in temperature and precipitation regimes, owl survival and reproduction appear to be sensitive to climatic events, and their ability to adapt may be disrupted by the presence of non-native competitor.

Most climate projection scenarios agree that the forests in the Northern Spotted Owl's range will have wetter winters and early-springs, colder winters in some areas, hotter/drier summers, and increased frequency and intensity of disturbance events. According to many climate projections, the frequency and duration of extreme climatic events, such as heat waves, wildfire and heavy rain or snow will increase over time. Extreme climatic variation has been linked to sudden large-scale mortality in avian populations in the past (Tompa 1971, Johnson et al. 1991, and Smith et al. 1991 as cited in Franklin et al. 2000).

Northern Spotted Owl demographic rates are linked to weather patterns and several studies have found a negative association between cold, wet weather during the early nesting season and owl survival and reproduction (Carrol et al. 2010, Olson et al. 2004, Franklin et al. 2000, Glenn et al. 2011). Olson et al. (2004) stated that survival was negatively associated with early-nesting season precipitation, and positively associated with late-nesting season precipitation. Population growth for Northern Spotted Owls range-wide was positively associated with wetter conditions during the growing season (May through October) due to more favorable conditions for prey species, but negatively associated with cold, wet winters and nesting seasons (Glenn et al. 2010). Over the extent of late-successional reserve land covered by the NWFP, Carroll (2010) predicted that winter precipitation was closely associated with a decrease in Northern Spotted Owl survival and recruitment.

In the Coastal and Klamath Mountains of northwestern California, Franklin et al. (2000) thoroughly examined the effects of climate on temporal and spatial variation of Northern Spotted Owl survival, reproductive output, and recruitment. In these models, climate explained most of the temporal variation in life history traits. The study suggested that the period most impacted by climate was during the spring, presumed largely due to higher energetic demands during the breeding season, as well as prey abundance and availability. In a study area immediately to the west in the coastal redwood region, Diller et al. (2010) also reported that early nesting temperature and precipitation impacted both survival and fecundity. Franklin et al. (2000) states, "extreme climate conditions during the early nesting period may exacerbate an energetic stress on an individual by decreasing it's time to starvation." However, the winter period did explain variation in recruitment, thought to be a function of reduced survival of young during their first year.

In Oregon and Washington, Glenn et al. (2011) found a negative association between Northern Spotted Owl reproduction (number of young fledged) and cold wet nesting season, thought to be a function of loss of eggs or young to exposure or terminating incubation (Forsman et al. 1984). Whereas reproduction was positively associated with late nesting season precipitation, thought to be a function of prey abundance and availability. Interestingly Glenn et al. (2011) also found that number of young fledged per year declined when precipitation in the year prior deviated from normal, and that number of young fledged per year increased following warm wet dispersal seasons. Some of these results differ from California studies such as Franklin et al. (2000), and may be a function of differing habitat, climate and targeted prey species. Regardless, Glenn et al. (2011) suggests that Northern Spotted Owl reproductive success involves a complex relationship between prey populations, body condition and weather prior to and within the nesting season.

The literature also indicates that Spotted Owls are sensitive to heat stress (Barrows 1981, Ting 1998, Franklin et al. 2000, Weathers et al. 2001, Glenn et al. 2010), which may be more problematic for Northern Spotted Owls as temperatures rise over time. For the California Spotted Owl, Weathers et al. (2001) found that when temperatures reached between 30 and 34°C (86-93°F), a relatively moderate level, owls increased behavioral heat responses (e.g., increase respiratory rate, gaping, wing drooping). Similarly, Ting (1998) found that Northern Spotted Owls in warm interior northwestern California forests selected roost sites that were significantly cooler than random sites in the same mature forest stands and from random sites in adjacent younger forest stands. Owls selected cooler roosts each time they changed roost sites when temperatures exceeded 25.2°C (77.4°F). In cooler coastal forests no significant temperature differences were detected between roost sites and random sites (Ting 1998). Glenn et al. (2010) found the rate of Northern Spotted Owl population growth was negatively associated with the number of hot summer days in their Oregon and Washington study sites.

As previously discussed, structural complexity (broken top trees, snags, overhead cover) is an important habitat component for Northern Spotted Owls. Structural complexity is an important factor in determining the availability of suitable nest sites. Rockweit et al. (2012) found that nest type selection played a role in Northern Spotted Owl reproductive success in California during period of inclement weather (i.e., low temperatures and high winds). Nests that were more exposed to the elements, such as platform-style nests with little to no overhead cover or side walls, were found to be less effective at protecting eggs from heat loss. These results support that optimal nesting habitat for Spotted Owls must include structurally complexity to provide nesting options with proper protection. The availability of high quality protective nest structures may influence the degree to which climate change impacts Northern Spotted Owls.

Although we are not aware of observations of direct mortality of Spotted Owls from wildfire, mortalities, especially among nestlings, may increase as frequency and intensity of wildfires increases. Indirect impacts may also include an increased level of predation if there is loss of older or structurally complex forests. However, neither direct mortality nor increased predation is specifically addressed in the literature. Habitat loss and alteration due to heightened disturbance events (e.g., wildfire, disease, insect outbreaks), may also impact forest species, such as the Northern Spotted Owl, by intensifying competitive pressure from other species, such as Barred Owl (Lenihan et al. 2003, Carroll 2010).

To better understand potential climatic impacts to Northern Spotted Owls, the Department compiled average 30-year (1980-2010) and 5-year (2010-2014) precipitation and temperature data and calculated the percent change within the owls range. Decreases in precipitation were most apparent in the southern portion of the coastal range (Marin, Sonoma and Mendocino counties), and within the interior range (Figure 30). Increases of precipitation were more limited, with increases seen in a small portion of northern Trinity County, and scattered within Humboldt and Del Norte counties. This analysis generally shows a drying trend throughout the owl's range, except in the northern portion of the California Coast Province and some small portion of the Klamath Province.

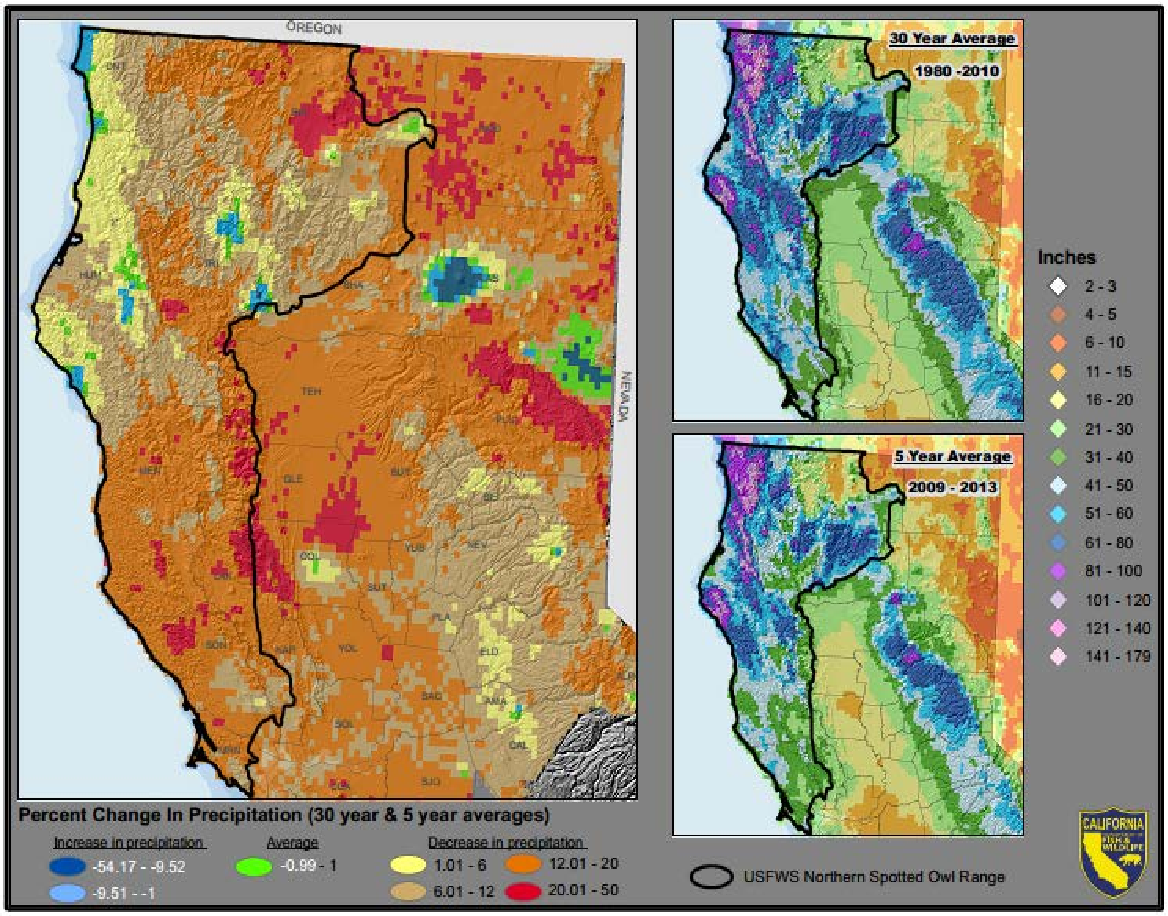

Figure 30. Percent change in precipitation within the Northern Spotted Owl range in California. Maps show both 30 year and 5 year averages. Data source: PRISM Climate Group, Oregon State University.

Temperature within the range of the Northern Spotted Owl was assessed for summer months (June-August) and winter months (December-February) separately (PRISM 2015). Comparing the 30-year average with the 5-year average, temperature increases during the summer months were seen mostly within the north and northwest portions of Siskiyou County (northern portion of the Klamath and Cascade provinces), and along scattered portions of the Coast Province (Figure 31). As shown in Figure 31, temperature decreases in the summer months were seen most prominently within the rest of the interior (Klamath and Cascade provinces). During the winter months, temperature increases were seen within interior (Klamath and Cascade provinces), while decreases were seen most prominently in the

Coast Province (Figure 32). This analysis generally shows warmer winters and cooler summers compared to normal within the interior portion of the Northern Spotted Owl range, and cooler winters and warmer summers along the coastal portion of the range.

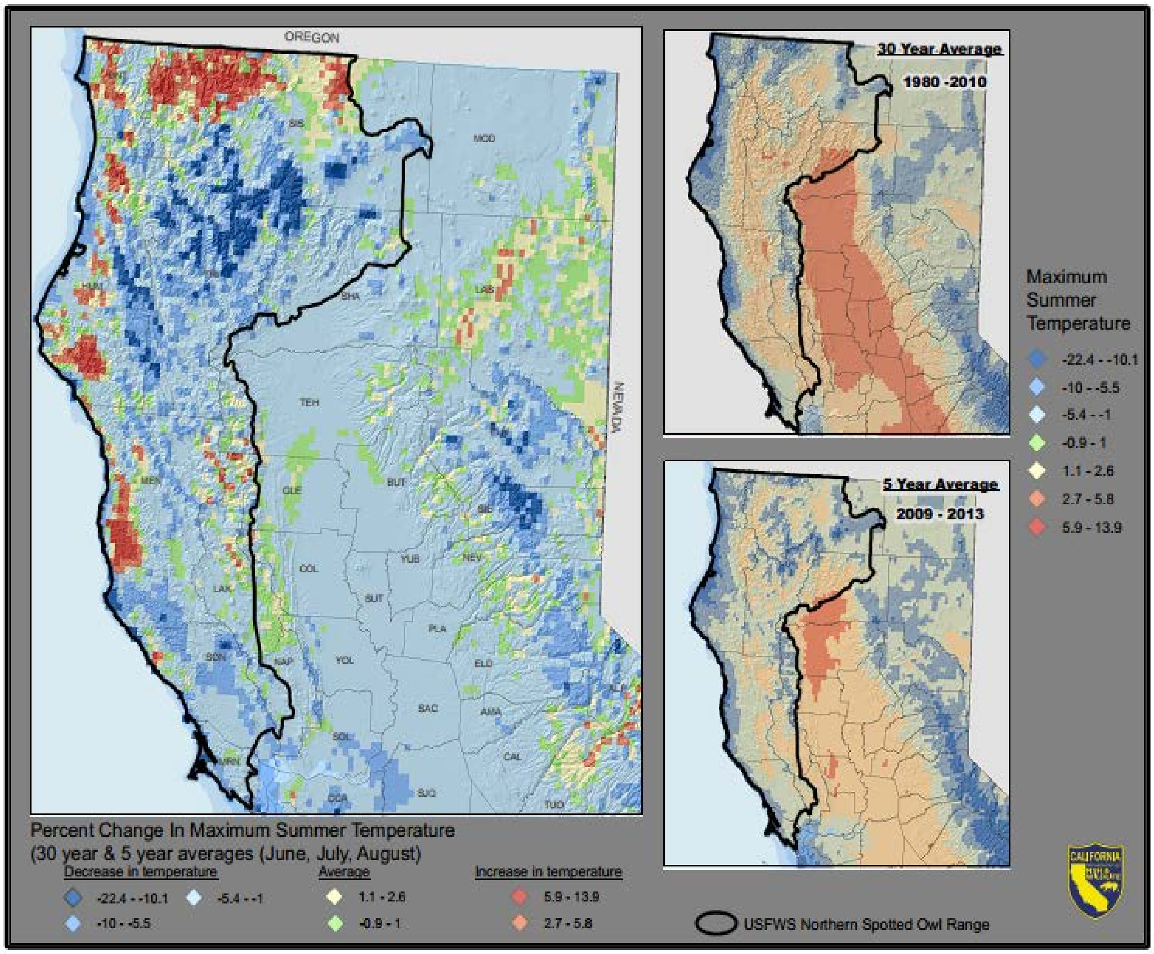

Figure 31. Percent change in maximum summer temperature within the Northern Spotted Owl range in California. Maps show both 30 year and 5 year average in June, July, and August. Data source: PRISM Climate Group, Oregon State University.

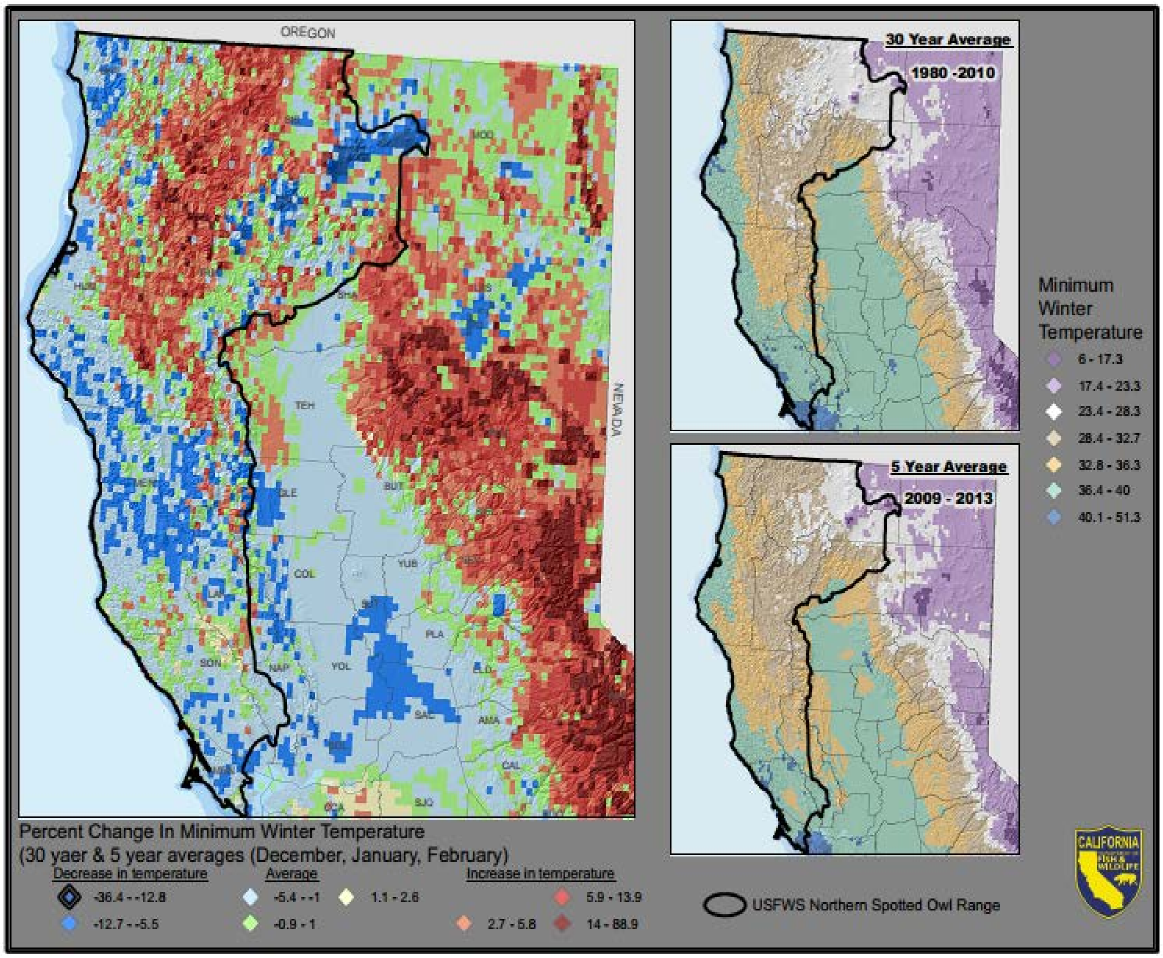

Figure 32. Percent change in minimum winter temperature within the Northern Spotted Owl range in California. Maps show both 30 year and 5 year average in December, January, and February. Data source: PRISM Climate Group, Oregon State University.

It is clear that climate change is occurring within the Northern Spotted Owl's entire range, with many climate projections forecasting steady changes in the future. Climate change studies predict future conditions that may negatively impact owls, such as wet and cold springs, more frequent and sever summer heat waves, decreased fog along the coast, shifts in forest species composition, and increased frequency of severe wildfire events. Yet in some instances predicted future conditions, such as increased frequency of low to moderate severity fires and expansion of suitable owl habitat forest types, may be favorable to the Spotted Owl in the long-term. In California, current rates of temperature and precipitation change predict hotter drier conditions in some areas of the owl's range and wetter colder conditions in other areas of the range. Looking at past precipitation and temperature trends, drying trends across most of the owl's range in California coupled with warmer winters and cooler summers in the interior and cooler winters and warmer summers along the coast may play a role in both owl and prey population dynamics

It will require additional research to assess the extent of these climate impacts and the Northern Spotted Owl's capacity to adjust to the changing climate. Studies are needed to better understand the impacts of climate change on survival rates, reproductive rates, and population growth of Northern Spotted Owls in California, and to determine the net effect of the positive and negative impacts of climate change on the California population.

Barred Owl

Barred Owl Identification

The Barred Owl is identified by its gray-brown coloration, round head with well-developed facial disc, lack of ear tufts, dark brown eyes, dull yellow bill, horizontal barring on its throat, and bold, dark, vertical streaks on the remainder of underparts (Mazur et al. 2000). Vocal identification is tied to its distinctive 8-note hooting call (Mazur et al. 2000). Barred Owl weight ranges from 470-1,050g, with a length form 43-50 cm (Mazur et al. 2000). The Barred Owl resembles the Northern Spotted Owl in appearance, with differences being that Spotted Owls have elliptical or irregular white spots rather than streaked below ruff on upper breast, and whitish spots rather than bars on head, back, and wing-coverts (Gutiérrez et al. 1995, Mazur et al. 2000). First generation hybrids exhibit physical and vocal characteristics of both species (Hamer et al. 1994, Kelly and Forsman 2004).

Barred Owl Expansion and Current Status in California

Historically, Barred Owls were residents of the eastern United States and southern Canada, east of the Great Plains and south of the boreal forest, and also in disjunct regions of south-central Mexico (Mazur and James 2000). Based on genetic analysis, Barrowclough et al (2011) found the disjunct Mexican populations to be distinct from populations in the United States and Canada at the species level, and recommended they be recognized as *Strix sartorii*. Barred Owls continue to occupy their historical range, and during the past century have expanded their range into western North America.

The timing and route of the Barred Owl range expansion into western North America has been debated, with an early and long-held view that Barred Owls expanded their range to the west via the boreal forests of Canada (Grant 1966, Hamer 1988, Houston and McGowan 1999, Holt et al. 2001). A slightly different view suggests the expansion began via riparian forests of the Missouri, Yellowstone, and Musselshell rivers of the northern Great Plains to the forested mountains of western Montana at the end of the 19th century (Figure 33; Livezey 2009a). Regardless of whether the initial range expansion was via the boreal forest of Canada or the riparian corridors of the northern Great Plains, once Barred Owls reached British Columbia in the 1940s, they continued their range expansion to the north and west across Canada to southeastern Alaska, and south through Washington, Oregon, and California (USFWS 2011, USFWS 2013). The range of the Barred Owl now completely overlaps the range of the Northern Spotted Owl from southwest British Columbia south along the western portion of Washington, Oregon, and northern California, and also includes a significant portion of the range of the California Spotted Owl.

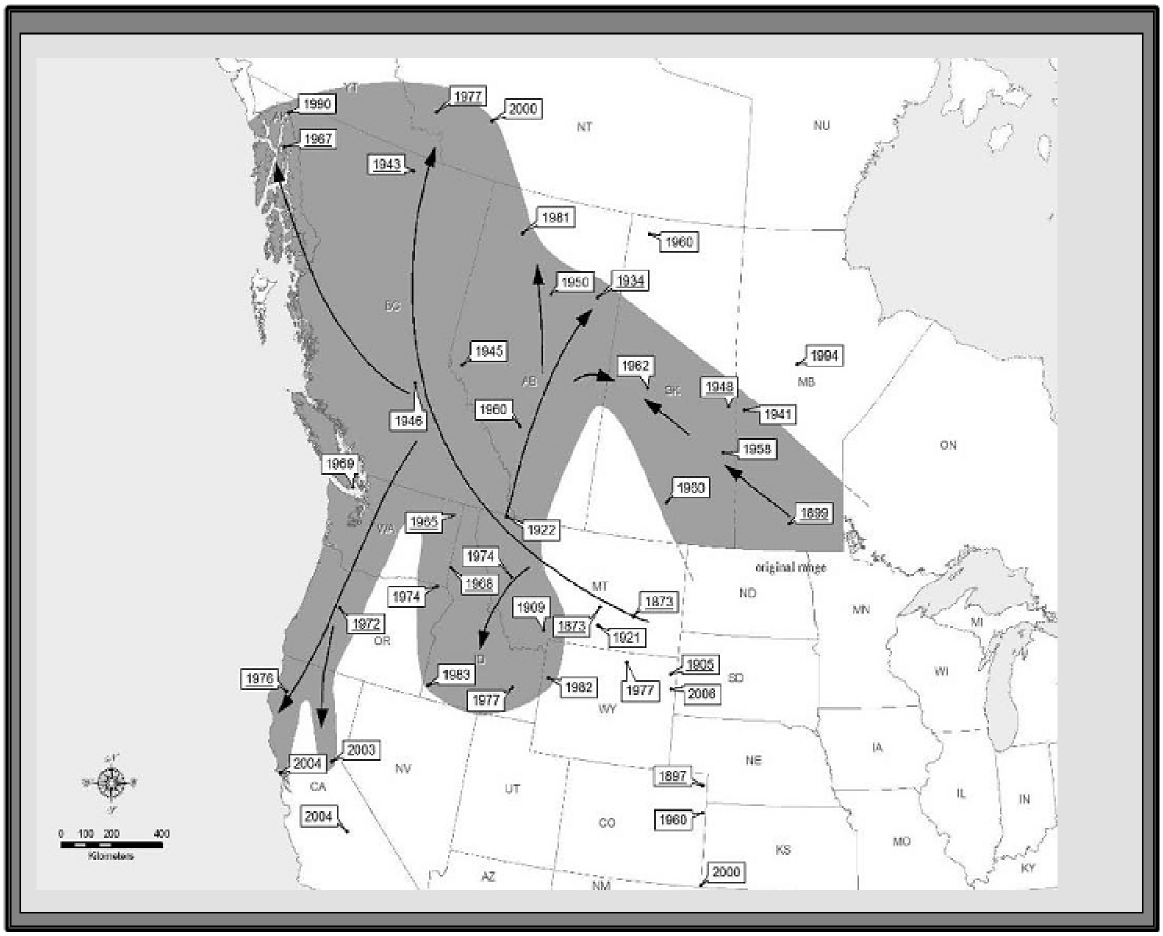

Figure 33. Range expansion of the Barred Owl, with selected arrival dates. Shaded area is an estimate of the expanded range of the Barred Owl in 2008 (from Livezey 2009a, Figure 2).

Barred Owls were first detected in California in 1976 (B. Marcot in Livezey 2009a). From then until 1996, 61 Barred Owl sites were identified in California (Dark et al. 1998). The majority of these sites (73%) were occupied by single owls. The first report of breeding in California was in 1991 (T. Hacking in Dark et al. 1998) and the first sighting in the Sierra Nevada was in 1991. The rate of detections of Barred Owls in California accelerated during the mid-1990s (Dark et al. 1998) and by 1996 Barred Owls had been detected as far south as Sonoma County in western California and Yuba County in the Sierra Nevada. Forsman et al. (2011, Appendix B) shows the rate of detection continued to accelerate through the 2000s. Currently, the known range of the Barred Owl in California extends along the coast south to Marin County (Jennings et al. 2011, Ellis et al. 2013) and to Tulare County in the Sierra Nevada.

The Department has processed data for 1,970[2] Barred Owl occurrences in California (Figure 34), and 111 additional occurrences of Barred-Spotted Owl hybrids. Occurrences include all detections of barred owls, whether or not they were associated with a nest or territory.

Following the range expansion of Barred Owl into the Northern Spotted Owl range, hybrids of the two species have occasionally been observed. The majority of hybrid observed in the field or genetically identified resulted from a cross between a female Barred Owl and a male Spotted Owl (Haig et al. 2004, Kelly and Forsman 2004). Second generation hybrids are generally difficult to distinguish from Barred or Spotted Owls using field identification only, and genetic samples may be the only sure way of identification (Kelly and Forsman 2004). Although the two species DNA sequences are largely divergent and can be separated into distinct clades with no signs of previous introgression (Haig et al. 2004), both first and second generation hybrids were found to be reproductively viable to some extent (Kelly and Forsman 2004).

[2] The 1,970 occurrences processed to date represent a subset of available data and come from 2 general sources: 1) state and private researchers, biologists and foresters from 1978-2013 and 2) the Forest Service's NRIS database with records from 1992-2011. Data omitted due to time constraints includes 1) hard copy data, 2) 2012-2013 NRIS detections and 3) NRIS detections that were within 1 mile of processed data to avoid duplicates; this data, not including duplicates, will be added in the future. An updated version of NRIS containing detections since 2011 is still needed. Additional data from the 2013 field season is also yet to be submitted. There is likely more data in holding and data from additional sources that has not been submitted.

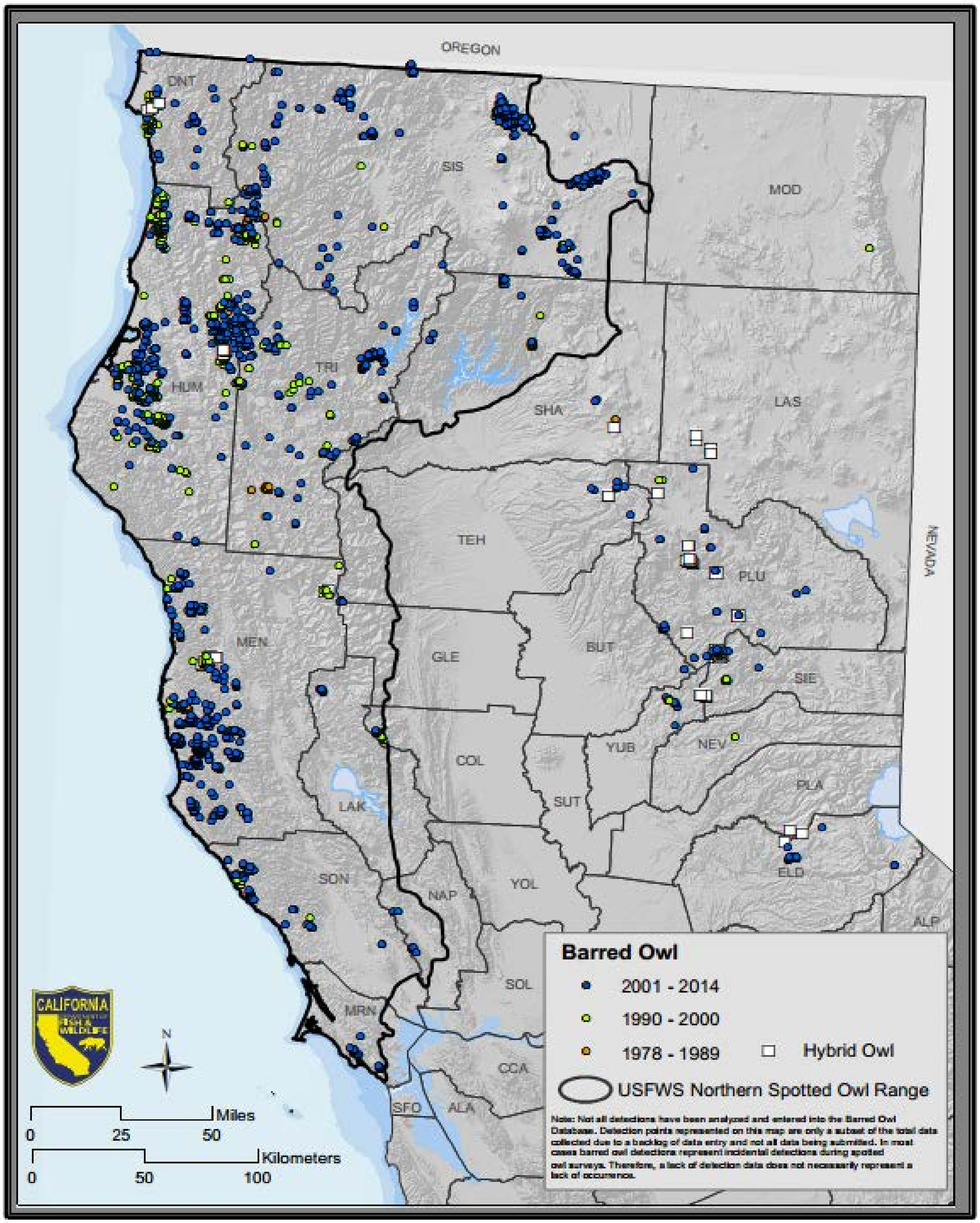

Figure 34. Barred Owl and Hybrid Spotted-Barred Owl detections in California documented within the Department's Barred Owl Database, from 1978 to 2014, overlaid on the range of the Spotted Owl in California. A portion of the increase in number of detections over time can be attributed to an increase in survey effort. Detections do not necessarily reflect current abundance or density.

Potential Mechanisms of Barred Owl Range Expansion

Factors that may have facilitated the range expansion have been debated in the literature at length. As mentioned above, two possible routes for the initial expansion from eastern North America have been suggested, i.e., riparian forests of the northern Great Plains and the boreal forest of Canada (Grant 1966, Hamer 1988, Houston and McGowan 1999, Holt et al. 2001, Livezey 2009a). It has been speculated that an ecological barrier existed prior to the end of the 19th century and that changes, either anthropogenic or natural, removed the barrier, and allowed for the initial westward expansion of the Barred Owl range (Johnson 1994, Dark et al. 1998, Wright and Hayward 1998, R. Gutiérrez in Levy 2004, Monahan and Hijmans 2007, Livezey 2009b).

The most prominent theory is that an increase in the number of trees and forested areas supported the expansion by providing suitable Barred Owl habitat where before there was none (e.g., within the Great Plains). The relatively fast Barred Owl range expansion coincides with a period of dramatic increases in wooded habitat across the northern Great Plains and the boreal forests of Canada following arrival of European settlers. Possible explanations for an increase in the number of trees are anthropogenic and include fire suppression, tree planting (including shelterbelts), extirpation of bison, and to a lesser extent reductions in beaver, elk and deer populations on the northern Great Plains due to market hunting (Dark et al. 1998, Wright and Hayward 1998, R. Gutiérrez in Levy 2004, Livezey 2009b).

Another hypothesis proposes that increased temperatures may have improved habitat value for Barred Owls in the northern boreal forest (Johnson 1994, Wright and Hayward 1998, Monahan and Hijmans 2007). This theory is based on an assumption that the boreal forests of southern Canada were too cold to be tolerated by Barred Owls, and that a warming climate brought these forests into the range of temperature tolerance for the species, thereby eliminating a natural barrier to Barred Owl range expansion (Monahan and Hijmans 2007). However, portions of the current Barred Owl range (e.g., northern Alberta and British Columbia, the Northwest Territories) are much colder than the forests of southern Canada, and the temperature increases reported to support this hypothesis occurred after the Barred Owl range expansion began (Johnson 1994, Monahan and Hijmans 2007); therefore the thermal barrier hypothesis seems unlikely (Livezey 2009a).

Once Barred Owls expanded across the middle of the continent, they encountered forests of the Rocky Mountains and the Pacific Northwest. Timber harvest may have facilitated the further expansion of the range by creating a mosaic of more open forest habitat that might be favored by a habitat generalist like the Barred Owl (Hamer et al. 1989, Dark et al. 1998). However, Barred Owls have become established in a variety of habitats, including mature forests that have not been harvested (USFWS 2013). Because Barred Owls are habitat and prey generalists (as explained below), the suggestion that they adapted to use of a novel (coniferous forest) habitat, which then allowed them to spread through the boreal forest and the forests of the west has largely been dismissed (Livezey 2009b, USFWS 2013).

Spotted Owl and Barred Owl Habitat, Prey Selection, and Home Range

Barred Owls tend to select low to high elevation areas with gentle slopes, large overstory tree with expansive crown diameter, and evergreen stands with a dense canopy, but will also nest in areas with young trees, deciduous tree species and open areas (Herter and Hicks 2000, Buchanan et al. 2004, Gremel 2005, Hamer et al. 2007, Jennings et al. 2011, Mazur and James 2000, Pearson and Livezey 2003, Singleton et al. 2010). In western Oregon, Barred Owls used available forest types more evenly than Spotted Owls, but were more strongly associated with large hardwood and conifer trees within relatively flat areas along streams (Wiens et al. 2014). In the eastern Cascades Range in Washington, Barred Owls used structurally diverse mixed grand fir and Douglas-fir forests during the breeding season more often than open ponderosa pine or simple-structure Douglas-fir forests, with less selection among forest types during the non-breeding season (Singleton et al. 2010, Singleton 2015). In coastal northwestern California, Barred Owls were more likely to select foraging habitat that was in close proximity to nests, consisted of high percent understory cover, high tree basal area, and a higher percent of hardwood species (Weisel 2015). Use of hardwoods for foraging was maximized at $80m^2$/ha (Weisel 2015). However, the pattern of Barred Owl colonization in coastal northern California indicated that Barred Owls completely occupied the old growth forests of Redwood National and State Parks (see Occupancy section above; Schmidt 2013) while occurring in relatively low numbers on the adjacent managed timberlands of the Green Diamond study area (Diller et al. 2014 , GDRC 2015).

Similarities between Barred Owl and Spotted Owl habitat preferences include selection of old forests with closed canopy and a high degree of structural complexity for nesting and roosting activities (Mazur et al. 2000, Singleton et al. 2010, Wiens et al. 2014, Singleton 2015, Weisel 2015). In coastal northwestern California, both species were found to use foraging areas closer to nest or activity centers and habitat that contained a hardwood component (Weisel 2015). Differences in habitat selection include the tendency for selection of lower elevation sites with gentle slopes (e.g., valley floors) by Barred Owls, the use of a larger variety of forest types by Barred Owls, and a stronger dependence on Douglas-fir dominant forests by Spotted Owls (Herter and Hicks 2000, Buchanan et al. 2004, Gremel 2005, Hamer et al. 2007, Jennings et al. 2011, Mazur and James 2000, Pearson and Livezey 2003, Singleton et al. 2010, Wiens et al. 2014, Singleton 2015). Spotted Owls may have a stronger affinity than Barred Owls to Douglas-fir dominant forests with more abundant dwarf mistletoe infestations, an important habitat feature for nesting Spotted Owls in the Washington’s eastern Cascades (Singleton 2015). Though a hardwood habitat component was found to be important for both species, Northern Spotted Owls in coastal northwestern California seemed to use less dense hardwood than Barred Owls (39 m^2/ha compared to $80m^2$/ha; Weisel 2015).

Barred Owls are opportunistic hunters that consume a wide array of prey, including small mammals ranging from rabbits to bats, small to medium sized birds, amphibians, reptiles, fish, and invertebrates; however, mammals make up a majority of prey items (Hamer et al. 2001, Mazur and James 2000, Mazur et al. 2000). Conversely, Northern Spotted Owls rely on a much more specialized prey base, comprised primarily of small mammals (Wiens et al. 2014). Diet overlap by biomass between Spotted and Barred

Owls was as much as 76% in a region of sympatry in the Cascades of Washington (Hamer et al. 2007), although more moderate in western Oregon (41%; Wiens et al. 2014).

Prey species composition and density drive habitat selection and home range size for both owl species; however, Spotted Owls are more sensitive to fluctuations in prey abundance and availability than Barred Owls due to their more limited number of preferred prey species (Bond et al. 2013, Franklin et al. 2000, Hamer et al. 2007, Meyer et al. 1998, Thomas et al. 1990, Ward 1990, Zabel et al. 1995, Zabel et al. 2003, Wiens et al. 2014). Home range analyses show the importance of mature forests for nesting by both Barred and Northern Spotted Owls (Wiens et al. 2014, Weisel 2015); however, limited data on owl movement in the Washington Cascades showed that Barred Owls select other forest cover types similar to their availability, whereas Spotted Owls are more tightly associated with old forests (Hamer et al. 2007, Singleton et al. 2010). Home ranges for both species have been found to be smaller in old mature forests; however, within forest types, home ranges of Spotted Owls are larger than those of Barred Owls (Hamer et al. 2007, Singleton et al. 2010, Wiens et al. 2014). The narrow range of prey selected by Spotted Owls contributes to the need for much larger home ranges in comparison to Barred Owls. Conversely, because Barred Owls use a much wider variety of prey their home ranges are smaller, which may result in higher densities of Barred Owls within the Spotted Owl range (Livezey et al. 2008). In western Oregon, Barred Owl home range and core area use (i.e., the portion of the fixed-kernel breeding season home range in which use exceeded that expected under a null model of a uniform distribution of space-use) was 581 hectares and 188 hectares, respectively; whereas Northern Spotted Owl home range and core area use was much larger, 1,843 hectares and 305 hectares, respectively (Wiens et al. 2014). In some areas of sympatry, little overlap exists between Barred and Spotted Owl home range, which is indicative of competitive exclusion of Northern Spotted Owls by Barred Owls (Hamer et al. 2007, Weins et al. 2014). However, 81% overlap between the two species with adjacent territories was observed in western Oregon with most space sharing observed in the foraging areas outside of the core area (Wiens et al. 2014). Despite overlap in foraging areas in this Oregon study, evidence suggests that interference competition with Barred Owls for territorial space constrained the availability of critical resources required for successful recruitment and reproduction of Northern Spotted Owls (Wiens et al. 2014). Availability of old forests and associated prey species appeared to be the most strongly limiting factors in the competitive relationship between these species.

Conversely, in coastal northwestern California, breeding season home range for Barred Owl and Northern Spotted Owl were found to be similar: 303 (SE = 37) and 391 (SE = 79) hectares, respectively, and nonbreeding home range was 442 (SE = 97) and 560 (SE = 159) hectares, respectively (Weisel 2015). Somewhat different than other home range studies in the northern portion of the Northern Spotted Owl range, these results showed home range size for Spotted Owls was only 1.29 times greater during the breeding season and 1.26 times greater during the nonbreeding than Barred Owl home range; however results were not statistically significant. The smaller home range sizes and lack of seasonal variation in northwestern California may be due to the milder climate in coastal forests together with the higher density of woodrats, and the relatively low Barred Owl density in the southern portion of the range compared with northern areas where Barred Owls have existed longer and are in higher densities (Weisel 2015).

Given the high degree of similarities in Barred Owl and Northern Spotted Owl habitat, there is no indication that the two species can partition forested habitats or that Barred Owls will not successfully use all the habitats preferred by Spotted Owls (Gutiérrezet al. 2007, Dugger et al. 2011, Singleton 2015, Weisel 2015). Thus, because these two species share the same habitat and prey-base, and there is little evidence that nesting habitat or food resources can be adequately partitioned to prevent competition, coexistence of both species is uncertain (Gutiérrez et al. 2007, Dugger et al. 2007, Wiens et al. 2014, Singleton 2015, Weisel 2015, Dugger et al. 2016). The similar habitat preference for older forests highlights the importance for maintaining this forest type on the landscape because a decrease in older forests will likely increase competitive pressure between the two species (Wiens et al. 2014). Protecting high-quality habitat on the landscape (e.g., older structurally complex forests) may provide some amount of refugia for Spotted Owls from competitive interactions with Barred Owls, allowing managers and others time to further evaluate competitive effects between the two species and resource partitioning options, as well as consider effectiveness and feasibility of Barred Owl control measures (USFWS 2011, USFWS 2013).

Impacts of Barred Owls on Spotted Owls

Data is lacking to adequately assess Barred Owl abundance in western North America; however, Barred Owl presence is increasing throughout the range of the Northern Spotted Owl (Dugger et al. 2016). The apparent density of Barred Owls is greatest in the north where they have been present the longest (British Columbia and Washington), and lower the southern edge of the range (California) where they have been present for a shorter duration (USFWS 2013). Despite this general north-south gradient in the density of Barred Owls, Dugger et al. (2016) provides strong evidence of increasing Barred Owl populations throughout the entire range of the Northern Spotted Owl (Figure 35). Regularly conducted meta-analyses incorporating long-term demographic data for up to 14 study areas across the range of the owl have resulted in six meta-analyses since 1994 (Burnham et al. 1994, 1996, Franklin et al. 1999, Anthony et al. 2006, Forsman et al. 2011, Dugger et al. 2016). The only demographic study area that has experienced decreased Barred Owl presence is on Green Diamond Resource Company land (i.e., GDR) where Barred Owl removal has occurred (Dugger et al. 2016). The Redwood National and State Parks (RNSP) in coastal northern California, a stronghold for remaining old-growth redwood forests in California, now has very low Northern Spotted Owl occupancy rate, thought to be the result of the rapid increase of Barred Owls into the area (Schmidt 2015). During 2013-2014, only four Northern Spotted Owls were detected at three separate sites with the RNSP, with only one non-reproductive pair observed (Schmidt 2015). In total, 40 barred owls were detected within RNSP between 2013 and 2014 (Schmidt 2015).

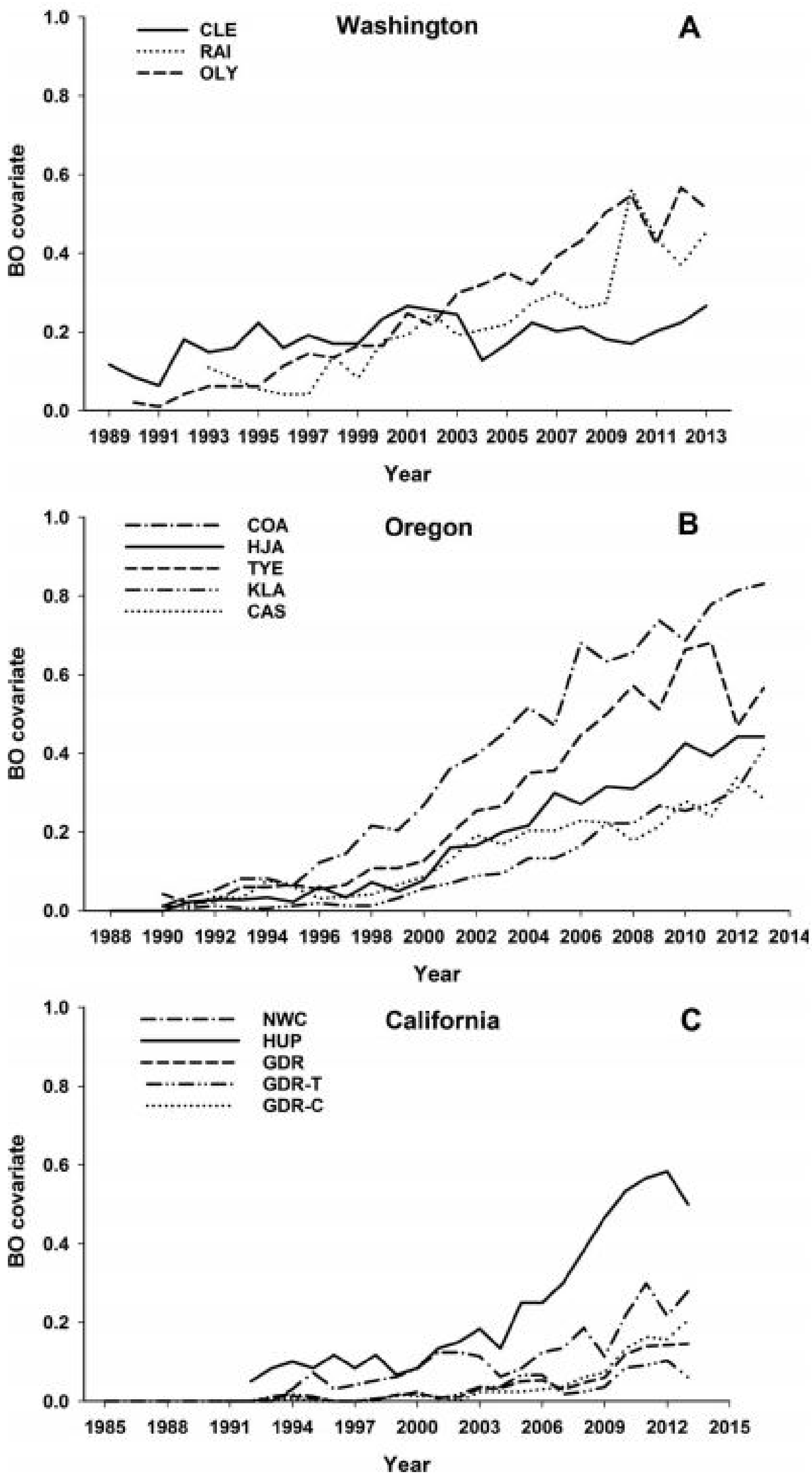

Figure 35. Annual proportion of Northern Spotted Owl territories with Barred Owl detections (BO covariate) in 11 study areas in (A) Washington, (B) Oregon, and (C) California, 1985-2013 (Dugger et al. 2016, Appendix C Figure 13). GDR-T is the Barred Owl removal treatment area on Green Diamond Resource Company land, and GDR-C is the Barred Owl removal control area. For all other abbreviations, see Table 5.

Barred Owl presence has been documented mainly through incidental detections during Spotted Owl surveys. Based on these detections, numerous researchers have reported that Barred Owl numbers quickly increase after a short period of slow increase once they arrive in a new area (Hamer et al. 1988, Kelly 2001, Anthony et al. 2006, Dugger et al. 2016). In the Oregon Cascades, Barred Owl detections increased from one initial detection in 1979 to over 700 detections by 1998 (Kelly 2001). Barred Owls can also quickly outnumber Spotted Owls; in the Northern Cascades in Washington, Barred Owl abundance was twice that of Spotted Owls within 17 years of the first detection (Hamer et al. 1988).

As discussed previously, documented Barred Owl occurrences in California are at 1,970 records (see Figure 34), of which a majority are from the last 10 years. All three California demographic study areas have reported increases of Barred Owl within historic Northern Spotted Owl territories (see Figure 35C; Dugger et al. 2016). The Hoopa Valley Indian Reservation (i.e., part of the HUP demographic study area) detected Barred Owls in over 85% of all historic Northern Spotted Owl territories between 2009 and 2014 (Higley and Mendia 2013). The Willow Creek Study Area (i.e., part of the NWC demographic study area) has experienced a dramatic increase in Barred Owl detections, from one barred owl site in 1991 to 22 in 2014, and Northern Spotted Owl territories having Barred Owl detections ranged between 0 and 37 within the same timeframe (Franklin et al. 2015). In 2014, there were 268 Barred Owl detections on Green Diamond Resource Company land (part of the GDR demographic study area), representing an estimated 65 territories, and demonstrating a 76% increase in detections from 2011 to 2014 (GDRC 2015).

Spotted Owls will reduce their calls or not call at all if Barred Owls are in the vicinity (Cozier et al. 2006, Kroll et al. 2010, Dugger et al. 2011, Diller 2014, Sovern at al. 2014), making it more difficult to detect Spotted Owls if Barred Owls are present. Thus, standard surveys might result in occupancy status being misclassified (e.g., a false-negative survey -- designating sites as unoccupied by Spotted Owls when in reality Spotted Owls are present but are not vocalizing). Beyond land management implications (e.g., timber harvest or not), this behavior shift by the Spotted Owl may also have implications for reproduction because calls are used to defend a territory and locate mates, and during pair bonding and prey delivery to the nest site (USFWS 2013).

Multiple studies indicate that Barred Owl presence negatively influence whether Northern Spotted Owls will occupy a territory (Kelly 2001, Pearson and Livezey 2003, Gremel 2005, Olson et al. 2004, 205, Kroll et al. 2010, Dugger et al. 2011, Diller 2014, Yackulic et al. 2012, 2014, Higley and Mendia 2013, Sovern et al. 2014, Weins et al 2014, GDRC 2015, Dugger et al. 2016). The most recent occupancy analysis was conducted as part of the latest demographic meta-analysis including data from all 11 study areas (Dugger et al. 2016). Territory occupancy rates declined in all 11 study areas with a strong positive relationship between the presence of Barred Owls and territory extinction rates (Dugger et al. 2016; also see Figure 11 of this report). In California between 1995 and 2013, Northern Spotted Owl occupancy rates declined from 75% to 38% in NWC, and from 79% to 47% in HUP, and between 1999 and 2013 declined from 92% to 55% in the GDR control area (Dugger et al. 2016; also see Status and Trends section of this report). Accounting for detection probability, Barred Owl presence was the main factor influencing increased extinction rates of Norther Spotted Owls in all study areas, though provided less consistent influences on colonization rates (Dugger et al. 2016). These results largely agree with previous Northern Spotted Owl occupancy studies (e.g., Olson et al. 2005 in western Oregon, Kroll et al. 2010 in eastern Washington Cascades, and Dugger et al. 2011 in southern Oregon Cascades). In 5 of 11 study areas (one in Washington and four in Oregon) there was strong negative association between Barred Owls presence and Northern Spotted Owl colonization rates (Dugger et al. 2016). Yet colonization rates remained stable in the California study areas with or without Barred Owl (also see Figure 11 of this report); possibly an artifact of the relatively recent expansion of Barred Owls into the more southerly portion of the Spotted Owl range (Dugger et al. 2016).

Through interspecific competition over territories, Barred Owls are displacing Northern Spotted Owls from their territories, forcing them into lower quality breeding and foraging habitat (Olson et al. 2004, Kroll et al. 2010, Dugger et al. 2011, Diller 2014, Sovern et al. 2014, GDRC 2015, Wiens et al. 2014, Weisel 2015, Davis et al. 2015, Dugger et al. 2016). It is uncertain if Barred Owl presence is associated with increased mortality of Northern Spotted Owls, or rather increased emigration either through displacement where they become undetectable floaters, or from exclusion from the entire study area (Dugger et al. 2016). When Barred Owls were first detected in a Northern Spotted Owl territory on Green Diamond Resource Company land, Northern Spotted Owls no longer responded to taped playback calls, demonstrating they were either absent from the territory or not responsive (Diller 2014). In addition, Northern Spotted Owl activity centers will shift away from areas where Barred Owls are present even if they do not entirely abandon their territory (Kelly 2001, Gremel 2005, Diller 2014, Weins et al. 2014). Wiens et al. (2014) concluded that Barred Owls were limiting the availability of old forests and associated prey species for Northern Spotted Owls and this was the most strongly limiting factor in the competitive relationship between these two species.

Barred Owls are aggressive toward Spotted Owls, and have attacked Spotted Owls on occasion. Courtney et al. (2004) reported several instances where Spotted Owls were attacked by Barred Owls, and where surveyors were attacked by Barred Owls while playing Spotted Owl calls. Using taped playback calls and taxidermy mounts for both Barred Owl and Northern Spotted Owl, Van Lanen et al. (2011) found Barred Owls responded more aggressively (both vocally and physically) toward Northern Spotted Owls than did Northern Spotted Owls toward Barred Owls, suggesting that Barred Owls would act in the dominant role during interactions with Spotted Owls. Anecdotal observations of aggressive physical interactions between the two species have indicated that Barred Owls tend to dominate due to their larger size (Van Lanen et al. 2011, Diller personal communication.). Most Spotted Owl biologists do not believe that these physical encounters frequently result in serious injury to Spotted Owls, but Leskiw and Gutiérrez (1998) suspected that a Barred Owl killed and partially consumed a Spotted Owl. Johnston (2002, as cited by Courtney et al. 2004) presented evidence that a Barred Owl likely killed a juvenile Spotted Owl. It is unclear if Barred Owls target Spotted Owls as prey, or if the documented mortalities were due to territorial aggression (USFWS 2013). By comparison, instances reported of Spotted Owl aggression toward Barred Owls are few (George and Lechleitner 1999, A. Ellingson, pers. comm, P. Loschl, pers. comm as cited in Courtney et al. 2004, Van Lanen et al. 2011).

Northern Spotted Owl survival rate is impacted by the presence of Barred Owl (Anthony et al. 2006, Forsman et al. 2011, Wiens et al. 2014, Dugger et al. 2016). In western Oregon, annual survival for Northern Spotted Owl was lower (0.81, SE=0.05) than that of Barred Owl (0.92, SE=0.04) (Wiens et al.

2014). The three most recent demographic meta-analyses (Anthony et al. 2006, Forsman et al. 2011, Dugger et al. 2016) show that in areas where Barred Owls are present, Northern Spotted Owl survival has decreased. The latest meta-analysis (Dugger et al. 2016), which analyzed Northern Spotted owl data through 2013, indicated the primary cause of Northern Spotted Owl declines are competition with Barred Owl, largely as a result of a strong negative effect of Barred Owl on Northern Spotted Owl apparent survival rates and a positive effect of Barred Owl on Northern Spotted Owl extinction rates. As noted within the Status and Trends section of this report, rate of population change and survival rates have declined across the range, with the exception of the GDR study area where a Barred Owl experimental removal occurred (Dugger et al. 2016). Apparent survival in the GDR treatment area was 0.857 (SE=0.009) before removal, and the highest across the entire range at 0.870 (SE=0.021) after removal. The lowest survival across the entire range (0.804, SE=0.032) was attributed to GDR control area after Barred Owls were removed from the GDR treatment area. The rate of population change at the GDR treatment area was also positive (λ=1.030, SE=0.040) after Barred Owls were removed (Dugger et al. 2016).

Weak relationships exist between Northern Spotted Owl fecundity across its range and Barred Owl presence (Forsman et al. 2011, Dugger et al. 2016), suggesting a complex competitive and displacement interactions (Wiens et al. 2014). Regardless of this weak influence on fecundity, Barred Owl presence negatively impacts Spotted Owl occupancy, which in turns impacts the number of young produced in a territory (Dugger et al. 2016). In western Oregon Northern Spotted Owl reproduction increased linearly with increasing distance from Barred Owl territory centers, and all Northern Spotted Owl nests failed when within 1.5 km (0.93 miles) of a Barred Owl nest (Wiens et al. 2014). Barred Owls may have competitive advantage regarding reproductive success and productivity due to large clutch size (1 to 5 chicks) and potential for multiple clutches within a season (Courtney et al. 2004, USFWS 2013). In addition, Barred Owls are prey generalists (Hamer et al. 2001, Mazur and James 2000, Mazur et al. 2000); a factor that may play into higher reproductive success (USFWS 2013).

To better understand the implications of Barred Owl presence on Northern Spotted Owl demographics, Barred Owl removal experiments have been initiated. In 2009 Green Diamond Resource Company started a Barred Owl removal study to assess the impacts Barred Owls were having on Northern Spotted Owls (Diller 2014, GDRC 2015). This study area (GDR) is one of the 11 study areas analyzed as part of the long-term demographic meta-analysis mentioned earlier (Dugger et al. 2016), and consists of control and treatment areas monitored consistent with all other demographic study areas across the Northern Spotted Owl range. When Barred Owls were removed from seven historic Northern Spotted Owl territories, Spotted Owls were detected within 13 to 152 days (Diller 2014). Four sites were re-occupied by at least one of the previous resident Spotted Owls associated with the site prior to Barred Owl occupancy, including one resident female that had not been detected for 7 years, while three sites were colonized by new individuals after the Barred Owls were removed (Diller 2014). These results suggest that some Northern Spotted Owls were displaced by Barred Owls but remained in the vicinity to quickly reoccupy their former territory. Experimental Barred Owl removal was also conducted at Hoopa Valley Indian Reservation during the winter of 2013-2014, including removal of a total of 71 Barred Owls (78% of all Barred Owls detected, 92.9% of all females detected, and 65.3% of all males detected), with at least one Barred Owl removed from 28 historic Northern Spotted Owl territories, and >2 removed from 21 Northern Spotted Owl territories (Higley 2014). Northern Spotted Owl occupancy dynamics have not yet been reported for this removal study area.

Investigation into the feasibility of conducting Barred Owl removal studies to enhance recovery of the Northern Spotted Owl was called out in Recovery Actions 22, 28, 29, and 30 (USFWS 2011). Lethal removal activities on Green Diamond Resource Company land (totaling 85,205 hectares of treatment area) was found to be technically feasible and cost-effective (Diller et al. 2014), at least at a local-scale. An average of 2 hours and 23 minutes was required to collect each Barred Owl, with most Barred Owls collected within 30 min after arrival at a site (Diller et al. 2014). A large-scale removal experiment across the range of the Northern Spotted Owl, as noted in the Final Environmental Impact Statement – Experimental Removal of Barred Owls to Benefit Threatened Northern Spotted Owls – is also being planned (USFWS 2013).

Barred Owls may act as a vector for parasites that can impact Northern Spotted Owls. At least two species of feather lice (*Phthiraptera*) and one Hippoboscid fly that are known Barred Owl ectoparasites also parasitize Northern Spotted Owls, suggesting that invasive Barred Owls may expose Northern Spotted Owls to novel pathogens via ectoparasites (Hunter et al. 1994). Lewicki et al. (2015) sampled blood from Northern Spotted Owls and western Barred Owls throughout Siskiyou, Trinity, Humboldt, and Mendocino counties in an attempt to evaluate parasite dynamics and the related impacts of Barred Owl range expansion on Spotted Owls. The study suggests that parasite dynamics in Northern Spotted Owls are not solely influenced by the presence or absence of Barred Owls, but that more research is needed to assess roles of additional factors relating invasion to host/parasite dynamics (Lewicki et al. 2015). Specific results related to parasite prevalence are noted within the Disease section of this report below.

In summary, the literature is clear that Barred Owls are now having a severe negative impact on Northern Spotted Owl at a range-wide level (Dugger et al. 2016), including reduced survival, fecundity and occupancy, reduced detection rates, increased extinction rates, and displacement from roosting, nesting and foraging habitat. Experimental removal of Barred Owls from territories previously occupied by Spotted Owls indicates Spotted Owl will respond favorably by reoccupying these newly available territories quickly (Diller 2014, Dugger et al. 2016). Removal experiments appear to be feasible at a local scale (Diller et al. 2014), but long-term use of removal as a management tool needs further consideration (USFWS 2013). Though some level of resource partitioning between Northern Spotted Owls and Barred Owls may be possible (Weisel 2015), similar habitat preference for older forests by both species (Hamer et al. 2007, Wiens et al. 2014) may limit the ability to manage to benefit Spotted Owls but not Barred Owls. This highlights the importance for maintaining this forest type on the landscape because a decrease in older forests will likely increase competitive pressure between the two species (Wiens et al. 2014).

Disease

The 2011 Revised Recovery Plan (USFWS 2011) states, "It is unknown whether avian diseases such as West Nile virus (WNV), avian flu, or avian malaria… will significantly affect Spotted Owls." Likewise, disease occurrence in Spotted Owls is likely under-reported because they tend to inhabit remote areas and, therefore, there is a small likelihood of carcass recovery for testing (K. Rogers, personal communication, September 25, 2014). Therefore, it is important to assess the literature on disease prevalence and impacts in other raptor species, especially owls, to determine if disease may pose a risk to Spotted Owl populations in California.

In California, two studies have investigated the prevalence of WNV in raptor populations (Hull et al. 2006, Hull et al. 2010). In migrating and wintering hawks, Hull et al. (2006) found WNV antibodies were present in 5-58 percent of the 271 Red-tailed Hawks, 19 Red-shouldered Hawks, and 30 Cooper's Hawks tested. However, no individuals that tested positive demonstrated any visible signs of illness. WNV antibodies were lacking in 62 Northern Goshawks, 209 Spotted Owls, and 22 Great Gray Owls sampled in another Sierra Nevada study, suggesting either a low prevalence in these species, or a high mortality assuming infected carcasses were not recovered (Hull et al. 2010). To date, three cases of WNV in Spotted Owls have been confirmed; 2 from Northern Spotted Owl (reported from suburban areas), and one from California Spotted Owl (K. Rogers, personal communication, 2015).

Research conducted elsewhere in North America, suggests WNV infection causes morbidity and mortality in several species of raptors. In Colorado, WNV infection was highest in Red-tailed Hawks and Great-horned Owls (compared to other raptor species) admitted to wildlife rehabilitation centers; clinical signs were variable and included emaciation, weakness, and inability to perch, fly, or stand (Saito et al. 2007). Additionally, 40 of 56 dead raptors, evaluated for WNV, tested positive; histological lesions most often included encephalitis and myocarditis (Saito et al. 2007). In Georgia, 40 out of 346 raptors tested for WNV were positive, including 4 Barred Owls, one Great Horned owl, and four Eastern Screech Owls (Ellis et al. 2007). All 40 cases occurred during summer and late fall (Ellis et al. 2007), when mosquito activity is most common. Gancz et al. (2004) investigated an outbreak of WNV in several species of captive owls in Ontario, Canada, including one Spotted Owl and eight Barred Owls. Owl species with more northerly breeding ranges (e.g., Snowy Owl, Great Gray Owl) showed higher rates of infection than more southerly breeding species (e.g., Barn Owl, Eastern Screech Owl) (Gancz et al. 2004). WNV infection in these captive birds was found to coincide with a summer louse fly (Hippoboscidae) infestation, suggesting bites from the louse flies aided in WNV transmission (Gancz et al. 2004). Additionally, there is evidence that raptors can become infected with WNV after feeding on infected prey (Nemeth et al 2006). WNV infection is routinely identified in squirrels (Family: Sciuridae) (Padgett et al. 2007), as well as jays and other songbirds (Wheeler et al. 2009, Hull et al. 2010) in California; the range of these species may overlap with that of Northern Spotted Owls, possibly posing an additional infection risk.

Significant mortality due to avian malaria or Leucocytozoonosis is rarely reported in avian species, with the exception of island endemics or birds in captive situations, and most infected birds seem to recover or may have chronic infections (Atkinson 2008, Forrester and Greiner 2008). There are no known studies or cases of mortality caused by avian influenza in Spotted Owls. The prevalence of avian influenza in the Spotted Owl population is expected to be low since the disease is primarily carried by waterfowl and shorebirds, two groups that have low interaction with Spotted Owls (K. Rogers, personal communication 2014). Thomas et al. (2002) documented a fatal infection of a *Borrelia* sp. in a Northern Spotted Owl from Washington. Borreliosis is transmitted by ticks, potentially including those ticks accidentally transferred to Spotted Owls from their rodent prey. Hunter et al. (1994) documented a tick (Ixodidae) and a flea (Ceratophyllidae) from Northern Spotted Owls, and considered them as likely accidentals from rodent prey. Northern Spotted Owls also hosted two species of feather lice (Phthiraptera), *Strigiphilus syrnii* and *Kurodaia magna*.

There are a handful of studies that have documented blood and intestinal parasites in owl species. Ishak et al. (2008) tested 111 Spotted Owls, and 44 Barred Owls, and 387 owls from nine other species for Leucocytozoon, Plasmodium, and Haemoproteus spp. (haemosporidian blood parasites). The study found both California and Northern Spotted Owls carried the greatest number of Leucocytozoon parasite lineages, California Spotted Owls had a higher prevalence of infection with more multiple infections than Northern Spotted Owl, and Barred Owls along the coast had lower rate of infection (15%) than Northern Spotted Owls (52%) and California Spotted Owls (79%). These results suggest that the greater infection load of Spotted Owls compared to Barred Owls may favor the later in competitive interactions. Interestingly, Ishak et al (2008) also documented the first ever case of Plasmodium infection in a Northern Spotted Owl. Gutiérrez (1989) tested 105 Spotted Owls (seven populations and all subspecies) for hematozoa (a blood parasite) and found all to be infected with at least one hematozoan. This study suggested that the owls large home range, spanning various forest types, the time spent caring for and provisioning young, and their long life span make this species more susceptible to higher rate of infection compared to other bird species (Gutiérrez 1989). From 2008 to 2012 blood samples were tested for blood parasite loads from Northern Spotted Owls (n=98) and western Barred Owls (n=49) throughout Siskiyou, Trinity, Humboldt, and Mendocino counties (Lewicki et al. 2015). For comparison, blood samples were also analyzed from eastern Barred Owls (n=135) housed in wildlife rehabilitation centers throughout their historic range. Lewicki et al. (2015) found Haemoproteus spp. infection prevalence higher in Northern Spotted Owl (76.5%) than western Barred Owl (30.6%), and highest in eastern Barred Owl (88.1%), and infection intensity was nearly 100 times greater in Northern Spotted Owl than western Barred Owl. The study tested 5 hypotheses regarding parasites and biological invasions (in this case Barred Owl invading Spotted Owl range), and found strong support for "Enemy Release" hypothesis (i.e. the host benefits from a loss of parasites in their invasive range) and "Parasite Spillback" (i.e. invasive hosts act as a new reservoir to native parasites) and "Dilution Effect" (i.e. invasive species act as poor hosts to native parasites and decrease the density of potential hosts in their invasive range) hypotheses (Lewicki et al. 2015).

Hoberg et al. (1989) reported that 71% of the Northern Spotted Owls from western Oregon that they tested were infected with helminth parasites including nematodes, cestodes, and acanthocephalans. Any adverse effect from these parasites was not documented. In Oregon, Hoberg et al. (1993) reported enteric coccidia (intestinal parasite) in a juvenile female Northern Spotted Owl. The presence of the parasite did not appear to contribute to the juvenile Spotted Owl's death; however, death has been attributed to this type of parasite in other raptor species (Hoberg et al. 1993). In this case study, transmission was thought to be through consumption of infected small mammal prey (e.g., mice, squirrels, woodrats).

Trichomonosis is a concern for Spotted Owls if they consume Columbids (pigeons and doves) infected with the protozoan parasite, *Trichomonas gallinae*, where species ranges overlap. The Department's Wildlife Investigation Lab documented two cases of Trichomonosis in California Spotted Owl in 2012, two cases in Northern Spotted Owl in 2014 from the Coastal Mountain Range, north of San Francisco Bay, and one in a Great Gray Owl in 2006 and in 2007 (K. Rogers, personal communication, September 25, 2014).

In northwestern California, Young et al. (1993) found Hippoboscid flies on 62 of the 382 Northern Spotted Owls captured over five years between April and September, with higher prevalence in adults that juveniles. The flies were more abundant in years when fall temperatures were high, winter precipitation levels were low, and summer temperatures were low, suggesting fly abundance is climate dependent. Consequently, the frequency of Hippoboscid flies in the Northern Spotted Owls population may vary in intensity as climate changes (Young et al. 1993). Hippoboscids may reduce the fitness of heavily infected individual Spotted Owls, and may act as vectors for other pathogens.

As mentioned above, relatively low disease prevalence may be due to the poor detection rate of Spotted Owl carcasses, not necessarily a lack of infection in the population. In addition, most research thus far has not assessed the impacts of disease to Northern Spotted Owls survival or reproductive fitness. One study in Spain (Martinez et al. 2010) documented lowered survival of wild-breeding female Blue Tits (*Cyanistes caeruleus*) infected with Haemoproteus parasites (Haemoproteus and Leucocytozoon spp.), indicating some possible level of impact to other avian species, such as Spotted Owls; however, more research is needed. To address the shortfall of information on disease impacts to Northern Spotted Owls, Recovery Action 17 of the recovery plan states, "Monitor for sudden oak death and avian diseases (e.g., WNV, avian flu, Plasmodium spp.) and address as necessary" (USFWS 2011). The Department's Wildlife Investigation Lab is currently conducting a raptor disease and contaminant surveillance study that will help determine disease occurrence and contaminant exposure in raptor populations statewide, including both Northern and California Spotted Owls. This study will include targeted surveillance for a wide array of diseases and contaminants such as, WNV, mange, Avian Trichomonosis, Avian Chlamydiosis, and Avian Herpesvirus, and rodenticide and lead poisoning.

Contaminants

As described above (see the Habitat Loss from Mariijuana Cultivation) marijuana grows are widespread in the Northern Spotted Owl range and growers, especially trespass growers, typically apply second-generation anticoagulant rodenticides (AR) at the base of plants to prevent small mammals from damaging the crop (Thompson et al. 2013, Gabriel et al 2013). These second-generation ARs present a risk to predators of small mammals, such as the Northern Spotted Owl, because this type of rodenticide is more acutely toxic, and persists in tissues and in the environment (Gabriel et al. 2013). Northern Spotted Owls feed on a variety of prey species, but mainly small mammals make up a bulk of their diet (e.g., Forsman et al. 2004). Consequently, the main contaminant threat to the owls is intoxication from secondary AR exposure. The anticoagulant rodenticides are grouped into first-generation compounds (FGARs; e.g., diphacinone, chlorophacinone and warfarin), requiring several doses to target species before death occurs, and second-generation compounds (SGARs; e.g., bromadiolone, brodifacoum, difenacoum and difethalone), requiring only a single dose. In general, SGARs are more acutely toxic and persist in tissues and in the environment (Gabriel et al. 2013). Both SGARs and FGARs have been detected in raptors; however, exposure and intoxication from SGARs is much more common than from FGARs.

Numerous field monitoring studies on other raptor and owl species indicate lethal and sublethal impacts of AR exposure (Mendenhall and Pank 1980, Stone et al. 2003, Walker et al. 2008, Albert et al. 2009, Lima and Salmon 2010, Murray 2011, Thomas et al. 2011, Christensen et al. 2012, Sánchez-Barbudo et al. 2012). In California, Lima and Salmon (2010) analyzed tissues from 96 raptors of 10 different species brought to wildlife rehabilitation centers in San Diego and the Central Valley, California, and found that 69% (Central Valley) to 92% (San Diego) had been exposed to ARs. In Massachusetts, Murray (2011) tested 161 wild Red-tailed Hawks, Barred Owls, Eastern Screech Owls (*Megascops asio*), and Great Horned Owls and found 86 percent with ARs in liver tissue, of which 99 percent was brodifacoum, a SGAR. Another study in New York found ARs present in 49% of wild raptors tested (n=265; 12 species), most prevalent in Great Horned Owls (43/53; 81%) and less prevalent in Barred Owls (3/13; 23%), with SGARs (brodifacoum and bromadiolone) being the most frequently detected (Stone et al. 2003). Nine of the 53 Great Horned Owls and one of the 13 Barred Owls died in this study, revealing a mortality rate of 17% and 8%, respectively (Stone et al. 2003).

In addition to the field monitoring that demonstrates widespread exposure of raptor and owl species to ARs, investigations of wildlife mortality incidents show that raptors comprise two-thirds of the anticoagulant-related wildlife mortalities (Department's Wildlife Investigation Lab files). These incidents are most likely to be reported in more populated areas, but it is reasonable to assume that any area where ARs are used for outdoor rodent control would share a similar pattern. The Department's Wildlife Investigation Lab have thus far tested 5 Northern Spotted Owls and 6 California Spotted Owls for AR exposure and all were positive (K. Rogers, personal communication, December 18, 2015). However, at this time it is unknown if morbidity and mortality is widespread for the Spotted Owl in California. As mentioned above, the Wildlife Investigation Lab is currently conducting a statewide raptor disease and contaminant surveillance study that will target AR occurrence in raptor populations to help shed light on the extent of this threat.

The fisher is a species whose range and prey base overlaps with the Northern Spotted Owl (Zielinski et al. 1999, Zielinski et al. 2004), thus, the impacts of rodenticides in fisher may be used as a surrogate for understanding potential impacts to Northern Spotted Owl. Thompson et al. (2013) studied impacts of ARs to fishers in the southern Sierra Nevada and found impacts of ARs in association with illegal marijuana grows significant. Toxicants found at grow sites within the southern Sierra Nevada included brodifacoum, and bromadiolone, and difethialone (SGARs), and diphacinone, chlorophacinone, and warfarin (FGARs). Thirty-nine out of 46 fisher carcasses recovered (88%) tested positive for one of more AR compound with brodifacoum being the most common (Thompson et al. 2013). A study in California's

Sierra Nevada found 79% of fisher carcasses (n=58) tested were exposed to ARs, and of that, 96% were exposed to SGAR compounds (Gabriel et al. 2013). Within a northern California study area (i.e., Hoopa Valley Indian Reservation) 52 fishers were tested for AR exposure (Gabriel et al. 2015). Seven fishers were confirmed to have died from AR poisoning, all of which had trespass marijuana grows within their home range (Gabriel et al. 2015). To better understand the potential extent of AR exposure in owls, an ongoing study is collecting and testing both Northern Spotted Owl and Barred Owl carcasses for AR exposure. Thus far, 4 Northern Spotted Owls were collected from remote forests in northwestern California, 3 of which tested positive for AR exposure, and over 50% of the 158 Barred Owls tested were positive (M. Gabriel, personal communication, December 20, 2015). The AR exposure rate for Barred Owls was 40% on Green Diamond's study area, where regular patrols limit the number and size of illegal grows, and 62% on the Hoopa study area (L. Diller, personal communication, 2015).

Given the results of the fisher studies (Gabriel et al. 2013, Thompson et al. 2013, Gabriel et al. 2015), preliminary results of laboratory testing on Spotted Owls (K. Rogers and M. Gabriel, personal communications), and the extent of marijuana cultivation in California (Gabriel et al. 2013, Thompson et al. 2013), it is likely that exposure to AR poses a serious and widespread threat to Northern Spotted Owls in California. Though the diet of Barred Owl and fisher vary somewhat from that of the Northern Spotted Owl, these species at least give some indication to the potential impacts of AR to Spotted Owls. The extent of exposure and impacts on overall owl fitness (e.g., survival and fecundity) remains unknown, and further research specific to Spotted Owl is warranted.

Sudden Oak Death Syndrome

Sudden oak death is an emerging plant disease particularly impacting hardwoods and expanding its distribution through a substantial portion of the Northern Spotted Owl range in California. Its impact on Northern Spotted Owl habitat includes large-scale die-off of tanoaks and other affected hardwood species. Die-offs will likely affect the habitat value of mature forests through simplifying the structure of the canopy, including the hardwoods' contribution to overall canopy cover. Die-offs could also affect early seral stage prey species, such as woodrats, by eliminating both cover and forage (both mast and leaves) derived from hardwood sources.

Sudden oak death is caused by a non-native, fungus-like pathogen (*Phytopthora ramorum*) which infects a variety of species. Davidson et al. (2003) and Garbelotto et al. (2003) note that nearly all tree species in mixed evergreen and redwood-tanoak forest types may be hosts; however, it is particularly lethal to tanoaks (*Lithocarpus densiflorus*). Several species of true oaks (*Quercus* spp.), especially those in the red oak subgroup, are susceptible. Members of the white oak subgroup appear to be unaffected (Davidson et al. 2003, Garbelotto et al. 2003). In other species it may cause dead bark, leaf blight, and twig dieback (Shaw 2007, USFWS 2011), or be asymptomatic (Davidson et al. 2003, Garbelotto et al. 2003). According to Goheen et al. (2006),

> "The pathogen has a wide host range including Douglas-fir, grand fir, coast redwood, and many other tree and shrub species common in Oregon and Washington forests. Tree mortality, branch and shoot dieback, and leaf spots result from infection depending on host species and location.

> *Phytopthora ramorum* spreads aerially by wind and wind-driven rain and moves within forest canopies and tree tops to stems and shrubs and from understory shrubs to overstory trees. The pathogen survives in infected plant material, litter, soil, and water. It is moved long distances in nursery stock… State and Federal personnel regularly survey forests and nurseries in the Pacific Northwest to detect the disease."

In 1995, sudden oak death was discovered in California within Mill Valley (Marin County), and has since spread across multiple coastal counties impacting coastal live oaks and tanoak forests (Tietje et al. 2006). According to recent submission to the GIS tool "OakMapper", confirmed locations of *P. ramorum* in California range from the coastal ranges in Monterey County and north up through portions of Humboldt County (California Oak Mortality Task Force 2015). Many studies have documented the widespread damage and mortality of oak-tanoaks coastal woodlands from Humboldt to Monterey counties (Rizzo and Garbelotto 2003, McPherson et al. 2006, Goheen et al. 2006, Cobb et al. 2010, 2012). The disease in California is likely linked to coastal climates that are typically warmer and wetter than more inland forest types (Shaw 2007). There is large-scale concern regarding the impacts of this disease on forest structure and composition in California, and the associated impacts to wildlife species that inhabit these forests.

Once sudden oak death infection is confirmed in an area, survival of susceptible species decreases quickly. Within coastal redwood forests from Sonoma to Monterey counties tanoaks confirmed to be infected died on average within 1-6 years, and larger trees that were close to other infected species, such as the California bay laurel (*Umbellularia californica*), were infected to a greater extent than smaller, more remote trees (Cobb et al. 2010). Tanoaks survived longer within redwood and Douglas-fir dominated forests than in hardwood dominated stands (Cobb et al. 2010). In Marin County, California, once infected with sudden oak death, live oak and tanoak survival declined as a function of disease state (McPherson et al. 2010). Coast live oak survival was 11.7 to 15.8 years for asymptomatic trees; 7.5 to 11.7 years for trees that were only "bleeding" (i.e. dark oozing fluid on trunk); and 2.6 to 3.4 years for trees bleeding with ambrosia beetles and/or bark beetle infestations (McPherson et al. 2010). Tanoak survival was 8.8 years for asymptomatic trees, 5.9 years for trees bleeding only, and 1.7 years for trees bleeding with ambrosia beetles and/or bark beetle infestations (McPherson et al. 2010).

After a susceptible tree is infected with sudden oak death fungi, secondary infection from other fungi and insects is common and impacts survival times (McPherson et al. 2006). For example, symptomatic progression and eventual mortality of coast live oaks and black oaks due to sudden oak death followed a similar sequence: bleeding, beetle colonization, emergence of *Hyposylon thouarsianum* (another fungal infection), and then death (McPherson et al. 2006). Here, approximately 50% of bleeding live oaks were infected by ambrosia beetles and bark beetles, or showed evidence of past beetle infestation, whereas beetles infested tanoaks with less frequency (McPherson et al. 2006).

The impact of sudden oak death on oak-tanoak forests will not likely subside in the future. Brown and Allen-Diaz (2006) examined past, current and future changes of coast live oaks-bay laurel woodland structure and composition within the San Francisco Bay Area due to sudden oak death infections. There was a 2-27% loss of coast live oak basal area (m^2/ha) during the study period (2002-2004), a 4-55% loss in the recent past (5-10 years prior to 2002) through 2004, and a projected 15-69% coast live oak basal area loss in the future, with a total stand basal area was predicted to decrease up to 42% within the next 5 years (Brown and Allen-Diaz 2006). Meentemeyer et al. (2010, 2011) predicted that with no control measures, sudden oak death will increase 10-fold by 2030, particularly along the coast north of San Francisco. The model suggests that wet weather conditions exacerbated by predicted change climate regimes serve to double the rate of spread in California (Meentemeyer et al. 2010). Predictive models note forests at high risk to sudden oak death in California occur in coastal forests of Santa Barbara County north through Humboldt County (Koch and Smith 2012).

Oak-tanoak forests are present within the Northern Spotted Owl range in California and are an important component to owl habitat (see Habitat Section of this report). Hardwood trees within conifer stands are not only important structural components within stands of suitable spotted owl habitat, but they also provide cover and food resources for the owl's main prey, the dusky-footed woodrat, as well as other small mammals that comprise a smaller component of the owl's diet. Higher densities of dusky-footed woodrats occur in early-seral redwood forests (Hamm 1995) so some loss of tanoaks in these areas may have less impact on woodrat abundance. Loss of some hardwood may benefit owl habitat in areas totally dominated by oaks at the expense of conifer, though this notion remains untested. The Department is unaware of published work evaluating either the structural consequences of sudden oak death with a focus on Northern Spotted Owl habitat or sudden oak death induced changes in the prey base. However, results from similar studies conducted outside of the Northern Spotted Owl range may inform potential or likely impacts of sudden oak death given what we know about owl habitat and prey needs.

Within an infected study site in Marin County, Temple and Tietje (2006) found coarse woody debris, a habitat component important for many small mammals, was 70 times higher than on an uninfected plot in Sonoma County, a difference supposedly due to sudden oak death-induced course woody debris generation. Within San Luis Obispo County, an area where sudden oak death has a low prevalence, areas in "high-risk" woodlands (i.e., those with species composition thought to be most impacted by sudden oak death) small mammals, including the dusky-footed woodrat, were more abundant (Tempel et al. 2006, Temple and Tietje 2006). The difference in species abundance between the sites is likely inherent, so the link to sudden oak death impacts in this comparison is unclear. However, these studies speculate that California bay laurel may replace coast live oak trees in the forest canopy. While having ecological importance, California bay laurel is relatively less productive than oaks as a wildlife habitat component.

Only one study has provided any direct link to Spotted Owl occupancy and habitat impacts due to sudden oak death. Within Big Sur forests of California, Holland et al. (2010) indicated that California Spotted Owl were more likely to occur in forests with greater amount of tree mortality, suggesting sudden oak death could benefit owls in the short-term by generating course woody debris (e.g., downed logs and branches), key habitat features for the owl's prey resources. However, Holland et al (2010) hypothesize that over the long-term, coarse woody debris and snags will decay and the supply will diminish thus prey resources may decrease and thereby impacting habitat suitability for the owls.

More generally, several studies indicate an impact on small mammal populations associated with sudden oak death infestations within coastal forests, but do not provide a link between Spotted Owl occupancy. Several studies suggested that that woodrats and mice (*Peromyscus* spp.) may benefit from immediate changes in habitat features (e.g., increase in coarse woody debris, increased shrub cover) within infected areas; however long-term abundance is less certain in the face of continued sudden oak death infection (Apigian et al. 2006, Temple and Tietje 2006). In addition, mortality from sudden oak death, or the treatment of sudden oak death outbreaks, may exacerbate problems associated with fuel accumulation and wildfire suppression (Valachovic et al. 2011).

The 2011 Northern Spotted Owl Recovery Plan (USFWS 2011) notes sudden oak death as a potential threat "due to its potential impact on forest dynamics and alteration of key prey and Spotted Owl habitat components (e.g., hardwood trees, canopy closure, and nest tree mortality)… especially in the southern portion of the Spotted Owl's range (Courtney et al. 2004)." However, the USFWS (2011) asserted that the extent of the impact of sudden oak death to owl habitat, prey species, and occupancy has not been thoroughly assessed. To address the shortfall of information, Recovery Action 17 of the 2011 Recovery Plan is to "Monitor for sudden oak death and avian diseases (e.g., WNV, avian flu, Plasmodium spp.) and address as necessary" (USFWS 2011). Monitoring techniques have been developed and may consist of regular aerial and ground surveys to assess rate of sudden oak death infection within oak-tanoak forest communities (Mai et al. 2006). However, such monitoring will detect spread well after a local invasion is established. Early detection techniques, such as eDNA sampling, may allow quicker intervention, but the efficacy of the various methods (Cobb et al 2013) still needs thorough evaluation.

Predation

The 2011 Revised Recovery Plan (USFWS 2011) states,

> "Known predators of Spotted Owls are limited to great horned owls (Forsman et al. 1984), and, possibly, barred owls (Leskiw and Gutiérrez 1998). Other suspected predators include northern goshawks, red-tailed hawks, and other raptors (Courtney et al. 2004). Occasional predation of Spotted Owls by these raptors is not considered to be a threat to Spotted Owl populations, so no criteria or actions are identified."

No new information has been generated since this statement was made, and therefore, the threat of predation to Northern Spotted Owls remains negligible.

Human Activities

Natural stress events (predator interactions, precipitous weather, disease, care of young), or anthropogenic stress events (vehicle traffic and noise, hikers) can impact species on multiple levels. This may include physiological impacts such as suppressed reproduction and growth, or behavioral responses such as avoidance (e.g., vocalizations and flushing).

Collecting and analyzing fecal samples has been shown to be effective at detecting stress hormone production (e.g., glucocorticoids) in owls (Wasser and Hunt 2005). By employing this methodology, a study conducted in the Shasta Trinity and Mendocino National Forests, California, found Northern Spotted Owls exhibit more stress when exposed to motorcycle activities, and exhibit lower reproductive success when exposed to busy roads (Hayward et al. 2014). Wasser et al. (1997) collected fecal samples from wild Northern Spotted Owl in Washington to measures stress hormone production in relation to timber activities (e.g., logging roads timber management). Males showed a more prominent increase in corticosterone production when the disturbance occurred with 0.41 km (0.25 miles) of the home range center, and in males whose home ranges were close to clearcut (vs. selective logging). Conversely, Northern Spotted Owls sampled in coastal northern California showed low levels of corticosteroid on a managed landscape with timer activities (L. Diller, personal communication, 2015). In the Sierra Nevada, chainsaws was used within 100 m of roost sites to induce a stress response in California Spotted Owls; however, no detectable difference was found in fecal corticosteroid levels (Temple and Gutiérrez 2003). When testing fecal corticosteroid levels in California Spotted Owls, Temple and Gutiérrez (2004) found the highest levels from a male at a nest site within 200 m from logging activities.

Presence of hikers has been shown to alter owl behavior at roosting and nesting sites. Stwarthout and Steidl (2001) found that juvenile and adult Mexican Spotted Owls were less likely to flush from the presence of a hiker at 212 and 224 meters, respectively, and neither juveniles nor adults were likely to alter behavior at distances 255 meter or more. At nesting territories, Mexican Spotted Owls in Utah increased contact vocalizations, decreased prey handling at the nest, decreased daytime maintenance with the presence of hikers (Swarthout and Steidl 2003).

Some recreational activities (e.g., hiking, roads, and motorcycles) may impact owls to some extent, but the level to which these activities may impact owl behavior, reproduction and overall survival has yet to be determined. It is unlikely anthropogenic stress events associated with recreation will impact Northern Spotted Owl reproduction and survival to any great extent, though, more field testing and research is may be warranted.

Loss of Genetic Variation

There had previously been little evidence in the literature of loss of genetic variation and population bottlenecks for the Northern Spotted Owl (Courtney et al. 2004). However, a recent genetic study across the range of the Northern Spotted Owl provides compelling evidence that a population bottleneck may have occurred within the last few decades (Funk et al. 2010). The study collected blood samples from 352 Northern Spotted Owls from six regions across the range which included limited samples from the northern portion of the California Klamath Province.

Funk et al. (2010) found the most significant evidence for recent (i.e., last several decades) bottlenecks in the Washington Cascades portion of the range, and no significant evidence of bottlenecks were found in the Olympics, Oregon Cascades, and Northwest California. The authors cautioned that genetic bottlenecks, while indicating a decrease in genetic variation and hence effective population size, do not necessarily indicate a decline in actual (demographic) population size (Funk et al. 2010) "… it is important to keep in mind that reductions in [effective population size] (detected with bottleneck tests) are different than reductions in demographic population size (detected with demographic field studies) and reductions in one of these parameters does not necessarily result in a change in the other." (Funk et al. 2010)

The scientific review of the Draft Recovery Plan reviewed unpublished genetic studies from Dr. Susan Haig (Courtney et al. 2008). Using samples collected from 352 owls, the results provided some evidence that recent bottlenecks have occurred at various spatial scales within the Northern Spotted Owl range, but could not definitively link the genetic declines to recent population declines (USFWS 2011, Courtney et al. 2008). Geneticists reviewing Haig's work concluded that the bottlenecks observed by Haig were likely the result of recent population declines rather than the cause of decline (Courtney et al. 2008). Specifically, Courtney et al. (2008) states, "The conclusion by Barrowclough and Coats (1985) is still appropriate here, which is that the population dynamics of the Spotted Owl likely will be more important to its short-term survival than will be its genetic makeup, regardless of the evidence for bottlenecks having occurred in the past. Our conclusions might warrant re-consideration at some future point, in the context of explicit evidence linking reductions in genetic diversity to current conditions, and current or future population performance."

Summary of Listing Factors

The California Endangered Species Act directs the Department to prepare this report regarding the status of the Northern Spotted Owl in California based upon the best scientific and other information available to the Department (Fish & G. Code, § 2074.6, subd. (a); Cal. Code Regs., tit. 14, § 670.1, subd. (f)). CESA's implementing regulations identify key factors that are relevant to the Department's analysis. Specifically, a "species shall be listed as endangered or threatened ... if the Commission determines that its continued existence is in serious danger or is threatened by any one or any combination of the following factors: (1) present or threatened modification or destruction of its habitat; (2) overexploitation; (3) predation; (4) competition; (5) disease; or (6) other natural occurrences or human-related activities." (Cal. Code Regs., tit. 14, § 670.1, subd. (i)(1)(A)).

The definitions of endangered and threatened species in the Fish and Game Code guide the Department's scientific determination. An endangered species under CESA is one "which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, over exploitation, predation, competition, or disease." (Fish & G. Code, § 2062). A threatened species under CESA is one "that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of special protection and management efforts required by [CESA]." (*Id.*, § 2067).

The Department has summarized its conclusions for each of the listing factors below:

Present or Threatened Modification or Destruction of Habitat

Timber Harvest and Regulatory Considerations

Although the rate of nesting and roosting habitat loss has declined since the Northern Spotted Owl was listed under the federal endangered species act in 1990, assessments performed range-wide since the implementation of the NWFP show that habitat loss on federal and private lands is ongoing. Wildfire has been the leading cause of habitat loss on federal land, with the fire-prone California Klamath Province experiencing the largest losses due to wildfire (10.7%; 199,800 acres since 1993). Since the development of a reserve system under the NWFP, timber harvest on federal land has declined, with only 1.3% of nesting and roosting habitat lost to harvest in the last two decades (Davis et al. 2015). Conversely, timber harvest has been the primary cause of habitat loss on nonfederal lands since 1993 (Davis et al. 2015). Although state regulations governing timber harvest on nonfederal lands in California (i.e., Forest Practice Rules) are the most protective state regulations in the range of the Northern Spotted Owl, losses of nesting and roosting habitat due to timber harvest in California have continued. From 1994-2007, 5.8% of nesting and roosting habitat on nonfederal lands in California was removed by timber harvest (Davis et al. 2011). Forest succession since 1994 has resulted in replacement of an unknown amount of nesting and roosting habitat, but forest growth in the two decades since implementation of the NWFP has resulted in limited recruitment of new habitat across most of the range. The California Klamath and Cascades provinces have experienced net losses of nesting and roosting habitat since 1994 (Davis et al. 2015). However, due to habitat recruitment in the California Coast Province where habitat development through forest succession can occur relatively quickly (Thome et al. 1999, Diller et al. 2010), estimates for net change of nesting and roosting habitat in this province are positive (Davis et al. 2015).

At the scale of individual owl territories, the amount and spatial configuration of different habitat types are strongly linked to Northern Spotted Owl site occupancy and demographic rates, and rates are generally positively associated with a greater amount of older forest (see the Habitat Effects on Demographics section; Dugger et al. 2016). The amount of older forest in Northern Spotted Owl territories is positively associated with occupancy rates (Dugger et al. 2011, Yackulic et al. 2012, Dugger et al. 2016), survival (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005, Diller et al. 2010), and in some cases with fecundity (Dugger et al. 2005, Diller et al. 2010, Dugger et al. 2016). Although study design has varied across the major research studies in California and southern Oregon, some consistent patterns have arisen. In order to support productive Spotted Owl territories, a minimum amount of older forest must be retained in the core area. The definition of 'older forest' evaluated in studies has varied, but consistently has included late-seral forests with large trees and high canopy cover. Territories with the highest habitat fitness potential contain at least about 50% older forest in the core area, intermixed with other forest and nonforest cover types (Franklin et al. 2000, Dugger et al. 2005, Diller et al. 2010). Large amounts of nonhabitat (defined as nonforest or sapling cover types) in a Northern Spotted Owl home range leads to declines in demographic rates. Results indicate that in order to support a Northern Spotted Owl territory with high habitat fitness potential, no more than about 50% of a home range should consist of nonhabitat (Olson et al. 2004, Dugger et al. 2005).

Minimum habitat retention requirements for timber harvest on nonfederal land in California and definitions of Northern Spotted Owl habitat in the Forest Practice Rules (Section 919.9 [939.9] subsection (g) and Section 895.1) do not appear to be sufficient to meet the habitat needs of Northern Spotted Owls in all cases. Habitat retention requirements and definitions were developed in the early 1990s and were established to protect a combination of nesting, roosting, and foraging habitat in the area immediately surrounding the activity center (500 and 1,000 foot radii), the core use area (0.7 mile radius), and the broader home range (1.3 mile radius). The USFWS found that the cumulative effects of repeated harvest entries within many Northern Spotted Owl home ranges in the northern interior region had reduced habitat quality to a degree that caused reduced occupancy rates and frequent site abandonment, and concluded that existing habitat guidelines in the Forest Practice Rules are not sufficient for avoiding take (USFWS 2009). Because of these concerns and based on the growing body of literature linking habitat characteristics to owl fitness, the USFWS provided revised guidance for avoiding take of Northern Spotted Owl, including changes to definitions of nesting, roosting, and foraging habitat, and to the amount of each habitat type to be retained (USFWS 2008b, 2009).

A comparison of the habitat definitions in the Forest Practice Rules (see Appendix 2) and the revised USFWS recommendations (see Table 22 for the interior portion of range in California) shows discrepancies in the definitions of nesting and roosting habitat. Under the Forest Practice Rules minimum retention requirements and habitat definitions, stands that meet the USFWS definition for nesting or roosting habitat must be retained within 500 feet of a nest (~18 acres). This is an inadequate amount of nesting habitat to support productive Northern Spotted Owls. The remainder of the 500 acres of Spotted Owl habitat that must be retained within 0.7 miles and the total of 1,336 acres that must be retained within 1.3 miles of an activity center can be composed of “functional foraging habitat” under Forest Practice Rules, a definition that is considered low quality foraging habitat by the USFWS. Therefore, there is no requirement under the Forest Practice Rules for habitat beyond 500 feet of a nest tree to include nesting or roosting habitat.

When reviewing a proposed timber harvest plan, CAL FIRE must make a finding as to whether or not the proposed timber operations will avoid take of Northern Spotted Owl (Forest Practice Rules Section 919.10 [939.10]). The degree to which the Northern Spotted Owl population is affected by timber harvest at activity centers depends on the habitat protection measures required by CAL FIRE in making this determination. After receiving revised guidance from the USFWS in 2008, CAL FIRE recommended that THP proponents consider incorporating habitat definitions and protection measures recommended by the USFWS (CAL FIRE 2008). In 2012, CAL FIRE reported that application of option (g) had involved using the standards contained in the Forest Practice Rules and often included additional measures derived from USFWS-recommended take avoidance guidelines (CAL FIRE 2012). Documentation of habitat types, amount, and distribution remaining around activity centers after harvests are conducted is poor, so it is difficult to broadly assess the degree to which THPs have met either the Forest Practice Rules or the USFWS recommendations for habitat retention. However, the Department’s assessment of cumulative timber harvest at a small number of Northern Spotted Owl activity centers reveals that in some cases harvest plans have not met habitat retention guidelines described in the Forest Practice Rules or the revised USFWS guidelines (USFWS 2008b), and could have resulted in negative impacts to

Northern Spotted Owl occupancy rates or fitness on some nonfederal lands. A thorough assessment of all activity centers at which timber harvest has been proposed is beyond the scope of this status review.

The THP review and post-harvest follow-up process should ensure that the best scientific information is being considered to avoid take of Northern Spotted Owl at known territories. Evaluation of additional timber harvest plans, collection of detailed pre- and post-harvest habitat data at a resolution that accurately quantifies Northern Spotted Owl habitat characteristics, and assessment of the response by territorial owls would be required to more fully evaluate the impact of timber harvest on owls. These activities should be applied in an adaptive management approach to better manage Spotted Owl habitat and to understand whether current practices are working or where they can be improved.

Wildfire and Salvage Logging

Wildfire and other natural disturbance has been the leading cause of habitat loss on federal land in the Northwest Forest Plan area; and the leading cause of nesting and roosting habitat loss in California from 1993-2012. The majority of the nesting and roosting habitat lost from the California portion of the Northwest Forest Plan area has been attributed to wildfire, and most of that loss has occurred in the Klamath Province.

The response of Spotted Owls to fire has been mixed. In some cases, Spotted Owls have been shown to use burned areas extensively, although nesting and roosting generally occurred only in unburned or low-severity burn areas. In these cases, foraging occurred across all burn severity types. Occupancy by California Spotted Owls across a wide area in the Sierra Nevada has been observed to be similar in burned and unburned areas, at least in burn areas that experienced mixed-severity burns. There is some evidence that high severity burns in the Sierra Nevada have resulted in declines in occupancy.

Conversely, occupancy rates for Northern Spotted Owls in southern Oregon declined following fire. These occupancy declines resulted from both high extinction rates in burned areas and low colonization rates. Northern Spotted Owls displaced by fire or occupying burned areas have also been shown to experience declines in survival rates. Food limitation in burned areas may have also been a factor in these declines. Northern Spotted Owls in southern Oregon were also shown to avoid large areas of high severity burn or areas experiencing extensive salvage logging post-fire.

Several variables complicate the interpretation of studies of owl response to fire, including variation in fire severity, fire size, fire history and pre-fire forest composition, post-fire salvage logging, and the timing and duration of research post-fire. Additionally, the key studies of Northern Spotted Owl response to wildfires in southern Oregon were unable to separate the effects of severe burns from salvage logging, but observational studies and occupancy modeling conducted to date suggest that post-fire landscapes that are salvage logged experience declines in Spotted Owl occupancy. The presence of snags has been suggested as an important component of prey habitat and as perch sites for foraging Spotted Owls. Conditions that lead to increased prey availability, including increased shrub and herbaceous cover and number of snags, may be impacted by salvage logging. The available information suggests that fires that burn at mixed severities or at small scales such that they create habitat heterogeneity without removing important nesting and roosting habitat components at the territory scale may benefit owls. However, uncharacteristically severe fires that burn at large scales are likely to have negative effects by eliminating required nesting and roosting habitat or reducing prey populations in Northern Spotted Owl territories. Additional studies over long durations are needed in order to inform the degree to which fire affects Spotted Owl, and the degree to which fire may be used as a management tool.

In recent decades, fires have become more frequent and average fire size has increased. In some cases fires have also burned at uncharacteristically high severities, especially during weather conditions that support fire (dry and hot conditions). Because climate change will likely increase the likelihood of conditions that support more frequent, large, and severe fires which are destructive to Northern Spotted Owl habitat, habitat loss due to wildfires will likely continue to present a risk to owls in the future.

Climate Change Impacts to Forest Composition and Structure

Most climate projection models indicate elevational and latitudinal shifts in forest habitats in the coming century. In climate projection scenarios specific to California, the most notable response to increase temperature was a shift from conifer-dominated forests (e.g., Douglas fir-white fir) to mixed conifer-hardwood forests (e.g., Douglas fir-tan oak) in the northern half of the state), expansion of conifer forests into the northeast portion of the state (e.g., Modoc Plateau), an increase dominance of oak forest at the expense of pine forest, a general decrease in large trees and basal area, shifts of redwood forests inland into Douglas-fir-tan oak forests, and advancement of conifer-dominated forests (e.g., redwood and closed-cone pine forests) along the north-central coast. Presence of fog along the coast may also decrease. Tree productivity along California's north-central coastal forests, and at high elevation forests may increase in response to longer growing seasons and increased growing season temperatures. The impacts of fog presence along the coastal redwood forest on productivity and growth has mixed results, with some studies suggesting decreased productivity and others suggesting an increase. The literature also suggests that climate change variables will increase the severity and frequency of wildfires within the Northern Spotted Owl range which would convert older, complex forests to young uniform stands of less suitable habitat.

Although climate projection models have uncertainties built-in, it is apparent from the literature that forests within California will likely experience some level of elevational and latitudinal shifts, changes in species composition, and alterations in fire regimes. The Northern Spotted Owl has a heavy reliance on specific forest structure components and tree species composition, and on associated prey habitat and abundance. Implications of forest shifts and fire regime changes on owl habitat and demographic rates remains uncertain, and more research is needed to elucidate whether these patterns will lead to negative impacts to Spotted Owls. Long-term landscape planning related to Northern Spotted Owls and their habitat should incorporate potential climate change impacts.

Other Mechanisms of Habitat Loss

Sudden Oak Death

Sudden oak death is an emerging plant disease caused by a non-native, fungus-like pathogen particularly impacting hardwoods (Davidson et al. 2003, Garbelotto et al. 2003, Goheen et al. 2006). The disease is expanding its distribution through a substantial portion of the Northern Spotted Owl range in California (California Oak Mortality Task Force 2015). Its impact to Northern Spotted Owl habitat includes large-scale die-off of tanoaks and other affected hardwood species (e.g., live oak, California bay laurel), reduction of hardwood canopy closure, simplified canopy structure, and reduced primary prey species (i.e., woodrat) abundance (Rizzo and Garbelotto 2003, McPherson et al. 2006, Goheen et al. 2006, Tietje et al. 2006, Cobb et al. 2010, 2012).

The impact of sudden oak death on oak-tanoak forests within Northern Spotted Owl habitat will not likely subside in the future (Brown and Allen-Diaz 2006, Meentemeyer et al. 2010, 2011), with high risk areas noted in coastal forests of Santa Barbara County north through Humboldt County (Koch and Smith 2012). Ultimately, spread of sudden oak death will likely result in reduced nesting, roosting and foraging opportunities for Northern Spotted Owls in most cases. The recovery plan (USFWS 2011) recognizes that sudden oak death has a potential impact to owl habitat, especially in the southern portion of the range, and notes the need for monitoring efforts to better understand the extent and impact to Northern Spotted Owls. Monitoring techniques have been developed to assess rate of sudden oak death infection within oak-tanoak forest communities (Mai et al. 2006), but may only be useful to detect the spread well after infection is established. Early detection techniques (e.g., eDNA sampling) and efficacy of various monitoring methods needs further investigation (Cobb et al 2013). Impacts of a decreased hardwood forest component, shifting forest structure, and the changes in Northern Spotted Owl prey base, resulting from an increased prevalence of sudden oak death also needs further investigation.

Marijuana Cultivation

Illegal and legal marijuana cultivation sites in remote forests on public and private land throughout California has been steadily increasing. Within the range of the Northern Spotted Owl, Shasta, Tehama, Humboldt, Mendocino, and Trinity counties comprise the areas known for the most marijuana cultivation in California due to the remote and rugged nature of the land (making cultivation difficult to detect), and habitat conditions favorable for growing marijuana (e.g., wetter climate, rich soils) (Gabriel et al. 2013, Thompson et al. 2013, National Drug Intelligence Center 2007, Bauer et al. 2015). Given the difficulties in detecting illegal marijuana cultivation sites and the lack of reporting for all legal cultivation sites, actual distribution and density of marijuana cultivation is likely larger and higher than current data suggests.

Activities associated with cultivation (e.g., removal of large trees, degradation of riparian habitat, use of rodenticides) may negatively impact Northern Spotted Owl habitat, and in turn, owl fitness (e.g., survival, fecundity), although there is little data assessing this impact. Areas with higher prevalence of marijuana cultivation sites may also contain high numbers of Northern Spotted Owl activity centers

(National Drug Intelligence Center 2007). The level of impact likely depends on several factors, including the density of cultivation sites in proximity to owl activity centers and how much owl habitat is affected and to what extent. Given that marijuana cultivation is on the rise in California, a thorough assessment of potential habitat impacts to Northern Spotted Owls should be implemented.

Abundance and Demographic Rates

There are no reliable range-wide estimates of Northern Spotted Owl population abundance because there is no sampling method that effectively detects all owls in a given area. There are 3,116 known Northern Spotted Owl activity centers in California, but the number of these sites occupied in any year is unknown, so this number represents the cumulative number of territories recorded over time in a dynamic landscape rather than an index of abundance. The immense amount of data available on Northern Spotted Owl habitat requirements and availability, home range sizes, age-specific survival rates, age-specific fecundity, dispersal behavior, and impacts of Barred Owls on survival, were used to model source-sink dynamics across the range of the owl and to simulate an estimate of population size (Schumaker et al. 2014). Simulations produced a range-wide population size of about 3,400 female Northern Spotted Owls, with about half of these occurring in California. However, the complexity of the model and its reliance on incomplete data limits its ability to accurately model population estimates, as demonstrated by its inability to correctly simulate the number of owls in some areas with known populations of territorial owls.

A huge effort to monitor the effectiveness of the NWFP has resulted in an enormous amount of data on the demographics of Northern Spotted Owl populations. These data have been collected over more than two decades at study areas covering a large portion of the Northern Spotted Owl range from Washington to California, and represent a mix of federal, private, and tribal lands (Dugger et al. 2016). The data likely represent the best population demographic information on an endangered species ever assembled (Gutiérrez 2008) and allow for estimation of population vital rates across a large portion of the Northern Spotted Owl range. Vital rates have been evaluated on each of 11 individual study areas and data from all study areas were combined for a range-wide assessment of population status and trends (meta-analysis) (Dugger et al. 2016). Population parameters estimated include the annual rate of population change, survival, fecundity, recruitment, site occupancy, and occupancy dynamics (colonization and local extinction rates).

Northern Spotted Owl populations are declining throughout the range of the subspecies and annual rates of decline have been accelerating in many areas, including in California. The range-wide population of Northern Spotted Owls is estimated to have declined by 3.8% per year since 1985 (Dugger et al. 2016). On all three study areas in California, vital rates estimated from these long-term datasets, including fecundity, survival, site occupancy, and rate of population change are declining, and the rates of population decline have accelerated in recent years on all three areas. Between 1995 and 2013, Northern Spotted Owl occupancy rates declined on all 3 California demographic study areas in California (75% to 38% in NWC, 79% to 47% in HUP, and 92% to 55% in the GDR control area; Dugger et al. 2016). In addition to the declines observed at these study areas in the California Coast and Klamath provinces, an independent study of occupancy that includes private timberlands in the California Cascades Province has shown declines in occupancy (Farber and Kroll 2012), and a study area just across the border in Oregon has shown that populations in the southern Cascades have experienced declines in population size, occupancy rate, and survival (Dugger et al. 2016).

Together these results reveal severe declines in the Northern Spotted Owl population throughout much of its range in California. Causes of population declines have included reductions in recruitment of owls into the breeding population (including fecundity) and reductions in apparent survival, both of which have been declining on all California study areas. In recent years, the declines in vital rates and populations in California have deteriorated to levels previously restricted to more northerly portions of the subspecies range in Washington and Oregon. With the exception of the Green Diamond Resource Company treatment areas where Barred Owls have been removed, the population sizes at California study areas have declined 31-55% since the 1990s and these declines are accelerating (Dugger et al. 2016). The rates of site occupancy at known territories in California study areas and in additional areas in the Cascades have declined dramatically, with 39-49% declines in occupied sites since 1995. These severe and accelerating declines, which until recently were relatively minor in California, puts the Northern Spotted Owl at risk of becoming extinct in all or a significant portion of its range in California in the absence of management efforts that can adequately address threats to the subspecies.

Although many factors have contributed to these declines, the best evidence suggests that increasing numbers of Barred Owls in California have had a strong negative impact on Northern Spotted Owls in recent years, primarily by decreasing apparent survival and increasing local territory extinction rates (Dugger et al. 2016). However, the amount of suitable owl habitat, local weather, and regional climatic patterns also effected survival, occupancy, recruitment, and fecundity. The ongoing and increasing effects of Barred Owls on Northern Spotted Owl populations, coupled with other threats including habitat loss due to timber harvest and wildfire and reduced recruitment due to climate change, will lead to additional declines in Spotted Owl populations unless additional management intervention is undertaken.

Predation

Though suspected predators of Northern Spotted Owls include Barred Owl, Northern Goshawk, Red-tailed Hawks, and other raptors, there is little evidence to suggest predation is a widespread threat. The 2011 Revised Northern Spotted Owl Recovery Plan also recognized that predation of Northern Spotted Owls is not a threat to the population. In the case of documented Barred Owl aggression toward Northern Spotted Owls, it is unclear if Barred Owls target Spotted Owls as prey, or if the documented mortalities were due to territorial aggression. Given that predation is not considered to be a major threat to Northern Spotted Owls at this time, the Department is not recommending actions to directly manage predation issues.

Competition

Historically, Barred Owls were residents of the eastern United States and southern Canada, east of the Great Plains and south of the boreal forest, and also in disjunct regions of south-central Mexico (Mazur and James 2000). The recent range expansion into the western United States has resulted in the Barred Owl range completely overlapping with that of the Northern Spotted Owl. Barred Owls were first detected in California in 1976 (B. Marcot in Livezey 2009a) with the first breeding record in 1991 (T. Hacking in Dark et al. 1998). The rate of detections in California accelerated during the mid-1990s (Dark et al. 1998), and today 1,970 Barred Owl records exist in the Department's species database throughout the entire range of the Northern Spotted Owl, and even further south within the California Spotted Owl range in the Sierra Nevada.

There is a high degree of similarity in Barred Owl and Northern Spotted Owl habitat and prey base preferences. Both species have a preference for old forests with closed canopy and a high degree of structural complexity for nesting and roosting activities (Hamer et al. 2007, Singleton et al. 2010, Weins et al. 2014, Singleton 2015, Weisel 2015). Northern Spotted Owl in California consists primarily of small mammals (mainly dusky-footed woodrats in California), though other prey (e.g. birds, bats) is also taken (Forsman et al. 1984, 2001, 2004, Zabel et al. 1995, Ward et al. 1998, Franklin et al. 2000, Hamer et al. 2001). The Barred Owl diet consists of a wide array of prey, including small mammals ranging from rabbits to bats, small to medium sized birds, amphibians, reptiles, fish, and invertebrates; however, mammals make up a majority of prey items (Hamer et al. 2001, Mazur and James 2000, Mazur et al. 2000). The broader range of prey selected by Barred Owls contributes to the smaller home ranges in comparison to Northern Spotted Owls, which may result in higher densities of Barred Owls within the Spotted Owl range (Livezey et al. 2008).

Barred Owls will negatively impact Northern Spotted Owls at several levels. Barred Owls are aggressive toward Spotted Owls (Van Lanen et al. 2011), and have attacked Spotted Owls on occasion (Leskiw and Gutiérrez 1998, Courtney et al. 2004). Spotted Owls will reduce their calls or not call at all if Barred Owls are in the vicinity (Cozier et al. 2006, Kroll et al. 2010, Dugger et al. 2011, Diller 2014, Sovern at al. 2014), making them more difficult to detect. Barred Owls will displace Northern Spotted Owls from their territories, forcing them out of their long-held territory (Olson et al. 2004, Kroll et al. 2010, Dugger et al. 2011, Diller 2014, Sovern et al. 2014, GDRC 2015, Weisel 2015, Dugger et al. 2016). Northern Spotted Owl activity centers will shift away from areas where Barred Owls are present even if they do not entirely abandon their territory (Kelly 2001, Gremel 2005, Diller 2014, Weins et al. 2014).

Competition between the two species has dramatically impacted Northern Spotted Owl site occupancy in California. A recent analysis (Dugger et al. 2016) determined territory occupancy rates declined in all 11 demographic study areas across the entire Northern Spotted Owl range, with a strong positive relationship between the presence of Barred Owls and territory extinction rates (Dugger et al. 2016). The primary cause of Northern Spotted Owl population declines are competition with Barred Owl, largely as a result of a strong negative effect of Barred Owl on Northern Spotted Owl apparent survival rates and a positive effect of Barred Owl on Northern Spotted Owl extinction rates.

When analyzing Northern Spotted Owl data through 2013, Dugger et al. (2016) indicated the primary cause of declines across the range are a result of a strong negative effect of Barred Owl on apparent survival rates and a positive effect of Barred Owl on extinction rates. Apparent survival and the rate population change rates declined on all 3 demographic study areas in California, with the exception of the Green Diamond Resource treatment area (i.e., the area where barred owls were removed). The Green Diamond Resource treatment area survival rate was 0.857 (SE=0.009) before removal, and 0.870 (SE=0.021) after removal (the highest across the entire range; Dugger et al. 2016). The rate of population change at the Green Diamond Resource treatment area was positive (λ=1.030, SE=0.040) after Barred Owls were removed (Dugger et al. 2016). When Barred Owls were removed from historical Northern Spotted Owl territories on the Green Diamond Resource Company land, Northern Spotted Owls were detected relatively soon afterward, and sometimes were the same Spotted Owls that held the territory previously (Diller 2014), suggesting these owls were displaced from their territory but remained in the vicinity to quickly reoccupy.

The literature is clear that Barred Owls are having a severe negative impact on Northern Spotted Owl at a range-wide level (Dugger et al. 2016), including reduced survival and occupancy, reduced detection rates, increased extinction rates, displacement, and predation. Ecological similarities between Barred Owl and Northern Spotted Owl gives little evidence that nesting, roosting, or foraging habitat or food resources can be adequately partitioned to prevent competition; therefore, coexistence of both species is uncertain into the future, even with habitat management action (Gutiérrez et al. 2007, Dugger et al. 2007, Wiens et al. 2014, Singleton 2015, Weisel 2015, Dugger et al. 2016). Barred Owl removal experiments seem to be successful at positively impacting Northern Spotted Owl demographics and are feasible at a local-scale (Diller et al. 2014), but broader long-term use of removal as a management tool needs further consideration (USFWS 2013). Protecting high-quality habitat (e.g., older structurally complex forests) on the landscape may provide some amount of refugia for Spotted Owls from competitive interactions with Barred Owls, and may allow managers and others time to further evaluate the feasibility of Barred Owl control measures (USFWS 2011, USFWS 2013).

Given the quick southerly expansion of Barred Owls into Northern Spotted Owl habitat and the documented negative impacts of Barred Owl on Spotted Owl demographic rates, there is urgency on deciding a course of action to take regarding Barred Owl removal or other management actions. Without management actions, the Northern Spotted Owl faces an uncertain future and declines will presumably continue to be severe and steep into the near future, much like has been documented in more northerly portions of the range in Washington and Oregon where Barred Owl have been established longer. To ease the negative public response to long-term Barred Owl lethal removal, if such action were decided on, outreach efforts should be instituted regarding the serious threat Barred Owls pose to Northern Spotted Owl populations. In addition, maintaining old-growth on the landscape, as well as investigating the potential for resource partitioning between Northern Spotted Owls and Barred Owls, are essential steps in limiting competitive exclusion of Spotted Owls from their preferred habitat.

Disease

West Nile Virus is prevalent in other raptor species in California and across the United States (Hull et al. 2006, Ellis et al. 2007, Saito et al. 2007, Hull et al. 2010). However, there is some variation as to whether infected individuals exhibit clinical signs and uncertainty to the extent infected individuals succumb to the disease. Vectors for disease transmission to raptors have been documented, and include mosquitos

(Ellis et al. 2007), louse flies (Gancz et al. 2004), and from eating infected prey (Padgett et al. 2007, Wheeler et al. 2009, Hull et al. 2010).

Haemosporidian blood parasites were found in Northern Spotted Owls, California Spotted Owls, and Barred Owls, with a greater infection load in Spotted Owls compared to Barred Owls (Gutiérrez 1989, Ishak et al. 2008, Lewicki et al. 2015). Other diseases and parasites documented in Spotted Owl populations include Trichomonosis (K. Rogers, personal communication, 2015), tick transmitted Borreliosis (Thomas et al. 2002), helminth parasites (Hoberg et al. 1989), enteric coccidia (Hoberg et al. 1993), Hippoboscid flies (Young et al. 1993), ticks and fleas (Hunter et al. 1994), and feather lice (Hunter et al. 1994). Diseases known to impact other raptor species, but not yet documented in Spotted Owl include avian malaria and avian influenza.

Disease occurrence in Northern Spotted Owls is likely under-reported because owls tend to inhabit remote areas where carcass recovery is difficult. Therefore, relatively low disease prevalence in California's Northern Spotted Owl population may be due to the poor detection rate of carcasses, not necessarily a lack of infection in the population. In addition, most research has not assessed the impacts of disease on survival or reproductive fitness. The 2011 Revised Recovery Plan (USFWS 2011) states, "It is unknown whether avian diseases such as West Nile virus (WNV), avian flu, or avian malaria… will significantly affect Spotted Owls." To assess these shortfalls in information, further research is needed regarding the type of diseases most prevalent in the population and if those diseases have an impact on Northern Spotted Owl demographic rates.

Other Natural Events or Human-related Activities

Contaminants

The main contaminant threat to the owls is intoxication from secondary anticoagulant rodenticide (an acutely toxic substance that persists in tissues and in the environment) exposure from either first- or second-generation anticoagulant rodenticides. Given the widespread occurrence of marijuana grows within the Northern Spotted Owl range, owl exposure to anticoagulant rodenticides is likely occurring as a consequence. Growers will apply second-generation anticoagulant rodenticides at the base of plants to prevent small mammals from damaging the crop (Thompson et al. 2013, Gabriel et al 2013). This presents a risk to predators of small mammals, such as the Northern Spotted Owl, (Gabriel et al. 2013).

Studies on other species that share the same prey-base can give some indication to the potential impacts to the Northern Spotted Owl population in California. Numerous field monitoring studies on other raptor and owl species indicate lethal and sublethal impacts of anticoagulant rodenticides exposure (Mendenhall and Pank 1980, Stone et al. 2003, Walker et al. 2008, Albert et al. 2009, Lima and Salmon 2010, Murray 2011, Thomas et al. 2011, Christensen et al. 2012, Sánchez-Barbudo et al. 2012). The Department's Wildlife Investigation Laboratory has found that raptors comprise two-thirds of the anticoagulant-related wildlife mortalities submitted. Anticoagulant rodenticides exposure associated with trespass marijuana grows and subsequent mortality has been documented for fishers (Gabriel et al.

2013, Thompson et al. 2013, Gabriel et al. 2015), a mammalian species whose range and prey-base overlap with Northern Spotted Owl.

The Department's Wildlife Investigation Laboratory has found positive anticoagulant rodenticides exposure in all Spotted Owl carcasses tested thus far, including 5 Northern Spotted Owls and 6 California Spotted Owls (K. Rogers, personal communication, December 18, 2015). Four Northern Spotted Owls and 158 Barred Owls were collected from remote forests in northwestern California; 3 Northern Spotted Owls and over 50% of Barred Owls carcasses tested positive for anticoagulant rodenticides exposure (M. Gabriel, personal communication, December 20, 2015).

Given the high-level of anticoagulant rodenticides exposure in other raptors and fisher, the preliminary results of Spotted and Barred Owl exposure studies, and the extent of marijuana cultivation across the Northern Spotted Owl range in California, it is likely that exposure to anticoagulant rodenticides poses a serious and widespread threat to Northern Spotted Owls. The extent of exposure to Northern Spotted Owls and impacts on overall owl fitness (e.g., survival and fecundity) remains unknown and is in need of further research.

Precipitation and Temperature Changes

Most climate projection scenarios agree that the forests in the Northern Spotted Owl's range will have wetter winters and early-springs, colder winters in some areas, hotter drier summers, and increased frequency and intensity of disturbance events. According to many climate projections, the frequency and duration of extreme climatic events, such as heat waves, wildfire and heavy rain or snow will increase over time. These changes will impact Northern Spotted Owls directly, as well as their forest habitats. Vulnerability to disturbance, such as wildfire, disease, and insect outbreaks, is expected to increase in most forests in the Northwest and may change forest composition and structure depending on changes to climate. Climate modeling studies agree that forest wildfire occurrence and severity will increase in most areas due to warmer spring/summer temperatures, reduced precipitation, reduced snowpack, earlier spring snowmelts, and longer drier summers.

Several studies investigated temperature and precipitation effects on Northern Spotted Owls. These studies indicate that winter precipitation is closely associated with a decrease in survival and recruitment; wetter conditions during the growing season (May through October) are positively associated with population growth; and cold wet winters and extreme heat events are negatively associated with population growth. Additionally, Northern Spotted Owls exhibit behaviors that suggest they are sensitive to high temperatures. Increasing summer temperatures could result in more heat-stress, and reduced population growth.

It is clear that climate change is occurring within the Northern Spotted Owl's entire range, with many climate projections forecasting steady changes in the future. Precipitation and temperature trends may play a role in both owl and prey population dynamics. More research is needed to assess the extent of these climate impacts on survival, population growth, and reproductive rates of Northern Spotted Owls in California and to explore the species' capacity to adapt to a changing climate.

Recreational Activity

Relatively few studies have been conducted on the impact of recreational activity on Northern Spotted Owls. A few studies suggest that stress levels increase in individual Northern Spotted Owls when exposed to motorcycle activities, timber harvest activities, and presence of hikers. It is clear recreational activities impact Northern Spotted Owls to some extent, but the level to which these activities may impact owls has yet to be determined. It is unlikely anthropogenic stress events associated with recreation will impact Northern Spotted Owl reproduction and survival to any great extent, though further research is warranted.

Loss of Genetic Variation

Loss of genetic variation is not considered to be a major threat to Northern Spotted Owls at this time, but if populations continue to decline, it could become an additive threat factor. Some recent studies provide evidence that a population bottleneck may have occurred within the last few decades across the range of the Northern Spotted Owl; though no effect was documented for Northwest California.

Management Recommendations

The goal of the Department is to secure recovery and long-term survival of the Northern Spotted Owl across their historic range. The Department has evaluated existing management measures and has identified the following management recommendations, listed in no particular order, as necessary to help achieve the aforementioned goal. Many of these recommendations are adapted from the USFWS Northern Spotted Owl Recovery Plan (USFWS 2011) and are based on the best available scientific information on the Northern Spotted Owl. The USFWS Recovery Actions (RA) are cited below where applicable. As new information becomes available, recommendations may be further refined.

<u>Planning and Timber Management Practices</u>

1. Encourage applicants to develop landscape-level planning (e.g., HCPs, NCCPs, and SHAs) that is consistent with the recovery of the Northern Spotted Owl (see RA14).

2. Consider, analyze and incorporate, as appropriate, potential climate change impacts in long-range planning, setting priorities for scientific research and investigations, and/or when making major decisions affecting the Northern Spotted Owl (see RA5).

3. Assist USFWS in soliciting recommendations from stakeholders to facilitate creative opportunities for nonfederal landowners to engage in management strategies (see RA15).

4. Consider long-term maintenance of local forest management infrastructure as a priority in planning and land management decisions (see RA16).

5. Coordinate with USFWS, Board of Forestry, and CAL FIRE in developing scientifically-based and contemporary Forest Practice Rules to (1) provide for the breeding, feeding and sheltering of Northern Spotted Owls (see RA21) and (2) conserve existing owl sites and high quality habitat (see RA10).

6. Develop a mechanism to regulate, manage, and monitor hardwood control measures (e.g., "hack and squirt") that are detrimental to Northern Spotted Owl foraging habitat.

7. Coordinate with USFWS, CAL FIRE and individual stakeholders in evaluating: (1) the potential recovery role of Northern Spotted Owl sites and high-quality habitat on nonfederal lands in California, and (2) implementation of appropriate conservation tools (e.g., carbon sequestration, HCPs, NCCPs, SHAs) to assist with supporting recovery (see RA20).

8. Improve documentation of harvest prescription methods within timber harvest plans (i.e.,. increase amount and detail of information), and conduct rigorous evaluations of post-harvest levels of foraging, nesting, and roosting habitat.

9. Evaluate the effects of silvicultural practices on important Northern Spotted Owl prey species (e.g., flying squirrel, woodrat) and their required habitat.

10. Institute an adaptive management approach to better manage Spotted Owl habitat and to understand whether current practices are working or where they can be improved. This approach should include, post-THP monitoring to assess response of Spotted Owls, including whether harvested sites remain occupied by Northern Spotted Owls and what levels of harvest render them unoccupied.

Population Trend and Demographic Parameters

11. Continue annual monitoring of the Northern Spotted Owls population trend to track whether the California population continues to decline, and expand demographic monitoring throughout other portions of its California range (see RA2).

12. Utilize predictive modeling methodology for estimating Northern Spotted Owl occupancy across its California range (see RA3).

13. Assess the extent of climate impacts (e.g., precipitation, temperature, drought) on survival, population growth and reproductive rates of Northern Spotted Owls in California, and determine if negative impacts of climate change outweigh the positive ones.

Habitat

14. Manage Northern Spotted Owl habitat in a way that accelerates the development of structural complexity and biological diversity that benefits Spotted Owl (see RA6)

15. Maintain and restore structurally complex multi-layered conifer forests (i.e., high quality owl habitat) while allowing for other threats, such as wildfire and insects, to be addressed by restoration management actions (see RA32).

16. Conserve and manage Northern Spotted Owl sites and high value habitat to provide additional demographic support to population dynamics (see RA10).

17. Via habitat modeling process described in the USFWS 2011 Recovery Plan, assist the USFWS to inform decisions concerning the possible development of habitat conservation networks in California (see RA4).

18. Assess habitat requirements for, and barriers to, dispersal in California through research on Northern Spotted Owl movement (e.g., telemetry on juveniles), prey abundance and availability, and habitat modeling.

19. Participate in interagency work groups created by the USFWS (i.e., Dry Cascades and Klamath Province) to assist evaluating landscape-level issues in the Provinces in California, including monitoring and adaptive management actions (see RA7 and RA9).

Wildfire

20. Analyze existing data on Northern Spotted Owl survival, reproduction and occupancy pre- and post-fire (see RA8).

21. Implement active management to restore forest resiliency to fire and to reduce losses of nesting and roosting habitat to wildfire.

22. Conduct experiments to better understand how vegetation management treatments (e.g., thinnings, restoration projects, prescribed fire, etc.) influence the development of Northern Spotted Owl habitat, prey abundance and distribution, and demographic performance (see RA11).

23. Gather information on the effect of historical fire suppression and current fire regimes on owl habitat, especially on the quality of habitat as assessed through demographic rates at individual owl territories.

24. Assess if and how post-fire salvage logging impacts foraging use, occupancy, reproduction and survival of Northern Spotted Owls in areas that have experienced salvage logging and areas that have not.

25. Develop a process for evaluating the likely effects of post-fire management activities, such as salvage, fuels reduction, or hazard tree mitigation, on Northern Spotted Owls, and incorporate this process into post-fire management decisions.

26. Concentrate post-fire silvicultural activities on conserving and restoring habitat elements that take a long time to develop, such as large trees, medium and large snags, downed wood (see RA12).

<u>Barred Owl</u>

27. Conduct Barred Owl specific surveys to assess Barred Owl abundance and distribution within the California range of the Northern Spotted Owl.

28. Continue investigations on the effects of Barred Owls on Northern Spotted Owl site occupancy, reproduction, survival and population trends in California (see RA23).

29. Promote coordinated experimental removal of Barred Owls within Northern Spotted Owl range in California (see RA28, RA 29 and RA 30)

30. Explore methods for implementation of lethal removal as a management tool, and under what scenarios and conditions, in California to mitigate negative effects of Barred Owls on Northern Spotted Owls and institute Department authority to implement such measures as appropriate (see RA22, RA28 and RA30).

31. Investigate resource partitioning of sympatric Barred Owls and Northern Spotted Owls (see RA26).

32. Conduct public outreach regarding the threat of Barred owls to Northern Spotted Owls populations (see RA 27).

33. Investigate parasite host/parasites dynamics related to Barred Owls and Northern Spotted Owl interactions.

<u>Sudden Oak Death</u>

34. Monitor prevalence and extent of sudden oak death within the Northern Spotted Owl range in California, and implement control measures where feasible (see RA17).

35. Investigate the potential influences of sudden oak death on Northern Spotted Owl occupancy, reproduction, survival and prey species abundance over the short- and long-term.

<u>Disease and Contaminants</u>

36. Expand assessment of the impacts of marijuana cultivation (both illegal and legal) on the Northern Spotted Owl and their habitat.

37. Monitor prevalence of avian diseases (e.g., West Nile Virus, avian flu, *Plasmodium* spp.) in the Northern Spotted Owl population, and address as appropriate (see RA17).

Listing Recommendation

CESA directs the Department to prepare this report regarding the status of the Northern Spotted Owl in California based upon the best scientific information. CESA also directs the Department based on its analysis to indicate in the status report whether the petitioned action is warranted (Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f).) The Department includes and makes its recommendation in its status report as submitted to the Commission in an advisory capacity based on the best available science. The Department finds that while not presently threatened with extinction, the Northern Spotted Owl is likely to become an endangered species in the foreseeable future due to the current population trend and a combination of threat factors, including present or threatened modification or loss of its habitat, competition from Barred Owls, and other natural occurrences or human-related activities, absent the special protections and management efforts required by CESA. The Department recommends that the Commission find that the Northern Spotted Owl warrants listing as Threatened.

Protection Afforded by Listing

The following is a discussion of potential protection that could be afforded to the Northern Spotted Owl in California if listed under CESA. While the protections identified in this section would help to ensure the future conservation of Northern Spotted Owls, there are protections now in place that would continue if the owl were not listed under CESA. These include current protections afforded under the Northern Spotted Owl federal status, protections afforded under the Forest Practice Rules, coverage of the owl under HCPs and NCCPs, current CEQA requirements, and existing laws and regulations that make it illegal under State law to take owls in California.

It is the policy of the Department to conserve, protect, restore and enhance any endangered or any threatened species and its habitat (Fish & G. Code, § 2052.). The conservation, protection, and enhancement of listed species and their habitat is of statewide concern (Fish & G. Code, § 2051(c)). CESA defines “take” as hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill. (Id. , § 86). Any person violating the take prohibition would be punishable under State law. When take is authorized through an incidental take permit, the impacts of the take must be minimized and fully mitigated, among other requirements.

Increased protection of Northern Spotted Owl following listing would occur with required public agency environmental review under CEQA. CEQA requires affected public agencies to analyze and disclose project-related environmental effects, including potentially significant impacts on endangered, rare, and threatened species. Where significant impacts are identified under CEQA, the Department expects project-specific required avoidance, minimization, and mitigation measures will also benefit the species.

CEQA would require analysis of potential impacts to Northern Spotted Owl regardless of listing status under CESA. In common practice, potential impacts to listed species is examined more closely in CEQA documents than potential impacts to unlisted species. State listing, in this respect, and required consultation with the Department during state and local agency environmental review under CEQA, is also expected to benefit the species in terms of related impacts for individual projects that might otherwise occur absent listing.

Without listing, Northern Spotted Owl take for research purposes is allowed via a Scientific Collecting Permit, and federal ESA 10a(1)(a). With listing, a state research Memoranda of Understanding (MOU) would also be required (Fish & G. Code, § 2081, subd. (a)). The added oversight allowed from MOU process is expected to benefit the species in terms of added coordination and research design, but will not likely add any additional protection.

In listing the Northern Spotted Owl under CESA, the Department would expect an increased level of coordination among public agencies, such as USFS, CAL FIRE, and the USFWS, and with private timber companies, increased level of Department involvement in the THP review and approval process, more regular and thorough acquisition of data, and a reevaluation of current management practices for the species. In addition, if the Northern Spotted Owl is listed under CESA, the likelihood that land and resource management agencies will allocate funds towards protection and recovery actions may increase.

Economic Considerations

The Department is not required to prepare an analysis of economic impacts (Fish & G. Code, § 2074.6).

Citations

Agee, J.K. 1993. Fire Ecology of Pacific Northwest Forests. Island Press, Washington, D.C.

Albert C.A., L.K. Wilson, P. Mineau, S. Trudeau, and J.E. Elliott. 2009. [Internet] Anticoagulant rodenticides in three owl species from western Canada, 1988-2003. Archives of Environmental Contaminate and Toxicology.[cited 2015 Jun 8] Available at DOI 10.1007/s00244-009-9402-z

American Ornithologists' Union (AOU). 2011. Fifty-second supplement to the American Ornithologists' Union Check-List of North American Birds. The Auk 128(3):600-613.

Anderson, D.R., and K.P. Burnham. 1992. Demographic analysis of northern Spotted Owl populations. Pages 319–328 in Draft final recovery plan for the northern Spotted Owl. U.S. Fish and Wildlife Service, Portland, Oregon.

Anthony, R.G., E.D. Forsman, A.B. Franklin, D.R. Anderson, K.P. Burnham, G.C. White, C.J. Schwarz, J. Nichols, J.E. Hines, G.S. Olson, S.H. Ackers, S. Andrews, B.L. Biswell, P.C. Carlson, L.V. Diller, K.M. Dugger, K.E. Fehring, T.L. Fleming, R.P. Gerhardt, S.A. Gremel, R.J. Gutiérrez, P.J. Happe, D.R. Herter, J.M. Higley, R.B. Horn, L.L. Irwin, P.J. Loschl, J.A. Reid, and S.G. Sovern. 2006. Status and trends in demography of northern Spotted Owls, 1985–2003. Wildlife Monograph No. 163. 180 p.

Apigian, K., L. Brown, J. Loda, S. Toas, and B. Allen-Diaz. 2006. Small Mammal and Herpetofauna Abundance and Diversity Along a Gradient of Sudden Oak Death Infection. Paper from Frankel, S.J., P.J. Shea, M.I. Haverty, tech. coord. Proceedings of the sudden oak death second science symposium: the state of our knowledge. Gen. Tech. Rep. PSW-GTR-196. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 571 p.

Atkinson, C.T. 2008. Avian Malaria. In: Parasitic diseases of wild birds, Atkinson CT, Thomas NJ, Hunter DB, editors. Wiley-Blackwell, Ames, Iowa, pp. 35-53.

Baldwin, Blomstrom, Wilkinson and Associates. 2006. Environmental Assessment of the 2006 Forest Management Plan for the Round Valley Indian Reservation.

Barrowclough, G.F., and R.J. Gutiérrez. 1990. Genetic variation and differentiation in the Spotted Owl (*Strix occidentalis*). The Auk 107: 737-744.

Barrowclough, G.F., J.G. Groth, and R.J. Gutiérrez RJ. 2005. Genetic structure, introgression and a narrow hybrid zone between northern and California Spotted Owls (*Strix occidentalis*). Molecular Ecology 14:1109–1120.

Barrowclough, G.F., R.J. Gutiérrez, J.G. Groth, J.E. Lai, and D.F. Rock. 2011. The hybrid zone between Northern and California Spotted Owls in the Cascade-Sierran Suture Zone. The Condor 113(3):581-589.

Barrows. C. 1981. Roost selection by Spotted Owls: An adaption to heat stress. The Condor 83:302-309.

Bart, J., and E.D. Forsman. 1992. Dependence of Northern Spotted Owls, *Strix occidentalis caurina*, on Old-Growth Forests in the Western United States. Biological Conservation 62:95-100.

Bauer, S. J. Olson, A. Cockrill, M. Van Hattem, L. Miller, M. Tauzer, and G. Leppig. 2015. Impacts of surface water diversions for marijuana cultivation on aquatic habitat in for northwestern California watersheds. PLoS ONE 10(3): e0120016. doi:10.1371/journal.pone.0120016

Beever, E. A., O'Leary, J., Mengelt, C., West, J. M., Julius, S., Green, N., Magness, D., Petes, L., Stein, B., Nicotra, A. B., Hellmann, J. J., Robertson, A. L., Staudinger, M. D., Rosenberg, A. A., Babij, E., Brennan, J., Schuurman, G. W. and Hofmann, G. E. 2015. Improving Conservation Outcomes with a New Paradigm for Understanding Species' Fundamental and Realized Adaptive Capacity. Conservation Letters. doi: 10.1111/conl.12190

Bigley, R., and J. Franklin. 2004. Habitat trends. Chapter 6 in S. Courtney (editor), Scientific evaluation of the status of the northern Spotted Owl. Sustainable Ecosystems Institute, Portland, Oregon.

Bingham B.B., and B.R. Noon. 1997. Mitigation of habitat "take": application to habitat conservation planning. Conservation Biology, 11(1): 127- 139.

Blakesley, J.A., A.B. Franklin, G.R. Gutiérrez. 1992. Spotted Owls roost and nest site selection in northwestern California. Journal of Wildlife Management 56(2):388-392.

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

Board of Equalization (BOE). 2014. Volumes of timber removed under an exemption as reported to the Board of Equalization. Unpublished raw data.

Bolton, Tabi. Personal Communication. 2014. Email received September 5, 2014.

Bond, M.L., R.J. Gutiérrez, A.B. Franklin, W.S. LaHaye, C.A. May, and M.E. Seamans. 2002. Short-term effects of wildfires on Spotted Owl survival, site fidelity, mate fidelity, and reproductive success. Wildlife Society Bulletin 30:1022–1028.

Bond, M.L., D.E. Lee, R.B. Siegel, and J.P. Ward, Jr. 2009. Habitat use and selection by California Spotted Owls in a postfire landscape. Journal of Wildlife Management 73:1116–1124.

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

Bosakowski, T., Smith, D.G., 1991. Comparative diets of sympatric nesting raptors in the eastern deciduous forest biome. Can. J. Zool. 70: 984-992.

Brown, L.B., B. Allen-Diaz. 2006. Forecasting the Future of Coast Live Oak Forests in the Face of Sudden Oak Death. Paper from Frankel, S.J., P.J. Shea, M.I. Haverty, tech. coord. Proceedings of the sudden oak death second science symposium: the state of our knowledge. Gen. Tech. Rep. PSW-GTR-196. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 571 p.

Buchanan, J.B., T.L. Fleming, and L.L. Irwin. 2004. A comparison of barred and Spotted Owl nest-site characteristics in the eastern Cascade Mountains, Washington. J. of Raptor Research 38(3):231-237

Buchanan, J.B. 2004. Managing habitat for dispersing northern Spotted Owls – are the current management strategies adequate? Wildlife Society Bulletin 32:1333–1345.

Butler, S.R., and T. Wooster. 2003. Terra Springs Habitat Conservation Plan, Northern Spotted Owl (*Strix Occidentalis caurina*).

Burnham, K.P., D.R. Anderson, and G.C. White. 1994. Estimation of vital rates of the northern Spotted Owl. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Ft. Collins, Colorado.

Burnham, K.P., D.R. Anderson, and G.C. White. 1996. Meta-analysis of vital rates of the northern Spotted Owl. Pp. 92-101 in E.D. Forsman, S. DeStefano, M.G. Raphael, and R.J. Gutiérrez (editors), Demography of the Northern Spotted Owl. Studies in Avian Biol. 17.

California Department of Forestry and Fire Protection (CAL FIRE) 2008. Important Information for Timber Operations Proposed within the Range of the Northern Spotted Owl. Unpublished Report. February 2008.

California Department of Forestry and Fire Protection (CAL FIRE). 2012. Northern Spotted Owl Update. Memorandum from Chris Browder, Deputy Chief, California Department of Forestry and Fire Protection to Board of Forestry and Fire Protection. September 11, 2012.

California Department of Forestry and Fire Protection (CAL FIRE). 2015. California Statewide Timber Harvesting Data. Available at ftp://ftp.fire.ca.gov/forest/Statewide_Timber_Harvest/

California Department of Forestry and Fire Protection (CDF). 2008. Jackson Demonstration State Forest Management Plan.

California Department of Forestry and Fire Protection (CDF). Presentation on Jackson Demonstration State Forest. Introduction to the Forest. History and Programs. Accessed on the CALFIRE website 10/30/14.

California Department of Fish and Wildlife (CDFW). 2014a. California Department of Fish and Wildlife request for consistency determination for Northern Spotted Owl Habitat Conservation Plan for California Timberlands. Letter to Green Diamond Resource Company dated January 17, 2014.

California Department of Fish and Wildlife (CDFW). 2014b. California Department of Fish and Wildlife request for consistency determination for Northern Spotted Owl Habitat Conservation Plan for California Timberlands. Letter to Humboldt Redwood Company, LLC, dated February 20, 2014.

California Department of Fish and Wildlife (CDFW). 2014c. California Department of Fish and Wildlife request for consistency determination for Northern Spotted Owl Habitat Conservation Plan for California Timberlands. Letter to Fruit Growers Supply Company dated March 5, 2014. California Department of Parks and Recreation (CDPR). 2001. Humboldt Redwoods State Park General Plan.

California Forestry Association (Calforests). 2014. Northern Spotted Owl Science Compendium. Comments and reports submitted to the California Department of Fish and Wildlife and the California Fish and Game Commission, May 1, 2014.

California Oak Mortality Task Force webpage, http://www.suddenoakdeath.org/. Accessed August 31, 2015.

Carey, A.B. and K.C. Peeler. 1995. Spotted owls: resource and space use in mosaic landscapes. Journal of Raptor Research 29:223-239.

Carey A.B., S.P. Horton, and B. Biswell. 1992. Northern Spotted Owls: influence of prey base and landscape character. Ecological Society of America 62(2): 223-250

Carroll, C. 2010. Role of climate 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: 1432-1437.

Carroll, C., and D.S. Johnson. 2008. The importance of being spatial (and reserved): assessing northern Spotted Owl habitat relationships with hierarchical Bayesian models. Conservation Biology 22:1026–1036.

Cayan, D., M. Tyree, D. Pierce, T. Das. 2012. Climate change and sea level rise scenarios for California vulnerability and adaptation assessment**.** California Energy Commission. Publication number: CEC-500-2012-008.

Chi, T., A. Henke, J. Smith and C. Brinegar. 2005. Spotted Owl mitochondrial DNA haplotyping. San Jose State University. Unpublished results submitted to U.S. Fish and Wildlife Service.

Chinnici, Sal. Personal Communication. 2014. Letter to the Department received September 3, 2014.

Christensen T.K., P. Lassen, and M. Elmeros. 2012. High exposure rates of anticoagulant rodenticides in predatory bird species in intensively managed landscapes in Denmark. Archives of Environmental Contamination and Toxicology, 63:437-444

Clark, D.A. 2007. Demography and habitat selection of northern spotted owls in post-fire landscapes of southwestern Oregon [Thesis]. Oregon State University, Corvallis, Oregon.

Clark, D.A., R.G. Anthony, and L.S. Andrews. 2011. Survival rates of northern spotted owls in post-fire landscapes of southwest Oregon. Journal of Raptor Research. 45:38-47.

Clark, D.A., R.G. Anthony, and L.S. Andrews. 2013. Relationship between wildlife, salvage logging, and occupancy of nesting territories by Northern Spotted Owls. Journal of Wildlife Management, 77 (4):672–688.

Cobb, R.C., J.A.N. Filipe, R.K. Meentemeyer, C.A. Gilligan, S.C. Lynch, and D.M. Rizzo. 2010. Community and Individual Effects on SOD Intensification in California Redwood Forests: Implications for Tanoak Persistence. Abstract from a paper presented at the Sudden Oak Death Science Symposium: The State of Our Knowledge, June 2009, Santa Cruz, California.

Cobb, R.C., J.A.N. Filipe, R.K. Meentemeyer, C.A. Gilligan, and D.M. Rizzo. 2012. Ecosystem transformation by emerging infection disease: loss of large tanoak form California forests. Journal of Ecology 100:712-722.

Cobb, R. C., D. M. Rizzo, K. J. Hayden, M. Garbelotto, J. A. N. Filipe, C A. Gilligan, W. W. Dillon, R. K. Meentemeyer, Y. S. Valachovic, E. Goheen, T. J. Swiecki, E. M. Hansen, and S. J. Frankel. 2013. Biodiversity Conservation In The Face Of Dramatic Forest Disease: An Integrated Conservation Strategy For Tanoak (*Notholithocarpus densiflorus*) Threatened By Sudden Oak Death. Madroño 60(2):151–164.

Comfort, E.J. 2013. Trade-offs between management for fire risk reduction and northern spotted owl habitat protection in the dry conifer forests of southern Oregon. PhD dissertation, Oregon State University, Corvallis, Oregon.

Comfort, E.J., D.A. Clark, R.G. Anthony, J. Bailey, and M.G. Betts. 2016. Quantifying edges as gradients at multiple scales improves habitat selection models for northern spotted owl. Landscape Ecology 31(1).

Cook, E.R., D. Meko, D.M. Stahle, and M.K. Cleaveland. 1996. Tree-ring reconstructions of past drought across the conterminous United States: tests of regression methods and calibration/verification results. Pages 155-169 in J.S Dean, D.M. Meko, and T.W. Swetnam, editors. Tree rings, environment, and humanity. Radiocarbon, Tucson, Arizona, USA.

Cormier, R.L. 2013. Northern Spotted Owl monitoring on Marin County Open Space District and Marin Municipal Water District Lands in Marin County, CA - 2013 Report. Point Blue Conservation Science, unpublished report.

Courtney, S.P., J.A. Blakesley, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleischer, A.B. Franklin, J.F.Franklin, R.J. Gutiérrez, J.M. Marzluff, and L. Sztukowski. 2004. Final Report: Scientific evaluation of the status of the Northern Spotted Owl. Sustainable Ecosystems Institute, Portland, Oregon.

Courtney, S.P., A.B. Carey, M.L. Cody, K. Engel, K.E. Fehring, J.F. Franklin, M.R. Fuller, R.J. Gutiérrez, J.F. Lehmkuhl, M.A. Hemstrom, P.F. Hessburg, S.L. Stephens, L.A. Sztukowski, and L. Young. 2008. Scientific Review of the Draft Northern Spotted Owl Recovery Plan and Reviewer Comments. Sustainable Ecosystems Institute, Portland, Oregon. 508 p.

Cohen, W.B., T.A. Spies, R.J. Alig, D.R. Oetter, T.K. Maiersperger, and M. Fiorella. 2002. Characterizing 23 Years (1972-95) of Stand Replacement Disturbance in Western Oregon Forests with Landsat Imagery. Ecosystems 5(2):122-137.

Crozier, M.L., M.E. Seamans, R.J. Guitierrez, P.J. Loschl, R.B. Horn, S.G. Sovern, and E.D. Forsman. 2006. Does the presence of barred owls suppress the calling behavior of Spotted Owls? The Condor 108:760-769.

Dalton, M.M., P.W. Mote and A.K. Snover. 2013 Climate change in the northwest; implications for our landscapes, waters and communities. Washington D.C. Island Press 271 p.

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

Davidson, J. M., S. Werres, M. Garbelotto, E.M. Hansen, and D.M. Rizzo. 2003. Sudden oak death and associated diseases caused by *Phytophthora ramorum*. Online. Plant Health Progress doi:10.1094/PHP-2003-0707-01-DG

Davis, R. and J. Lint. 2005. Habitat status and trends. Pages 21–82 in J. Lint (technical coordinator), Northwest Forest Plan—the first 10 years (1994–2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon. 30 p.

Davis, R.J., K.M. Dugger, S. Mohoric, L. Evers, and W.C. Aney. 2011. Northwest Forest Plan—the first 15 years (1994–2008): status and trends of northern spotted owl populations and habitats. Gen. Tech. Rep. PNW-GTR-850. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 147 p.

Davis, R., R. Horn, P. Caldwell, R. Crutchley, K. Fukuda, T. Kaufmann, C. Larson, and H. Wise. 2013. Demographic characteristics of northern spotted owls (*Strix occidentalis caurina*) in the Klamath Mountain Province of Oregon, 1990-2013. Annual report, FY 2013.

Dias, P.C. 1996. Sources and sinks in population biology. Trends in Ecology and Evolution 11:326–330.

Diller, L. 2014. 2013 Annual Report to the California Department of Fish and Game. In compliance with: Attachment to Scientific Collecting Permit for Lowell Diller (SC-000687), Green Diamond Resource Company Conditions for Research on Barred Owls. Dated January 22, 2014.

Diller, L.V. and D.M. Thome. 1999. Population density of northern spotted owls in managed young-growth forests in coastal northern California. Journal of Raptor Research 33:275–286.

Diller, L., K. Hamm, D. Lamphear and T. McDonald. 2010. Green Diamond Resource Company, Northern Spotted Owl Habitat Conservation Plan, Ten-Year Review Report. Report to U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California. 232 + viii pp.

Diller, L, K. Hamm, D. Lamphear, and T. McDonald. 2012. Two Decades of Research and Monitoring of the Northern Spotted Owl on Private Timberlands in the Redwood Region: What do We Know and What Challenges Remain? In Proceedings of coast redwood forests in a changing California: a symposium for scientists and managers. USDA, Forest Service, Pacific Southwest Research Station, General Technical Report - 238, Albany, CA, pp. 399-407

Diller, L.V., J.P. Dumbacher, R.P. Bosch, R.R. Bown, and R.J. Gutiérrez. 2014. Removing Barred Owls from Local Areas: Techniques and Feasibility. Wildlife Society Bulletin; DOI: 10.1002/wsb.381

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

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

Dugger, K.M., R.G. Anthony, and E.D. Forsman. 2009. Estimating northern spotted owl detection probabilities: updating the USFWS northern spotted owl survey protocol. 55 p. Unpublished report. On file with: Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331.

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

Elliott, K. 2006. Declining numbers of Western Screech-Owl in the Lower Mainland of British Columbia. British Columbia Birds 14:2-11.

Ellis A.E., D.G. Mead, A.B. Allison, D.E. Stallknecht, and E.W. Howerth. 2007. Pathology and epidemiology of natural west nile viral infection of raptors in Georgia. Journal of Wildlife Diseases. 43(2): 214-223.

Ellis, T., E. Schultz, and D. Press. 2013. Monitoring Northern Spotted Owls on Federal Lands in Marin County, California. 2012 Report. Natural Resource Technical Report NPS/SFAN/NRTR - 2013/829. National Park Service Inventory and Monitoring Program. Point Reyes Station, CA.

Erler, J. 2012. Environmental Assessment (EA) for the Forest Management Plan (FMP), Yurok Indian Reservation, California.

Eyes, S.A. 2014. The effects of fire severity on California Spotted Owl habitat use patterns. MS thesis, Humboldt State University, Arcata, CA.

Farber, S.L., and A.J. Kroll. 2012. Site Occupancy Dynamics of Northern Spotted Owls in Managed Interior Douglas-Fir Forests, California, USA, 1995–2009. J. Wildl. Manage. 76(6):1145–1152.

Farber, S.L. and J. Whitaker. 2005. Diets of Northern Spotted Owls (*Strix occidentalis caurina*) in the Southern Cascades and Klamath Provinces of interior Northern California. Report prepared for US Fish and Wildlife Service for the review of the Spotted Owl Management Plan. Timber Products Company, Yreka, California.

Forest Ecosystem Management Team (FEMAT). 1993. Forest Ecosystem Management: An Ecological, Economic, and Social Assessment. Report of the FEMAT. Washington, D.C.: U.S. Government Printing Office.

Forest Stewardship Council (FSC). 2010a. FSC-US Forest Management Standard (v1.0). 2010.

Forest Stewardship Council (FSC). 2010b. FSC-US Draft High Conservation Value Forest Assessment Framework. 2010.

Forsman, E. 1975. A preliminary investigation of the Spotted Owl in Oregon [Thesis].Oregon State University, Corvallis. 145 p.

Forsman, E.D., E.C. Meslow, and H.M. Wight. 1984. Distribution and biology of the spotted owl in Oregon. Wildlife Monographs 87:1–64.

Forsman, E.D., S. DeStefano, M.G. Raphael, and R.J. Gutiérrez, editors. 1996. Demography of the northern spotted owl. Studies in Avian Biology No. 17.

Forsman, E.D., I.A. Otto, S.G. Sovern, M. Taylor, D.W. Hays, H. Allen, S.L. Roberts, and D.E. Seaman. 2001. Spatial and temporal variation in diets of spotted owls in Washington. J. Raptor Res. 35:141–150.

Forsman, E.D., R.G. Anthony, J.A. Reid, P.J. Loschl, S.G. Sovern, M. Taylor B.L. Biswell, A. Ellingson, E.C. Meslow, G.S. Miller, K.A. Swindle, J.A. Thrailkill, F.F. Wagner, and D.E. Seaman. 2002. Natal and breeding dispersal of northern spotted owls. Wildlife Monographs 149:1–35.

Forsman, E.D., R.G. Anthony, K.M. Dugger, E.M. Glenn, A.B. Franklin, G.C. White, C.J. Schwarz, K.P. Burnham, D.R. Anderson, J.D. Nichols, J.E. Hines, J.B. Lint, R.J. Davis, S.H. Ackers, L.S. Andrews, B.L. Biswell, P.C. Carlson, L.V. Diller, S.A. Gremel, D.R. Herter, J.M. Higley, R.B. Horn, J.A. Reid, J. Rockweit, J. Schaberel, T.J. Snetsinger, and S.G. Sovern. 2011. Population Demography of the northern spotted owls: 1985-2008. Studies in Avian Biology.

Folliard, L.B., K.P. Reese and L.V. Diller. 2000. Landscape characteristics of northern spotted owl nest sites in managed forests of northwestern California. The Journal of Raptor Research 34(2):75-84.

Forrester, D.J., and E.C. Greiner. 2008. Leucocytozoonosis. In: Parasitic diseases of wild birds, Atkinson CT, Thomas NJ, Hunter DB, editors. Wiley-Blackwell, Ames, Iowa, pp. 54-107.

Forsman, E. D. 1983. Methods and materials for locating and studying spotted owls. U.S. Forest Service General Technical Report PNW-162, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Forsman, E.D., S.G. Sovern, M. Taylor, and B.L. Biswell. 2015. Home range and habitat selection by Northern Spotted Owls on the eastern slope of the Cascade Mountains, Washington. J. Raptor Res. 49(2):109-128.

Franklin, A.B. 1992. Population regulation in northern spotted owls: theoretical implications for management. Pages 815–827 in D.R. McCullough and R.H. Barrett (editors), Wildlife 2001: populations. Elsevier Applied Sciences, London, England.

Franklin, A. B., and R. J. Gutiérrez. 2002. Spotted owls, forest fragmentation, and forest heterogeneity. Studies in Avian Biology 25:203-220

Franklin, A.B., J.P. Ward, R.J. Gutiérrezand G.I. Gould, Jr. 1990. Density of Northern Spotted Owls in northwest California. J. Wildl. Management 54:1-10.

Franklin, A.B., D.R. Anderson, E.D. Forsman, K.P. Burnham, and F.W. Wagner. 1996. Methods for collecting and analyzing demographic data on the northern spotted owl. Studies in Avian Biology 17:12-20.

Franklin, A.B., K.P. Burnham, G.C. White, R.G. Anthony, E.D. Forsman, C. Schwarz, J.E. Nichols, and J. Hines. 1999. Range-wide status and trends in northern spotted owl populations. Colorado Cooperative Fish and Wildlife Research Unit, USGS, Biological Resources Division, Colorado State University, Ft. Collins, CO, and Oregon Cooperative Fish and Wildlife Research Unit, USGS, Biological Resources Division, Department of Fish and Wildlife, Oregon State University, Corvallis, OR.

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

Franklin, A.B., B.R. Noon, and T.L. George. 2002. What is habitat fragmentation? Studies in Avian Biology 25:20-29.

Franklin, A.B., P.C. Carlson, J.T. Rockweit, A. Rex, T. Zaffarano, B.N. Rubeck, D. Hecht, S. Philibosian and K. Wilson. 2013. Monitoring the population ecology of spotted owls, *Strix occidentalis caurina*, in Northwestern California: annual results, 2012. Annual progress report to Region 5, USDA Forest Service, Colorado State University.

Franklin, A.B., P.C. Carlson, J.T. Rockweit, A. Rex, D. Garza, L. Platt, G. Sousa, C. Smith, and K. Wilson. 2015. Monitoring the population ecology of spotted owls (*Strix occidentalis caurina*) in northwestern California: Annual results, 2014. Annual progress report for Region 5, USDA Forest Service. Colorado State University, Ft. Collins, CO. 32 p.

Franklin, A.B., R.J. Gutiérrez, J.D. Nichols, M.E. Seamans, G.C. White, G.S. Zimmerman, J.E. Hines, T.E. Munton, W.S. LaHaye, J.A. Blakesley, G.N. Steger, B.R. Noon, D.W.H. Shaw, J.J. Keane, T.L. McDonald, and S. Britting. 2004. Population dynamics of the California Spotted Owl (*Strix occidentalis occidentalis*): a meta-analysis. Ornithological Monographs 54:1-55.

Franklin, J.F., and C.T. Dyrness. 1973. Natural vegetation of Oregon and Washington. Oregon State UniversityPress, Corvallis, OR. 452p.

Fruit Growers Supply Company (FGSC). 2012. Habitat Conservation Plan submitted to U.S Fish and Wildlife Service and California Department of Fish and Wildlife in fulfillment to obtain an incidental take permit for northern spotted owls, under section 10(a)(11)(B) of the Endangered Species Act and the state consistency determination. March 2012.

Fuel, P.Z., T.W. Swetnam, P.M. Brown, D.A. Falk, D.L. Peterson, C.D. Allen, G.H. Aplet, M.A. Battaglia, D, Binkley, C. Farris, R.E. Keane, E.Q. Margolis, H. Grissino-Mayer, C. Miller, C.H. Sieg, C. Skinner, S.L. Stephens, and A. Taylor. 2014. Unsupported inferences of high-severity fire in historical dry forests of the western United States: response to Williams and Baker. Global Ecology and Biogeography 23:825-830.

Fuller, Terra. Personal Communication. 2014. Email received September 2, 2014.

Funk, C.W., E.D. Forsman, T.D. Mullins, and S.M. Haig. 2008. Introgression and dispersal among spotted owl (*Strix occidentalis*) subspecies. Evolutionary Applications 1:161-171

Funk, C.W., E.D. Forsman, M. Johnson, T. D. Mullins, and S. M. Haig. 2010. Evidence for recent population bottlenecks in northern spotted owls: *Strix occidentalis caurina*. Conserv. Genet. 11:1013-1021.

Gabriel M.W., G.M. Wengert, J. M. Higley, S. Krogan, W. Sargent, and D. L. Clifford. 2013. Silent forest? rodenticides on illegal marijuana crops harm wildlife. The Wildlife Society. [Internet] [cited 2015 Jun 4] Available at www.wildlife.org

Gaines, W.L., R.A. Strand, and S.D. Piper. 1997. Effects of the Hatchery Complex fires on Northern Spotted Owls in the Eastern Washington Cascades. Proceedings, Fire Effects on Rare and Endangered Species and Habitats Conference, 1995. Coeur d'Alene, Idaho.

Gancz A.Y., I.K. Barker, R. Lindsay, A. Dibernardo, K. McKeever and B. Hunter. 2002. West nile virus outbreak in north American owls, Ontario, 2002. Emerging Infectious Diseases. 10(12): 2136-2142

Garbelotto, M., J.M. Davidson, K. Ivors, P. E. Maloney, D. Hüberli, S. T. Koike, and D. M. Rizzo. 2003. Non-oak native plants are main hosts for sudden oak death pathogen in California. Cal. Agric. 57(1):18-23.

Glenn, E.M., R.G. Anthony and E.D. Forsman. 2010. Population trends in northern spotted owls: Associations with climate in the Pacific Northwest. Biological Conservation 143:2543-2552.

Glenn, E.M., R.G. Anthony, E.D. Forsman, and G.S. Olson. 2011. Reproduction of northern spotted owls: the role of local weather and climate. J. Wildlife Management, 75(6):1279-1294.

Goheen, E.M., E. Hansen, A. Kanaskie, N. Osterbauer, J. Parke, J. Pscheidt, and G. Chastagner. 2006. Sudden oak death and *phytophthora ramorum*. Oregon State University-Extension Service. EM 8877. 16p.

Grant, J. 1966. The barred owl in British Columbia. The Murrelet, 47(2):39-45

Green Diamond Resource Company (GDRC). 2015. 22nd Annual Habitat Conservation Report. Annual report submitted to U.S Fish and Wildlife Service and California Department of Fish and Wildlife in fulfillment of requirements specified in condition I. of permit #PRT-767798, incidental take permit for northern spotted owls, under section 10(a)(11)(B) of the Endangered Species Act and the state consistency determination. February 15, 2015.

Gremel, S.A. 2005. Factors controlling distribution and demography of Northern Spotted Owls in a reserved landscape. Thesis, University of Washington.

Gutiérrez, R.J., A.B. Franklin, W. LaHaye, V.J. Meretsky, and J.P. Ward. 1985. Juvenile spotted owl dispersal in northwestern California: Preliminary results, p. 60-65. In R.J. Gutiérrez and A.B. Carey. (eds], Ecology and Management of the Spotted Owl in the Pacific Northwest. USDA Forest Service General Technical Report PNW-185.

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

Gutiérrez, R.J., J.E. Hunter, G. Chávez-León, and J. Price. 1998. Characteristics of spotted owl habitat in landscapes disturbed by timber harvest in northwestern California. Journal of Raptor Research 32(2):104-110.

Gutiérrez, R.J. 1996. Biology and distribution of the northern spotted owl. Studies in Avian Biology 17:2–5.

Gutiérrez, R.J., A.B. Franklin, and W.S. LaHaye. 1995 . Spotted Owl (*Strix occidentalis*) in A. Poole and F. Gill (editors), The birds of North America, No. 179. The Academy of Natural Sciences and the American Ornithologists' Union, Washington, D.C. 28 p.

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

Gutiérrez, R.J. 2008. Spotted Owl research: A quarter century of contributions to education, ornithology, ecology, and wildlife management. Condor 110:792-798.

Hadfield, J.S., R.L. Mathiasen, and F.G. Hawksworth. 2000. Douglas-fir dwarf mistletoe. Forest Insect and Disease, Leaflet 54. USDA Forest Service. 10 p.

Haig, S.M., T.D. Mullins, and E.D. Forsman. 2004a. Subspecific relationships and genetic structure in the spotted owl. Conservation Genetics 5:683–705.

Haig, S.M., T.D. Mullins, E.D. Forsman, P.W. Trail, and L. Wennerberg. 2004b. Genetic identification of spotted owls, barred owls, and their hybrids: legal implications of hybrid identity. Cons. Biology 18(5):1347-1357

Hamer T.E. 1988. Home range size of the northern barred owl and northern spotted owl in western Washington. [Thesis] Western Washington University. 172 p.

Hamer, T.E., E.D. Forsman, E.D. Fuchs, and M.L. Walters. 1994. Hybridization between barred and spotted owls. The Auk 111(2): 487-492.

Hamer, T.E., D.L. Hays, C.M. Senger, and E.D. Forsman. 2001. Diets of Northern Barred Owls and Northern Spotted Owls in an area of sympatry. J. Raptor Res. 35:221–227.

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

Hamm, K. A. 1995. Abundance of dusky-footed woodrats in managed forests of north coastal California. M.S. Thesis, Humboldt State University, Arcata, CA. 46 p.

Hamm, K.A. and L.V. Diller. 2009. Forest management effects on abundance of woodrats in northern California. Northwestern Naturalist 90:97-106.

Hansen, A.J. 2011. Contribution of source-sink theory to protected area science. Pgs 339-360 in J. Liu, V. Hull, A. Morzillo, and J. Wiens (eds). Sources, Sinks, and Sustainability across Landscapes. Cambridge University Press.

Hanson, C.T., D.C. Odion, D.A. DellaSala and W.L. Baker. 2009. Overestimation of fire risk in the Northern Spotted Owl Recovery Plan. Conservation Biology 23:1314-1319.

Hanson, C.T., D.C. Odion, D.A. DellaSala and W.L. Baker. 2010. More comprehensive recovery actions for northern spotted owls in dry forests: reply to Spies et al. Conservation Biology 24:334-337.

Hayward, L. A. Bowles, J. Ha, and S. Wasser. 2014. Impacts of Vehicle Exposure on the Northern Spotted Owl. Center for Conservation Biology, University of Washington. Presentation given October 2014.

Healey, S.P., W.B. Cohen, T.A. Spies, M. Moeur, D. Pflugmacher, M.G. Whitley, and M. Lefsky. 2008. The relative impact of harvest and fire upon landscape-level dynmaics of older forests: Lessons from the Northwest Forest Plan. Ecosystems 11(7):1106-1119.

Henke, A.L., T.Y. Chi, J. Smith and C. Brinegar. 2005. Spotted Owl (*Strix occidentalis*) microsatellite variation in California. Department of Biological Sciences, San Jose State University, San Jose, California. (referenced in USFWS Revised Recovery Plan, 2011)

Herter, D.R., and L.L. Hicks. 2000. Barred owl and spotted owl populations and habitat in the Central Cascade Range of Washington. J. of Raptor Research 34(4):279-286.

Hessburg, P.F., J.K. Agee, and J.F. Franklin. 2005. Dry forests and wildland fires of the inland Northwest USA: contrasting the landscape ecology of the pre-settlement and modem eras. Forest Ecology and Management 211: 117-139.

Higley, J.M. 2012. Hoopa Valley Tribe Forest Management Plan (2011-2026) Programmatic Biological Assessment. Prepared January 16, 2012.

Higley, J.M. 2014. Barred Owl Experimental Removal: Hoopa Study Area End of Season Report. Report dated September 9, 2014.

Higley, J.M. and S.M. Mendia. 2013. Hoopa Valley Northern Spotted Owl Banding and Monitoring Report 2013. Hoopa Tribal Forestry.

Hoberg, E.P., G.S. Miller, E. Wallner-Pendleton, and O.R. Hedstrom. 1989. Helminth parasites of Northern Spotted Owls (*Strix occidentalis caurina*) form Oregon. Journal of Wildlife Diseases 25:246-251.

Hoberg, E.P., R.J. Cawthorn, and O.R. Hedstrom. 1993. Enteric Coccidia (*Apicomplexa*) in a small intestine of the Northern Spotted Owl (*Strix occidentalis caurina*). Journal of Wildlife Diseases 29(3): 495-497.

Holland, E., J. hart, K. Cooper, M. Borchert, K. Frangioso, D.M. Rizzo, and R.K. Meentemeyer. 2010. Abstract from a paper presented at the Sudden Oak Death Science Symposium: The State of Our Knowledge, June 2009, Santa Cruz, California.

Holt, D.W., R. Domenech, and A. Paulson. 2001. Status and distribution of barred owl in Montana. Northwestern Naturalist 82(3):102-110.

Houston, C.S., and K.J. McGowan 1999 . The westward spread of the Barred Owl. Blue Jay 57:190-195.

Hughes, K. D. 2005. Habitat associations of dusky-footed woodrats in managed Douglas-fir / hardwood forests or northern California. M.S. Thesis, Humboldt State University, Arcata, CA. 40 p.

Hull, J., A. Hull, W. Reisen, Y. Fang, and H. Ernest. 2006. Variation of West Nile Virus antibody prevalence in migrating an dwintering hawks in Central California. The Condor 108: 435-439.

Hull, J.M., J.J. Keane, L. Tell and H.B. Ernest. 2010. West Nile Virus Antibody Surveillance in three Sierra Nevada raptors of conservation concern. The Condor 112(1):168-172.

Humboldt Redwood Company (HRC). 2013. Humboldt Redwood Company, LLC: Northern Spotted Owl Science Forum Status Review. Northern Spotted Owl Science Compendium, California Forestry Association, May 1, 2014.

Humboldt Redwood Company (HRC). 2014. Northern Spotted Owl Annual Report 2013. Sixteenth Annual Report submitted to the U.S. Fish and Wildlife Service, the California Department of Fish and Wildlife, the NOAA Fisheries, and the California Department of Forestry and Fire Protection; to fulfill the requirements of the Habitat Conservation Plan, 6.2, Northern Spotted Owl Conservation Plan. February 1, 2014.

Humboldt Redwood Company (HRC). 2015. Northern Spotted Owl Annual Report 2014. Sixteenth Annual Report submitted to the U.S. Fish and Wildlife Service, the California Department of Fish and Wildlife, the NOAA Fisheries, and the California Department of Forestry and Fire Protection; to fulfill the requirements of the Habitat Conservation Plan, 6.2, Northern Spotted Owl Conservation Plan. February 1, 2015.

Hunter, J.E., R.J. Gutiérrez, A.B. Franklin, and D. Olson. 1994. Ectoparasites of the spotted owl. Journal of Raptor Research 28:232-235.

Hunter, J.E., R.J. Gutiérrez, and A.B. Franklin. 1995. Habitat configuration around spotted owl sites in Northwestern California. The Condor 97:684-693.

Ishak, H. D., J.P. Dumbacher, J.P., N.L. Anderson, J.J. Keane, G. Valkiunas, S.M. Haig, L. A. Tell and R.N.M. Sehgal. 2008. Blood parasites in owls with conservation implications for the spotted owl (*Strix occidentalis*). PLoS ONE 3(5): e2304 1-10. doi:10.1371/journal.pone.0002304

Irwin, L.L., D.F., Rock, and S.C Rock. 2007. Modeling foraging habitat of California Spotted Owls. Journal or Wildlife Management 71(4):1183-1191.

Irwin, L.L., D.F., Rock, and S.C Rock. 2012. Habitat selection by northern spotted owls in mixed-coniferous forests. J. Wildlife Manage. 76:200–213.

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

Jenness, J.S., P. Beier, and J.L. Ganey. 2004. Associations between forest fire and Mexican Spotted Owls. Forest Science 50(6):765-772.

Jennings, S., R.L. Cormier, and T. Gardali. 2011. Status of the barred owl in Marin County, California. Western Birds 42:103-110.

Jenson, H.J., D.B. Adams, W.M. Merkle. 2006. Northern Spotted Owls in Marin County: 2005 Annual Report. National Park Service, 22 p.

Johnson, N. K. 1994. Pioneering and natural expansion of breeding distributions in western North American birds. Pages 27-43 in A century of avifaunal change in western North America (J. R. Jehl and N. K. Johnson, Eds.). Studies in Avian Biology No. 15.

Johnson, K.N., J.F. Franklin, J.W. Thomas and J. Gordon. 1991. Alternatives for management of late successional forests of the Pacific Northwest. A report to the Agriculture and Merchant and Marine

Fisheries Committees of the U.S. House of Representative. Scientific Panel on Late Successional Forest Ecosystems, Washington, D.C.

Johnstone, J.A., and T.E. Dawson. 2010. Climatic context and ecological implications of summer fog decline in the coast redwood region. Proceedings of the National Academy of Sciences of the United States of America 107:4533–4538.

Kelly, E.G.. 2001. The range expansion of the Northern Barred Owl: and evaluation of the impact on Spotted Owls [Thesis]. Oregon State University.

Kelly, E.G., and E.D. Forsman. 2004. Recent records of hybridization between barred owls (*Strix varia*) and northern spotted owl (*S. occidentalis caurina*). The Auk 121(3):806-810.

Koch, F.H., and W.D. Smith. 2012. A revised sudden oak death risk map to facilitate national surveys. Chapter 7 in Potter, K.M.; Conkling, B.L. (eds.). Forest Health Monitoring 2009 National Technical Report. Gen. Tech. Rep. SRS-167. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station, pp. 109-136.

Kroll, A.J., T.L. Fleming, and L.L. Irwin. 2010. Site occupancy dynamics of northern spotted owls in the Eastern Cascades, Washington, USA, 1990-2003. J. of Wildl Management 74(6):1264-1274.

LaHaye, W.S. and R.J. Gutiérrez. 1999. Nest sites and nesting habitat of the northern spotted owl in northwestern California. Condor 101:324-330.

LaHaye, W.S., R.J. Gutiérrez and J.R. Dunk. 2001. Natal dispersal of the spotted owl in southern California: Dispersal profile of an insular population. Condor 103:691–700.

Lebreton, J.D., Burnham, K.P., Clobert, J. and D.R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: A unified approach with case studies. Ecological Monographs 62:67-118.

Lee, D.E., M.L. Bond, and R.B. Siegel. 2012. Dynamics of Breeding-Season Site Occupancy of the California Spotted Owl in Burned Forests. The Condor 114(4): 792-802.

Lee, D.E. and M.L. Bond. 2015. Previous year's reproductive state affects Spotted Owl site occupancy and reproduction responses to natural and anthropogenic disturbances. The Condor 117:307-319.

Lehmkuhl, J.F., K.D. Kistler, J.S. Begley and J. Boulanger. 2006. Demography of northern flying squirrels informs ecosystem management of western interior forests. Ecological Applications 16:584–600.

Lenihan J.M., R. Drapek, R. Neilson, and D. Bachelet. 2003. Climate change effects on vegetation distribution, carbon stocks, and fire regimes in California. Ecological Applications 13:1667–1681. http://dx.doi.org/10.1890/025295

Leskiw, T., and R.J. Gutiérrez. 1998. Possible predation of a spotted owl by a barred owl. Western Birds 29:225-226.

Lewicki, K.E., K. P. Huyvaert, A. J. Piaggio , L. V. Diller, and A. B. Franklin. 2015. Effects of barred owl (*Strix varia*) range expansion on Haemoproteus parasite assemblage dynamics and transmission in barred and northern spotted owls (*Strix occidentalis caurina*). Biol Invas. 17:1713–1727.

Levy S. 2004. Native incursions: avian range expansions imperil threatened species. Biosciences 54(2): 94- 98.

Lima L.L., and T.P. Salmon. 2010. Assessing some potential environmental impacts from agriculture anticoagulant uses. University of California, Davis 2010. pp. 199-203

Lint, J., B. Noon, R. Anthony, E. Forsman, M. Raphael, M. Collopy, and E. Starkey. 1999. Northern Spotted Owl effectiveness monitoring plan for the Northwest Forest Plan. General Technical Report PNW-GTR-440. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Littell, J.S., D. McKenzie, D.L. Peterson, and A.L. Westerling. 2009. Climate and wildfire area burned in western U.S. ecoprovinces, 1916–2003. Ecological Applications 19:1003–1021.

Livezey, K.B., M.F. Elderkin, P.A. Cott, J. Hobbs, and J.P. Hudson. 2008. Barred owls eating worms and slugs: the advantage in not being picky eaters. Northwestern Naturalist 89:185-190.

Livezey, K.B. 2009a. Range Expansion of Barred Owls, Part I: Chronology and Distribution. Am. Midl. Nat. 161:49–56.

Livezey, K.B. 2009b. Range Expansion of Barred Owls, Part II: Facilitating ecological changes. Am. Midl. Nat. 161:323-349

MacKenzie, D.I., Nichols, J.D., Hines, J.E., Knutson, M.G., and A.D. Franklin. 2003. Estimating site occupancy, colonization and local extinction when a species is detected imperfectly. Ecology 84:2200-2207.

MacKenzie, D.I., J.D. Nichols, J.A. Royle, K.H. Pollack, L.L. Bailey, and J.E. Hines. 2006. Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrence. Academic Press, Burlington, MA, USA.

Mai, J.A., W. Mark, L. Fischer, and A. Jirka. 2006. Aerial and Ground Surveys for Mapping the Distribution of *Phytopthora ramorum* in California. Paper from Frankel, S.J., P.J. Shea, M.I. Haverty, tech. coord. Proceedings of the sudden oak death second science symposium: the state of our knowledge. Gen. Tech. Rep. PSW-GTR-196. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 571 p.

Martinez-de la Puente J., S. Merino, G. Tomas, J. Moreno, J. Morales, E. Lobato, S. Garcia-Fraile and E.J. Belda. 2010. The blood parasite haemoproteus reduces survival in a wild bird: medication experiment. Biology Letters 6, 663- 665. doi:10.1098/rsbl.2010.0046

Mazur, Kurt M. and Paul C. James. 2000. Barred Owl (Strix varia), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online:

http://bna.birds.cornell.edu.bnaproxy.birds.cornell.edu/bna/species/508McIntyre, P.J., J.H. Thorne, C.R. Dolanc, A.L. Flint, L.E. Flint, M. Kelly, and D.D. Ackerly. 2015. Twentieth-century shifts in forest structure in California: denser forests, smaller trees, and increased dominance of oaks. Proc. Natl. Acad. Sci. USA 2015 112(13):4009-4014. Available online at <http://www.pnas.org/content/112/5/1458.full>

McPherson, B.A., S.R. Mori, D.L. Wood, A.J. Storer, P. Svihra, N.M. Kelly, and R.B. Standiford. 2006. Sudden Oak Death Disease Progression in Oaks and Tanoaks. Paper from Frankel, S.J., P.J. Shea, M.I. Haverty, tech. coord. Proceedings of the sudden oak death second science symposium: the state of our knowledge. Gen. Tech. Rep. PSW-GTR-196. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 571 p.

McPherson, B. A., et al. 2010. Impacts of *Phytophthora ramorum* on Oaks and Tanoaks in Marin County, California Forests since 2000. Pp 210-212 in S. J. Frankel et al (Tech. Coord.), Gen. Tech. Rep. PSW-GTR-229. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 378 p.

McKenzie, D., Z.E. Gedalof, D.L. Peterson, and P. Mote. 2004. Climatic change, wildfire, and conservation. Conservation Biology 18:890–902.

Meentemeyer, R.K., N. Cunniffe, A.Cook, D.M. Rizzo, and C.A. Gilligan. 2010. Predicting the Spread of Sudden Oak Death in California (2010-2030): Epidemic Outcomes Under No Control. Abstract from a paper presented at the Sudden Oak Death Fourth Science Symposium, June 2009, Santa Cruz, California. [http://www.fs.fed.us/psw/publications/documents/psw_gtr229/]

Meentemeyer, R. K., N. J. Cunniffe, A. R. Cook, J. A. N. Filipe, R. D. Hunter, D. M. Rizzo, and C. A. Gilligan. 2011. Epidemiological modeling of invasion in heterogeneous landscapes: spread of sudden oak death in California (1990–2030). Ecosphere 2(2):1-24.

Mendenhall, V.M., and L.P. Pank. 1980. Secondary poisoning of owls by anticoagulant rodenticides. Wildl. Soc. Bull. 8(4):311-315.

Mendocino Redwood Company (MRC). 2014. Northern Spotted Owl Conservation and Management on Mendocino Redwood Company Forestlands. Northern Spotted Owl Science Compendium, California Forestry Association, May 1, 2014.

Mendocino Redwood Company (MRC). 2015. 2014 Annual Report of Activities Covered Under Permit TE-058630-3 for Mendocino Redwood Company. Submitted to the U.S. Fish and Wildlife Service and the California Department of Fish and Wildlife. January 31, 2015.

Merenlender, A., R. Standiford, and G. Giusti (Editors). 1996. Hardwood retention for North Coast California Timberlands: Northern Sonoma, Mendocino, Southwest Trinity, and Southern Humboldt Counties. A report of the Regional Committee on Hardwood Retention, North Coast facilitated by Integrated Hardwood Range Management Program. 34 pp + 5 Apps.

Meyer, J.S., L.L. Irwin and M.S. Boyce. 1998. Influence of habitat abundance and fragmentation on northern Spotted Owls in western Oregon. Wildlife Monographs 139:1–51.

Miller, G.S. 1989. Dispersal of juvenile spotted owls in western Oregon [Thesis]., Oregon State University, Corvallis.

Miller, C. and D. Urban. 2000. Connectivity of forest fuels and surface fire regimes. Landscape Ecology 15:145-154.

Miller, G.S., S.K. Nelson and W.C. Wright. 1985. Two-year-old female spotted owl breeds successfully. Western Birds 16:69–73.

Miller, G.S., R.J. Small and E.C. Meslow. 1997. Habitat selection by spotted owls during natal dispersal in western Oregon. J. Wildlife Management 61:140–150.

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

Miller. J.D., C.N. Skinner, H.D. Safford, E.E. Knapp, and C.M. Ramirez. 2012. Trends and causes of severity, size, and number of fires in northwestern California, USA. Ecological Applications 22(1):184-203.

Monahan, W.B., and R.J. Hijmans. 2007. Distribution dynamics of invasion and hybridization by *Strix* spp. in western North America. Ornithological Monographs No. 63:55-66.

Mouer, M., J.L. Ohmann, R.E. kennedy, W.B. Cohen, M. J. Gregory, Z. Yand, H.M. Roberts, T.A. Spies, and M. Fiorella. 2011. Status and Trends of Late-Successional and Old-Growth Forests. The Northwest Forest Plan, the first 15 years (1994-2008). USDA General Technical Report PNW-GTR-853. 50 pp.

Murray M. 2011. Anticoagulant rodenticide exposure and toxicosis in four species of birds of prey presented to a wildlife clinic in Massachusetts, 2006-2010. Journal of Zoo and Wildlife Medicine, 42(1):88-97.

National Drug Intelligence Center. 2007. Domestic Cannabis Cultivation Assessment 2007, Appendix A. Document ID: 2007-L0848-001. Available at: http://www.justice.gov/archive/ndic/pubs22/22486/appa.htm#start

Nemeth N., D. Gould, R. Bowen, and N. Komar. 2006. Natural and experimental west nile infection in five raptor species. Journal of Wildlife Diseases, 42(1):1-13.

Norman, S. P., and A. H. Taylor. 2002. Variation in fire return intervals across a mixed conifer forest landscape. Proceedings of Fire in Sugihara, N.C., Moreales, M.E., Morales, T.J., Proceedings of the symposium on fire in California ecosystems: integrating ecology, prevention, and management. Association of Fire Ecology Miscellaneous Publication 1:170–179.

Norman, S. P., and A. H. Taylor. 2003. Tropical and north Pacific teleconnections influence fire regimes in pine-dominated forests of northeastern California, USA. Journal of Biogeography 30(7): 1081-1092.

Odion D.C., Hanson C.T. 2006. Fire severity in conifer forests of the Sierra Nevada, California. Ecosystems 9:1177–89.

Odion, D.C., E.J. Frost, J.R. Strittholt, H. Jiang, D.A. DellaSala, and M.A. Moritz. 2004. Patterns of fire severity and forest conditions in the western Klamath Mountains, California. Conservation Biology 18(4): 927-936.

Office of National Drug Control Policy. Marijuana on Public and Tribal Lands webpage, accessed on September 2, 2015. https://www.whitehouse.gov/ondcp/marijuana-on-public-lands.

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

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

Padgett K.A., Reisen W.K., N. Kahl-Purcell, Y. Fang, B. Cahoon-Young, R. Carney, N. Anderson, L. Zucca, L. Woods, S. Husted and V.L. Kramer. 2007. West nile virus infection in tree squirrels (*rodentia: sciuridae*) in California, 2004-2005. The American Society of Tropical Medicine and Hygiene 76(5): 810-813.

Paton, P., C.Zabel, B. Bingham, H. Sakai, and C. Ogan. 1990. Examination of home range size and habitat use of the spotted owl in Klamath Province, Progress Report. Pacific Southwest Forest and Range Experiment Station, Redwood Science Laboratory, Arcata, CA

Pearson, R.R., and K.B. Livezey. 2003. Distribution, number, and site characteristics of spotted owls and barred owls in the Cascade Mountains of Washington. J. Rapt. Res. 37:265-76.

Pierce D.W., T. Das, D.R. Cayan, E.P. Maurer, N.L. Miller, Y. Bao, M. Kanamitsu, K. Yoshimura, M.A. Snyder, L.C. Sloan, G. Franco and M. Tyree. 2011. Probabilistic estimates of future changes in California temperature and precipitation using statistical and dynamical downscaling. [Internet] Springer-Verlags [cited 2015 Jun 8] Available from (doi:10.1007/s00382-012-1337-9)

Pious, M. 1995 Home range and habitat use of spotted owls in managed Redwood/Douglas fir forests, California. Louisiana-Pacific Corporation, Forestry Department, Calpella, CA.

Press, D., W. Merkle, H. Jensen, F. Taroc, and T. Ellis. 2012. Monitoring northern spotted owls on federal lands in Marin County, California: 2010-2011 Report. Natural Resources Technical Report NPS/SFAN/NRTR – 2012/606. USDI, National Park Service, Natural Resouce Stewardship and Science, Fort Collins, Colorado.

PRISM Climate Group. 2015. Precipitation and temperature data. Oregon State University. http://prism.oregonstate.edu.

Pulliam, R.H. 1988. Sources, sinks, and population regulation. American Naturalist 132:652–661.

Rapp, V. 2005. Conserving old forest in landscape shaped fire. USDA Forest Service, Pacific Northwest Research Station, Issue 11.[cited 2015 Jun 8] Available at [link]

Regli Estate. 1995. Multi-Species Habitat Conservation Plan and Section 10(a) Application. Habitat Conservation Plan to U.S Fish and Wildlife Service and California Department of Fish and Wildlife in fulfillment to obtain an incidental take permit for northern spotted owls, under section 10(a) of the Endangered Species Act and the state consistency determination. July 7, 1995.

Richmond, O.M., J.E. Hines, and S.R. Beissinger 2010. Two species occupancy models: A new parameterization applied to co-occurrence of secretive rails. Ecological Applications 20:2036-2046.

Ripple W.J., P.D. Lattin, K.T. Hershey, F.F. Wagner, and E. Charles. 1997. Landscape composition and pattern around northern spotted owl nest sites in southwest Oregon. The Journal of Wildlife Management, 61(1): 151-158.

Ripple, W.J., K.T. Hershey, and R.G. Anthony. 2000. Historical forest patterns of Oregon's central Coast Range. Biological Conservation 93:127-133.

Ritchie, M. W. 2005. Ecological research at the Goosenest Adaptive Management Area in northeastern California. USDA Forest Service, Pacific Northwest Research Station, Gen. Tech. Rep. PSW-GTR-192: 128 p.

Rizzo, D.M., and M. Garbelotto. 2003. Sudden oak death: endangering California and Oregon forest ecosystems. Front Ecology Environment 1(5): 197-204.

Roberts, S.L., J.W. Wagtendonk, A.K. Miles, and D.A. Kelt. 2011. Effects of fire on Spotted Owl site occupancy in a late-successional forest. Biological Conservation 144:610-619.

Roberts, K., B. Dotters, R. Feamster, and J. Kelley. 2015. 2014 Sierra Pacific Industries Annual Reporting for Northern Spotted Owl Census in Northern California. Submitted to California Department of Fish and Wildlife, Sacramento, CA, January 31, 2015.

Rockweit J.T., A.B. Franklin, G.S. Bakken, R.J. Gutiérrez . 2012. Potential influences of climate and nest structure on spotted owl reproductive success: a biophysical approach. PLoS ONE 7(7): e41498 1-11. doi:10.1371/journal.pone.0041498

Rosenberg, D.K., K.A. Swindle, and R.G. Anthony. 2003. Influence of prey abundance on northern spotted owl reproductive success in western Oregon. Can. J. Zool 81:1715-1725.

Rosenberg, D. K., and K. S. McKelvey. 1999. Estimation of habitat selection for central-place foraging animals. Journal of Wildlife Management 63:1028-1038

Saito, E.K., L. Sileo, D.E. Green, C.U. Meteyer, G.S. McLaughlin, K.A. Converse, and D.E. Docherty. 2007. Raptor mortality due to West Nile Virus in the United States, 2002. J. of Wildl Diseases 43(2):206-213.

Sakai, H.F., and B.R. Noon. 1993. Dusky-footed woodrat abundance in different-aged forests in Northwestern California. Journal of Wildlife Management 57(2): 373-382.

Sakai, H.F., and B.R. Noon. 1997. Between-habitat movement of dusky-footed woodrats and vulnerability to predation. Journal of Wildlife Management 61(2): 343-350.

Sanchez-Barbudo I.S., P.R. Camarero, R. Mateo. 2012 Primary and secondary poisoning by anticoagulant rodenticide of non-target animals in Spain. Science of the Total Environment 420 (2012) 280-288.

Schilling, J.W., K.M. Dugger, and R.G. Anthony. 2013. Survival and home-range size of northern spotted owls in Southwestern Oregon. J. of Rap Research 47(1):1-14.

Schmidt, K. 2013. Northern spotted owl monitoring and inventory Redwood National and State Parks 2012 annual report.

Schmidt, K. 2015. Northern Spotted Owl Surveys in Redwood National and State Parks 2013-2014 Report.

Schwind, B. (compiler). 2008. Monitoring trends in burn severity: Report in the PNW and PSWt Fires - 1984 to 2005. Available online: http://mtbs.gov/.

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

Seamans, M.E. and R.J. Gutiérrez. 2007. Sources of variability on spotted owl population growth rate: testing predictions using long-term mark-recapture data. Oecologia 152:57-70.

Shaw D., 2007. Sudden oak death *phytophthora ramorum*. Forest Health Fact: EC 1607-E

Sillet, S. 2013. Separating effects of size and age on trunk growth in California redwoods. Presentation made at the Past, Present and Future of Redwoods: a Redwood Ecology and Climate Symposium, 2013.

Simpson Timber Company (STC). 1992. Habitat Conservation Plan (HCP) Habitat Conservation Plan for the Northern Spotted Owl on the California Timberlands of Simpson Timber Company. Habitat conservation plan submitted to U.S Fish and Wildlife Service and California Department of Fish and Wildlife in fulfillment of requirements to obtain a federal permit for the incidental take of northern spotted owls, under section 10(a)(11)(B) of the Endangered Species Act and the state consistency determination. September 17, 1992.

Singleton, P.H. 2015. Forest structure within Barred Owl (*Strix varia*) home ranges in the Eastern Cascade Range, Washington. J. Rap. Res. 49(2):129-140.

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

Sisco, C.L. 1990 . Seasonal home range and habitat ecology of spotted owls in northwestern California. Thesis, Humboldt State University, Arcata, California.

Skinner, C.N. And A.H. Taylor. 2006. Southern Cascades Bioregion. In: Sugihara, N. G. van Wagtendonk, J. W.; Fites-Kaufmann, J.; Shaffer, K. E.; Thode, A. E., editors. 2006. Fire in California's ecosystems. University of California Press, Berkeley. pp. 195-224.

Skinner, C.N., A.H. Taylor, J.K. Agee. 2006. Klamath Mountains Bioregion. in: N. G. Sugihara, J. W. van Wagtendonk, J. Fites-Kaufmann, K. E. Shaffer, and A. E. Thode, editors. Fire in California's ecosystems. University of California Press, Berkeley: 170-194.

Solis, D.M. 1983. Summer habitat ecology of spotted owls in Northwestern California. M.S. Thesis, Humboldt State University, Arcata, CA. 168 p.

Solis, D.M., and R.J. Gutiérrez. 1990. Summer habitat ecology of northern spotted owls in northwestern California. Condor 92:739–748.

Sovern, S.G., E.D. Forsman, B.L. Biswell, D.N. Rolph and M. Taylor. 1994. Diurnal behavior of the spotted owl in Washington. Condor 96:200–202.

Sovern, S.G., E.D. Forsman, G.S. Olson, B.L. Biswell, M. Taylor, and R.G. Anthony. 2014. Barred owls and landscape attributes influences territory occupancy of northern spotted owls. The Journal of Wildlife Management 78(8): 1436-1443

Spracklen, D.V., L. J. Mickley, J.A. Logan, R.C. Hudman, R. Yevich, M.D. Flannigan, and A.L. Westerling. 2009. Impacts of climate change from 2000 to 2050 on wildfire activity and carbonaceous aerosol concentrations in the western United States, J. Geophys. Res., 114, D20301, doi:10.1029/2008JD010966

Spies, T.A., M.A. Hemstrom, A. Youngblood, and S. Hummel. 2006. Conserving old-growth forest diversity in disturbance-prone landscapes. Conservation Biology 20(2): 351-362.

Spies, T.A., J.D. Miller, J.B. Buchanan, J.F. Lehmkuhl, J.F. Franklin, S.P. Healey, P.F. Hessburg, H.D. Safford, W.B. Cohen, R.S.H. Kennedy, E.E. Knapp, J.K. Agee and M. Moeur. 2010b. Underestimating risks to the northern spotted owl in fire-prone forests: response to Hanson et al. Conservation Biology 24:330–333.

Steel, Z.L., H.D. Safford, and J.H. Viers. 2015. The fire frequency-severity relationship and the legacy of fire suppression in California forests. Ecosphere 6(1):8.

Stralberg, D., K.E. Fehring, L.Y. Pomara, N. Nur, D.B. Adams, D. Hatch, G.R. Geupel, and S. Allen. 2009. Modeling nest-site occurrence for the northern spotted owl at is southern range limit in central California. Landscape and Urban Planning 90: 76–85.

Stoelting,. R.E., R.J. Gutiérrez, W.L. Kendall, and M.Z Peery. 2015. Life-history tradeoffs and reproductive cycles in Spotted Owls. The Auk 132:46-64.

Stone, W.B., J.C. Okoniewski, J.R. Stedelin. 2002. Anticoagulant rodenticides and raptors: recent findings from New York, 1998-2001. Bulletin of Environmental Contamination and Toxicology. (2003) 70:34-40

Strittholt, J.R., D.A. Dellasala, and H.Jiang. 2006. Status of Mature and Old-Growth Forests in the Pacific Northwest. Conservation Biology 20(2): 363-374

Swarthout, E.C.H., and R. J. Steidl. 2001. Flush responses of Mexican Spotted Owls to recreationists. J. Wildlife Management 55(2):312-317.

Swarthout, E.C.H., and R.J. Steidl. 2003. Experimental effects of hiking on breeding Mexican Spotted Owls. Conservation Biolog, 17(1):307-315

Swindle, K.A., W.J. Ripple, E.C. Meslow, and D.J. Schafer. 1999. Old-forest distribution around spotted owl nests in the central Cascade Mountains, Oregon. J. Wildlife Management 63:1212-1221.

Tanner, R.G., and R.J. Gutiérrez. 1995. A partial inventory of Northern Spotted Owls (*Strix occidentalis caurina*) in Redwood National Park, 1994. Unpubl. Rep., Arcata, CA U.S.A.

Arcata, CA U.S.A. Taylor, A.H. 2000. Fire regimes and forest changes in mid and upper montane forests of the southern Cascades, Lassen Volcanic National Park, California, U.S.A. Journal of Biogeography 27:87-104.

Taylor, A.H., and C.N. Skinner. 1998. Fire history and landscape dynamics in a late-successional reserve, Klamath Mountains, California, USA. Forest Ecology and Management 111: 285-301.

Taylor, A.H., and C.N. Skinner. 2003. Spatial patterns and controls on historical fire regimes and forest structure in the Klamath Mountains. Ecological Applications 13(3): 704-719.

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

Tempel, D. J., and R. J. Gutiérrez. 2004. Factors Related to Fecal Corticosterone Levels in California Spotted Owls: Implications for Assessing Chronic Stress. Conservation Biology 18:538-547.

Tempel, D.J., and W.D. Teitje. 2006. Potential Effects of Sudden Oak Death on Small Mammal and Herpetofauna in Coast Live Oak (*Quercus agrifolia*) Woodlands. Paper from Frankel, S.J., P.J. Shea, M.I. Haverty, tech. coord. Proceedings of the sudden oak death second science symposium: the state of our knowledge. Gen. Tech. Rep. PSW-GTR-196. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 571 p.

Tempel, D.J., W.D. Tietje, and D.E. Winslow. 2006. Vegetation and Small Vertebrate of Oak Woodlands and Low and High Risk for Sudden Oak Death in Sam Luis Obispo County, California. Paper from Frankel, S.J., P.J. Shea, M.I. Haverty, tech. coord. Proceedings of the sudden oak death second science symposium: the state of our knowledge. Gen. Tech. Rep. PSW-GTR-196. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 571 p.

Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl. USDA Forest Service, USDI Bureau of Land Management, USDI Fish and Wildlife Service, and USDI National Park Service. Portland, Oregon. 458 p.

Thomas, Jack Ward, Jerry F. Franklin, John Gordon, and K. Norman Johnson. 2006. The Northwest Forest Plan: Origins, Components, Implementation Experience, and Suggestions for Change. Conservation Biology 20 (2): 277–87.

Thomas, N.J., J. Bunikis, A.G. Barbour, and M.J. Wolcott. 2002. Fatal spirochetosis due to a relapsing fever-like *Borrelia* sp. in a Northern Spotted Owl. Journal of Wildlife Diseases 38:187-193.

Thomas, P.J., P. Mineau, R.F. Shore, L. Champoux, P.A. Martin, L.K. Wilson, G. Fitzgerald, and J.E. Elliot. 2011. Second generation anticoagulant rodenticides in predatory birds: probalistic characterization of toxic liver concentrations and implications for predatory bird populations in Canada. Environ. Int. 37:914-920.

Thome, D.M. C.J. Zabel, and L.V. Diller. 1999. Forest stand characteristics and reproduction of northern spotted owls in managed north-coastal California forests. J. Wildlife Management 63(1):44-59.

Thome, D.M., C.J. Zabel and L.V. Diller. 2000. Spotted owl turnover and reproduction in managed forest of north-coastal California. Journal of Field Ornithology 71(1):140-146

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

Tietje, W.D., D.E. Winslow, and D.J. Tempel. 2006. The Effects of Sudden Oak Death on Wildlife – Can Anything Be Learned From the American Chestnut Blight? Paper from Frankel, S.J., P.J. Shea, M.I. Haverty, tech. coord. Proceedings of the sudden oak death second science symposium: the state of our knowledge. Gen. Tech. Rep. PSW-GTR-196. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 571 p.

Ting, Tih-Fen. 1998. The thermal environment of northern spotted owls in northwestern California: Possible explanations for use of interior old growth and coastal early successional stage forest. MS thesis. Humboldt State University. Arcata, CA. 43 p.

Tompa, F.S. 1971. Catastrophic mortality and its population consequences. Auk 88:753–759

USDA Forest Service (USFS). 2003. Biscuit post-fire assessment - Rogue River and Siskiyou National Forests: Josephine and Curry Counties. Siskiyou National Forest. Grants Pass, OR. 210 p.

U.S. Department of Agriculture Forest Service (USDA) and Bureau of Land Management (BLM). 1994a. Final Supplemental Environmental Impact Statement (EIS) on Management of Habitat for Late-Successional and Old-Growth Forest Related Species within the Range of the Northern Spotted Owl. USDA Forest Service, Portland, Oregon, and BLM, Moscow, Idaho.

U.S. Department of Agriculture Forest Service (USDA) and Bureau of Land Management (BLM). 1994b. Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents within the Range Of the Northern Spotted Owl and Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species within the Range of the Northern Spotted Owl. USDA Forest Service, Portland, Oregon, and BLM, Moscow, Idaho.

U.S. Department of Agriculture Forest Service (USDA) and USDI (U.S. Department of the Interior). 1994. Final supplemental environmental impact statement on management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. U.S. Forest Service and U.S. Bureau of Land Management, Portland, Oregon.

U.S. Department of Interior (USDOI), Bureau of Land Management (BLM), and California Department of Fish and Game (CDFW). 2003. Final Environmental Impact Statement/Environmental Impact Report (EIS/EIR) for Headwaters Forest Reserve Proposed Resource Management Plan. USDOI BLM Arcata, California, and CDFG Eureka, California.

U.S. Department of Interior (USDOI) and Bureau of Land Management (BLM). 2004a. Record of Decision (ROD) for Headwaters Forest Reserve Resource Management Plan.

U.S. Department of Interior (USDOI) and Bureau of Land Management (BLM). 2004b. Proposed Resource Management Plan and Final Environmental Impact Statement (EIS) for King Range National Conservation Area. Department of the Interior BLM, Arcata, California.

U.S. Department of Interior (USDOI) and Bureau of Land Management (BLM). 2005. Record of Decision (ROD) for King Range National Conservation Area Resource Management Plan. Department of the Interior BLM, Arcata, California.

U.S. Fish and Wildlife Service (USFWS). 1990. Endangered and threatened wildlife and plants; determination of threatened status for the northern Spotted Owl. Federal Register 55:26114–26194.

U.S. Fish and Wildlife Service (USFWS). 1992. Recovery plan for the Northern Spotted Owl. Unpublished Report. U.S. Department of Interior, Washington, DC.

U.S. Fish and Wildlife Service (USFWS). 2002. Safe Harbor Agreement with Forster-Gill, Inc., for Voluntary Enhancement/Restoration Activities Benefiting Northern Spotted Owl at Blue Lake, California. Permit N. TE057898-0.

U.S. Fish and Wildlife Service (USFWS). 2008a. Final Recovery Plan for the Northern Spotted Owl (*Strix occidentalis caurina*). Portland, Oregon.

U.S. Fish and Wildlife Service (USFWS). 2008b. U.S. Fish and Wildlife Service review of timber harvest plans and non-industrial management plans, transitional documents. Letter to CAL FIRE dated February 1, 2008.

U.S. Fish and Wildlife Service (USFWS). 2009. Regulatory and scientific basis for U.S. Fish and Wildlife Service guidance for evaluation of take for northern spotted owls on private timberlands in California's northern interior region.

U.S. Fish and Wildlife Service (USFWS). 2011. Revised Recovery Plan for the Northern Spotted Owl (*Strix occidentalis caurina*). Portland, Oregon.

U.S. Fish and Wildlife Service (USFWS). 2012a. Protocol for Surveying Proposed Management Activities that May Impact Northern Spotted Owls. Portland, Oregon.

U.S. Fish and Wildlife Service (USFWS). 2012b. Revised Northern Spotted Owl Critical Habitat. Portland, Oregon.

U.S. Fish and Wildlife Service (USFWS). 2013. Experimental Removal of Barred Owls to Benefit Threatened Northern Spotted Owls. Final Environmental Impact Statement, July 2013. U.S. Fish and Wildlife Service, Portland, Oregon.

U.S. National Park Service (NPS). 2000a. Redwood National and State Parks General Management Plan / General Plan. U.S. Department of the Interior & California Department of Parks and Recreation.

U.S. National Park Service (NPS). 2000b. Record of Decision for Final EIS/GMP for Redwood National and State Parks.

U.S. National Park Service (NPS). 2004. Final Fire Management Plan Environmental Impact Statement, Point Reyes National Seashore and North District of Golden Gate National Recreation Area.

U.S. National Park Service (NPS). 2006a. Operational Strategy for the Fire Management Plan, Point Reyes National Seashore and Northern Lands of Golden Gate National Recreation Area.

U.S. National Park Service (NPS). 2006b. Record of Decision for the Final Environmental Impact Statement/Fire Management Plan Golden Gate National Recreation Area Marin, San Francisco and San Mateo Counties, California.

U.S. National Park Service (NPS). 2008. South Fork Lost Man Creek Second Growth Forest Restoration Environmental Assessment.

U.S. National Park Service (NPS). 2009a. Finding of No Significant Impact for Second Growth Forest Restoration South Fork Lost Man Creek Redwood National Park.

U.S. National Park Service (NPS). 2009b. Redwood National Park Trail and Backcountry Management Plan Environmental Assessment.

U.S. National Park Service (NPS). 2010a. Redwood National Park Fire Management Plan Environmental Assessment (EA) and Draft Fire Management Plan.

U.S. National Park Service (NPS). 2010b. Redwood National and State Parks Draft Fire Management Plan.

U.S. National Park Service (NPS). 2014. Final General Management Plan Environmental Impact Statement for the Golden Gate National Recreation Area and Muir Woods National Monument. U.S. Department of the Interior. Available online [http://www.nps.gov/goga/learn/management/index.htm]

U.S. National Park Service (NPS) and California Department of Parks and Recreation (CDPR). 2013. Forest and Beach Corvid Monitoring and Management Trail and Backcountry Management Plan Implementation 2012 Progress Report.

University of California (UC). http://nrs.ucop.edu/map.htm. Natural Reserve System. Accessed 10/30/2014

Valachovic, Y.S., C.A. Lee, H. Scanlon, J.M. Varner, R. Glebocki, B.D. Graham D.M. Rizzo. 2011. Sudden oak death-caused changers to surface fuel loading and potential fire behavior in Douglas-fir forests. Forest Ecology and Management 261:1973-1986.

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

Vose J.M., D.L. Peterson, and T. Patel-Weynand. 2012. Effects of Climatic Variability and Change on Forest Ecosystems: A Comprehensive Science Synthesis for the U.S. Forest Sector. U.S. Department of Agriculture. Pacific Northwest Research Station. General Technical Report PNW-GTR-870. [cited 2015 Jun 12]

Walker, L.A., A. Turk, S.M. Long, C.L. Wienburg, J. Best, and R.F. Shore. 2008. Second generation anticoagulant rodenticides in tawny owls from Great Britain. Sci. Total Environ. 392(1):93-98.

Ward, J.W. Jr. 1990. Spotted owl reproduction, diet and prey abundance in northwest California. Thesis, Humboldt State University, Arcata, California.

Ward, J.W. Jr., R.J. Gutiérrez and B.R. Noon. 1998. Habitat selection by northern Spotted Owls: the consequences of prey selection and distribution. Condor 100:79-92.

Wasser, S.K., K. Bevis, G. King, and E. Hanson. 1997. Noninvasive physiological measures of disturbances in the northern spotted owl. Conservation Biology, Vol. 11, No. 4(Aug., 1997) pp. 1019-1022

Wasser, S.K., and K. Hunt. 2005. Noninvasive measures of reproduction function and disturbance in the barred owl, great horned owl, and northern spotted owl. New York Academy of Science 1046:1-29.

Watkinson, A.R., and W.J. Sutherland. 1995. Sources, sinks and pseudo-sinks. Journal of Animal Ecology 64:126-130.

Weathers, W.W., P.J. Hodum and J.A. Blakesley. 2001. Thermal ecology and ecological energetics of the California Spotted Owl. Condor 103:678-690.

Weisel, L.E. 2015. Northern Spotted Owl and Barred Owl home range and habitat selection in coastal Northwestern California. M.S. Thesis, Humboldt State University, Arcata, CA. 54 p.

Westerling, A.L., and B.P. Bryant. 2008. Climate change and wildlife in California. Climate Change, 87(1): S231-S249.

Westerling, A.L., B.P. Bryant, H.K. Preisler, T.P. Holmes, H.G. Hidalgo, T. Das, and S.R. Shrestha. 2011. Climate change and growth scenarios for California wildfire. Climatic Change 109:445-463.

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

Wiens, J.D., R.G. Anthony, and E.D. Forsman. 2011. Barred Owl occupancy surveys within the range of the Northern Spotted Owl. Journal of Wildlife Management 75:531–538.

Wiens, J.D., R.G. Anthony, and E.D. Forsman. 2014. Competitive interactions and resource partitioning between Northern Spotted Owls and Barred Owls in Western Oregon. Wildlife Monographs 185: 1-50.

Wilson, T.M., and E.D. Forsman. 2013. Thinning Effects on Spotted Owl Prey and Other Forest-dwelling Small Mammals. In P.D. Anderson and K.L. Ronnenberg, (eds.). Density Management for the 21st Century: West Side Story. General Technical Report PNW-GTR-880. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Wheeler S.S., C.M. Barker, Y. Fang, M.V. Armijos, B.D. Carroll, S. Husted, W.O. Johnson, and W. K. Reisen. Differential impact of west nile virus on California birds. The Condor 111(1):1–20

Wright, A.L., and G.D. Hayward. 1998. Barred owl range expansion into the central Idaho wilderness. J. of Rap Research 32(2):77-81.

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

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

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

Yurok Forestry Department. 2012. Forest Management Plan Yurok Indian Sustained Yield Lands.

Zabel, C.J., K. McKelvey, P.W.C. Paton, B.B. Bingham, and B.R. Noon. 1993. Home range size and habitat use patterns of northern spotted owls in northwestern California and southwestern Oregon. Unpublished manuscript.

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

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

Zielinski, W. J., N. P. Duncan, E. C. Farmer, R. L. Truex, A. P. Clevenger, and R. H. Barrett. 1999. Diet of fishers (*Martes pennanti*) at the southernmost extent of their range. J. Mammalogy 80:961-971.

Zielinski, W.J., R.L. Truex, G.A. Schmidt, F.V. Schlexer, K.N. Schmidt, and R.H. Barrett. 2004. Home range characteristics of fishers in California. J. Mammalogy, 85(4):6.