27. NORTHERN SPOTTED OWL

Today's Item **Information** ☐ **Action** ☒

Consider whether to add the northern spotted owl (NSO) to the list of endangered species and, if FGC determines that listing may be warranted, authorize staff to publish notice of its intent to amend Section 670.5, Title 14, CCR.

Note: **DFW has notified FGC staff that it intends to request this agenda item be deferred to the Aug 24-25, 2016 meeting to finish reviewing and responding to the new information provided after the Apr 2016 meeting.**

Summary of Previous/Future Actions

• Received petition	Sept 7, 2012
• FGC transmits petition to DFW	Sept 10, 2012
• Published notice of receipt of petition	Oct 5, 2012
• Approved DFW request for 30-day extension	Dec 12, 2012; San Diego
• Received DFW's evaluation and recommendation	Mar 6, 2013; Mount Shasta
• Postponed whether petitioned action may be warranted	Apr 17, 2013; Santa Rosa
• Accepted petition for candidacy	Aug 7, 2013; San Luis Obispo
• Approved DFW request for six month extension	Dec 3, 2014; Van Nuys
• Received DFW status review report	Feb 10-11, 2016; Sacramento
• Discussion; deferred action to Jun 2016 meeting	April 13-14, 2016; Santa Rosa
• **Today's action to determine if listing is warranted**	**Jun 22-23, 2016; Bakersfield**

Background

A petition to list NSO was received in Sep 2012 (Exhibit 1). DFW submitted a status review report to FGC at the Feb 2016 meeting (Exhibit 2).; t

At the Apr 14, 2016 meeting, FGC delayed action on the petition, continued this item to the Jun 23, 2016 meeting and set a deadline of May 2 for submittal of supplemental information relevant to the action. Several comments and supplemental informational documents were submitted by the May 2, 2016 submittal deadline (see Significant Public Comments below and exhibits 3-10).

Note: DFW has notified FGC staff that it intends to request this agenda item be deferred to the Aug 24-25 meeting to finish reviewing and responding to the new information provided between the Apr meeting and the May 2 deadline.

Significant Public Comments

1. Environmental Protection and Information Center (EPIC) independent report, dated May 7, 2015 (Exhibit 3)
2. EPIC peer review comments on independent report, dated Jul 3, 2015 (Exhibit 4)
3. Email and supportive documents from Bill Snyder regarding Department of Fish and Wildlife

Staff Report Findings Regarding the Potential for Take of NSO Attributable to Timber Harvesting on Non-federal Ownerships (Exhibit 5)

4. EPIC email regarding NSO Stakeholder Working Group (Exhibit 6)
5. California Forestry provides three new studies relating to NSO (Exhibit 7)
6. Email from Matt Green regarding a need for alterations to the status review report about NSO on small industrial landowner forest lands (Exhibit 8)
7. Email from Craig Blencowe regarding regulatory burden on non-industrial owners (Exhibit 9)
8. Email from Lisa Weger regarding the regulatory burden on small non-industrial land owners (Exhibit 10)

Recommendation

FGC: Staff agree and support DFW recommendation to request this decision be deferred until the Aug 24-25 meeting to finish reviewing and responding to the new information provided after the Apr meeting.

DFW: DFW is expected to request this decision be deferred until the Aug 24-25 meeting to finish reviewing and responding to the new information provided after the Apr meeting.

Exhibits

1. Petition
2. DFW's NSO status review report (see: http://www.fgc.ca.gov/regulations/2012/index.aspx#nso)
3. EPIC independent report, dated May 7, 2015
4. EPIC peer review comments, dated Jul 3, 2015
5. Email from Bill Snyder, received May 2, 2016
6. Email from from Rob DiPerna, EPIC, received Apr 19, 2016
7. Email from George Gentry, California Forest Association, received May 3, 2016
8. Email from Matt Green, received May 3, 2016
9. Email from Craig Blencowe, received May 2, 2016
10. Email from Lisa Weger, received May 1, 2016

Motion/Direction (N/A)

BEFORE THE STATE OF CALIFORNIA
FISH AND GAME COMMISSION

PETITION TO LIST THE NORTHERN SPOTTED OWL AS "THREATENED" OR "ENDANGERED" UNDER THE CALIFORNIA ENDANGERED SPECIES ACT

ENVIRONMENTAL PROTECTION INFORMATION CENTER

September 4, 2012

Notice of Petition

California Fish and Game Commission
1416 Ninth Street, Suite 1320
Sacramento, CA 95814

The Environmental Protection Information Center (EPIC) hereby formally petitions the California Fish and Game Commission to list the northern spotted owl (*Strix occidentalis caurina*) as "threatened" or "endangered" pursuant to the California Endangered Species Act (CESA). California Fish and Game Code §§ 2050 *et seq*. This petition is filed under Sections 2072 and 2073 of the California Fish and Game Code and pursuant to Section 670.1, Title 14 of the California Code of Regulations which grants interested parties the right to petition for issue of a rule. This petition demonstrates that the northern spotted owl clearly warrants listing under CESA based on the factors specified in the statute.

This petition sets in motion a specific process placing definite response requirements on the California Fish and Game Commission and the California Department of Fish and Game and specific time constraints upon those responses. Petitioner certifies that all statements made in this petition are true and complete.

Petitioner:

Andrew J. Orahoske, Conservation Director
Environmental Protection Information Center
145 G Street, Suite A
Arcata, CA 95521

The Environmental Protection Information Center (EPIC) is a nonprofit organization that works to protect and restore ancient forests, watersheds, coastal estuaries, and native species in Northern California. EPIC's members have a direct interest in the conservation of the forests that support Northern Spotted Owls on both public and private lands which contribute to the continued existence of this species. Consequently, EPIC seeks to promote sustainable, restoration-based forestry through education, outreach, litigation, advocacy, and collaboration.

www.wildcalifornia.org

Executive Summary

The Northern Spotted Owl (*Strix occidentalis caurina*) has been listed under the federal Endangered Species Act (ESA) as "threatened" since 1990. By definition, a threatened species is ". . . likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." 16 U.S.C. §1531. Despite more than 20 years of protections, the northern spotted owl is now closer to extinction than ever. Recently, spotted owl biologists have published a comprehensive analysis that determined the species has been declining on seven of eleven active demographic study areas at about 3% annually range-wide from 1985-2008, and that the decline is accelerating in recent years (Forsman et al. 2011). The rate of decline is steepest in northern Oregon and Washington, where spotted owl populations would decline by more than half in the next 20 years. On the remaining federal lands, population decline is accelerating and vital rates are deteriorating (Forsman et al. 2011). On non-federal lands, including areas that once provided some of the highest quality habitat for spotted owls, declines are significantly greater than on federal lands, with vast areas no longer supporting any spotted owls at all. (Forsman et al. 2011, Anthony et al. 2006). The outlook for the northern spotted owl is dire based on the population trends, continued habitat loss, competition by the aggressive, invading barred owl, and the inadequacy of regulatory mechanisms, especially the lack of recovery efforts on state and private lands. This petition requests the U.S. Fish and Wildlife Service (USFWS) to acknowledge the best available science, and to act accordingly by changing the status of the northern spotted owl from "threatened" to "endangered" under the ESA.

The State of California has never acted to protect the northern spotted owl under the California Endangered Species Act (CESA). California Fish and Game Code §§ 2050 *et seq*. This is despite clear declines throughout the species range in California, as well as the remainder of the range. After listing the owl under the ESA, the USFWS and federal land managers developed a strategy, the "Northwest Forest Plan," to recover the spotted owl by heavily relying on a selection of federal lands to shoulder the burden of conservation. The plan's centerpiece was a network of habitat islands for spotted owls, termed "late-successional reserves" (LSRs). Unfortunately, the reliance on the Northwest Forest Plan meant that the conservation needs for spotted owls outside of the LSRs were largely ignored. This was especially true on state and private lands where spotted owls have been largely extirpated, with the remaining individuals in dire need of protections. The heavy reliance on fragmented reserves on federal lands without a comprehensive approach to spotted owl conservation on non-federal lands has proven to be a critical error, and one of the primary reasons why recovery has failed. Coupled with continued habitat loss is the very significant threat posed by the barred owl, which displaces spotted owls and thrives in the highly fragmented and simplified industrial forest landscapes.

It is now time for the State of California Fish and Game Commission to recognize its duties under CESA, and based on the overwhelming evidence, act swiftly to protect the northern spotted owl. Without a more holistic view of species recovery and landscape-scale conservation, the spotted owl is likely to go extinct in the foreseeable future.

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I. Introduction

The northern spotted owl (*Strix occidentalis caurina*) is a subspecies of spotted owls that was listed as "threatened' under the federal Endangered Species Act (ESA) in 1990, due to widespread loss of suitable habitat and the inadequacy of existing regulatory mechanisms. (USFWS 1990). The State of California has never acted to protect the northern spotted owl under the California Endangered Species Act (CESA). California Fish and Game Code §§ 2050 *et seq*. This subspecies has a low reproductive rate, restrictive habitat requirements and specializes on a limited number of prey species. In this petition we summarize the evidence of population declines and ongoing threats that are well documented in recently published literature making the subspecies vulnerable to extinction (Forsman et al 2011, Courtney et al. 2004, 2008, Davis et al. 2011, Anthony et al. 2006, Noon and Blakesley 2006).

This petition, combined with recent extensive studies of spotted owls, and the extensive documentation provided to the Fish and Game Commission herein, leads to the conclusion that northern spotted owls should be listed as "threatened' or "endangered" under the CESA. The best available science clearly shows that threats faced by the northern spotted owl have increased since listing the subspecies as "threatened" in 1990, and that the owl has been extirpated or nearly extirpated in many portions of its range. In light of this overwhelming evidence, the northern spotted owl is presently in danger of extinction, as defined by the CESA.

II. The Listing Process under the California Endangered Species Act

The State of California enacted the California Endangered Species Act (CESA) in order to address and prevent the extinction of native biological diversity. The purpose of CESA is to "conserve, protect, restore, and enhance any endangered species or any threatened species and its habitat...." Fish & Game Code § 2052. The first step under CESA is to identify and list species as "threatened" and "endangered." A "threatened species" refers to a native species or subspecies of a bird, mammal, fish, amphibian, reptile, or plant 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. Fish & G. Code § 2067. An "endangered species" refers to a native species or subspecies of a bird, mammal, fish, amphibian, reptile, or plant 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, overexploitation, predation, competition, or disease. Fish & G. Code § 2062.

The California Fish and Game Commission (Commission) is the administrative body that makes all final decisions regarding the listing of species under CESA. The California Department of Fish and Game (DFG) is the expert agency that makes recommendations to the Commission regarding species listings. The listing process may be set in motion in two ways: "any person" may petition the Commission to list a species, or the Department may on its own initiative put

forward a species for consideration. “Petitions shall 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 any other factors that the petitioner deems relevant.” Fish & G. Code § 2072.3. In the case of a citizen proposal, CESA sets forth a process for listing that contains several discrete steps.

Upon receipt of a petition to list a species, a 90-day review period ensues during which the Commission refers the petition to the Department, as the relevant expert agency, to prepare a detailed report. The Department’s report must determine whether the petition, along with other relevant information possessed or received by the Department, contains sufficient information indicating that listing may be warranted. Fish & G. Code § 2073.5.

During this period interested persons are notified of the petition and public comments are accepted by the Commission. Fish & G. Code § 2073.3. After receipt of the Department’s report, the Commission considers the petition at a public hearing. Fish & G. Code § 2074. At this time the Commission is charged with its first substantive decision: determining whether the Petition, together with the Department’s written report, and comments and testimony received, present sufficient information to indicate that listing of the species “may be warranted.” Fish & G. Code § 2074.2. This standard has been interpreted as the amount of information sufficient to "lead a reasonable person to conclude there is a substantial possibility the requested listing could occur." Natural Resources Defense Council v. California Fish and Game Comm. 28 Cal.App.4th at 1125, 1129.

If the petition, together with the Department’s report and comments received, indicates that listing “may be warranted,” then the Commission must accept the petition and designate the species as a “candidate species.” Fish & G. Code § 2074.2. “Candidate species” means a “native species or subspecies of a bird, mammal, fish, amphibian, reptile, or plant that the commission has formally noticed as being under review by the department for addition to either the list of endangered species or the list of threatened species, or a species for which the commission has published a notice of proposed regulation to add the species to either list.” Fish & G. Code § 2068.

Once the petition is accepted by the Commission, then a more exacting level of review commences. The Department has twelve months from the date of the petition’s acceptance to complete a full status review of the species and recommend whether such listing “is warranted.” Following receipt of the Departments status review, the Commission holds an additional public hearing and determines whether listing of the species “is warranted.” If the Commission finds that the species is faced with extinction throughout all or a significant portion of its range, it must list the species as endangered. Fish & G. Code § 2062. If the Commission finds that the species is likely to become an endangered species in the foreseeable future, it must list the species as threatened. Fish & G. Code § 2067.

Notwithstanding these listing procedures, the Commission may adopt a regulation that adds a species to the list of threatened or endangered species at any time if the Commission finds that there is any emergency posing a significant threat to the continued existence of the species. Fish & G. Code § 2076.5.

Despite the fact that the northern spotted owl has been threatened with extinction since the 1980's, and listed under the federal Endangered Species Act since 1990, the Commission has not protected the northern spotted owl under the California Endangered Species Act (CESA).

III. Biology and Ecology of the Northern Spotted Owl

A. Physical Description and Taxonomy

The northern spotted owl is a medium-sized owl and the largest of the three subspecies of spotted owls currently recognized by the American Ornithologists' Union (Gutierrez et al.1995). It is dark brown with a barred tail and white spots on the head and breast, and has dark brown eyes that are surrounded by prominent facial disks. The taxonomic separation of these three subspecies is supported by numerous factors (Courtney et al. 2004), including genetic (Barrowclough and Gutierrez 1990, Barrowclough et al. 1999, Haig et al. 2004, Barrowclough et al. 2005) morphological (Gutierrez et al. 1995), behavioral (Van Gelder 2003), and biogeographical characteristics (Barrowclough et al. 1999).

B. Range

Historically, the northern spotted owl was found from British Columbia through western Washington, western Oregon, and northwestern California from Siskiyou County south to Marin County (American Ornithological Union 1957, Forsman 1976, Forsman et al. 1984, Gutiérrez et al. 1995). The ranges of the northern and California subspecies of spotted owls meet at the southern end of the Cascade Range, near the Pit River area in northern California (Thomas et al. 1990, USFWS 1992, Barrowclough et al. 1999, Haig et al. 2001).

Currently, the northern spotted owl is extirpated or nearly extirpated from a portion of its historic range. Populations in British Columbia are nearly extinct (COSEWIC 2008), and those in Washington have been extirpated or nearly extirpated in many areas, including most notably southwestern Washington and much of the Olympic Peninsula and Puget Sound where the owl has suffered particularly precipitous declines. Significant populations remain in southern Oregon, but in northwestern Oregon and much of the Oregon Coast Range the owl is nearly extirpated. And, in California, populations are declining in two of three long-term monitoring sites, while numerous historic territories have been lost from interior forests in California. The Revised Recovery Plan for the northern spotted owl states: "Many historical spotted owl site-centers are no longer occupied because spotted owls have been displaced by barred owls, timber harvest, or fires" (USFWS 2011). The California Department of Fish and Game maintains records of

spotted owl territories in the California Natural Diversity Database (CNDDB). Detailed distribution maps of northern spotted owls are provided below.

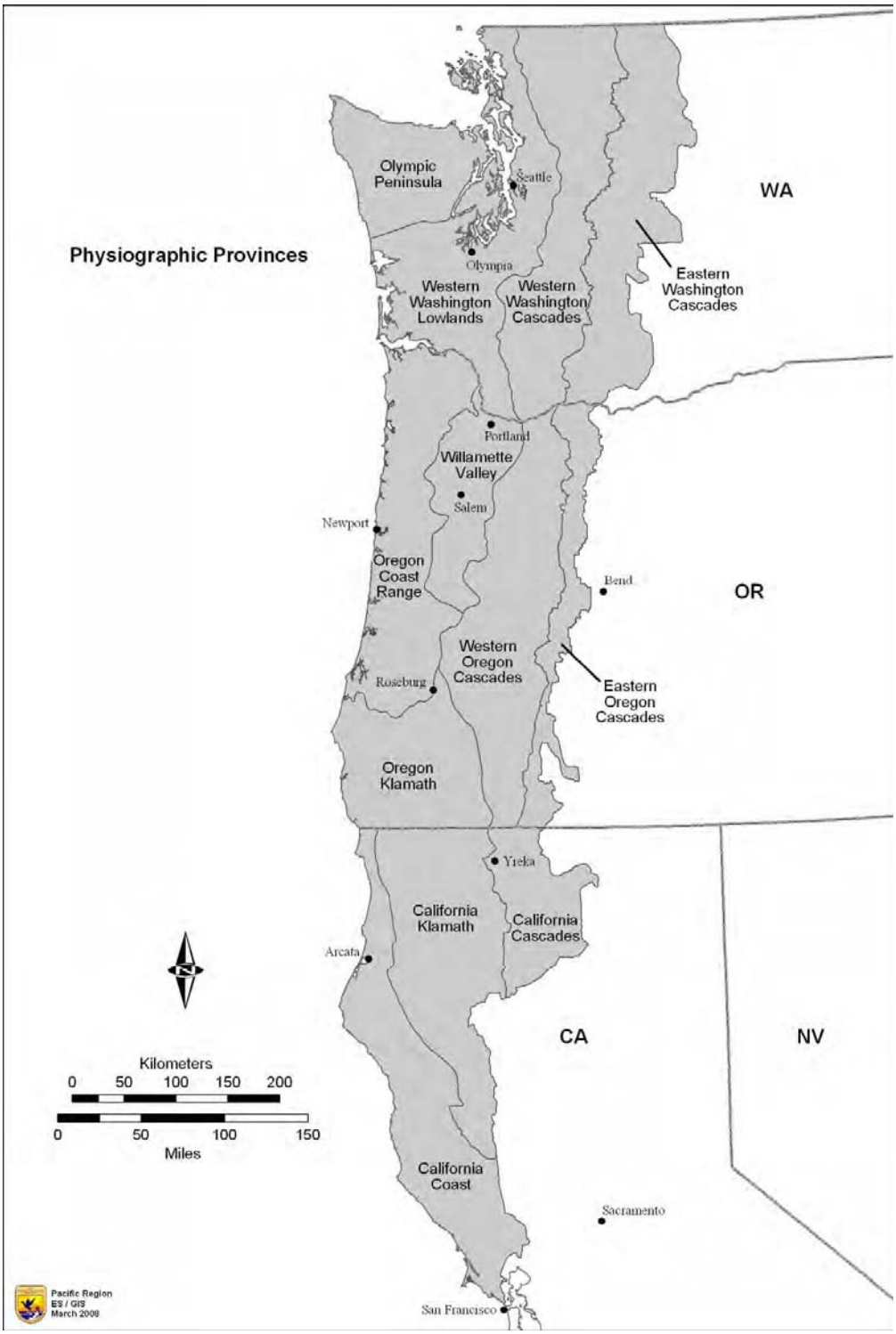


Figure 1: Overall range of the Northern Spotted Owl

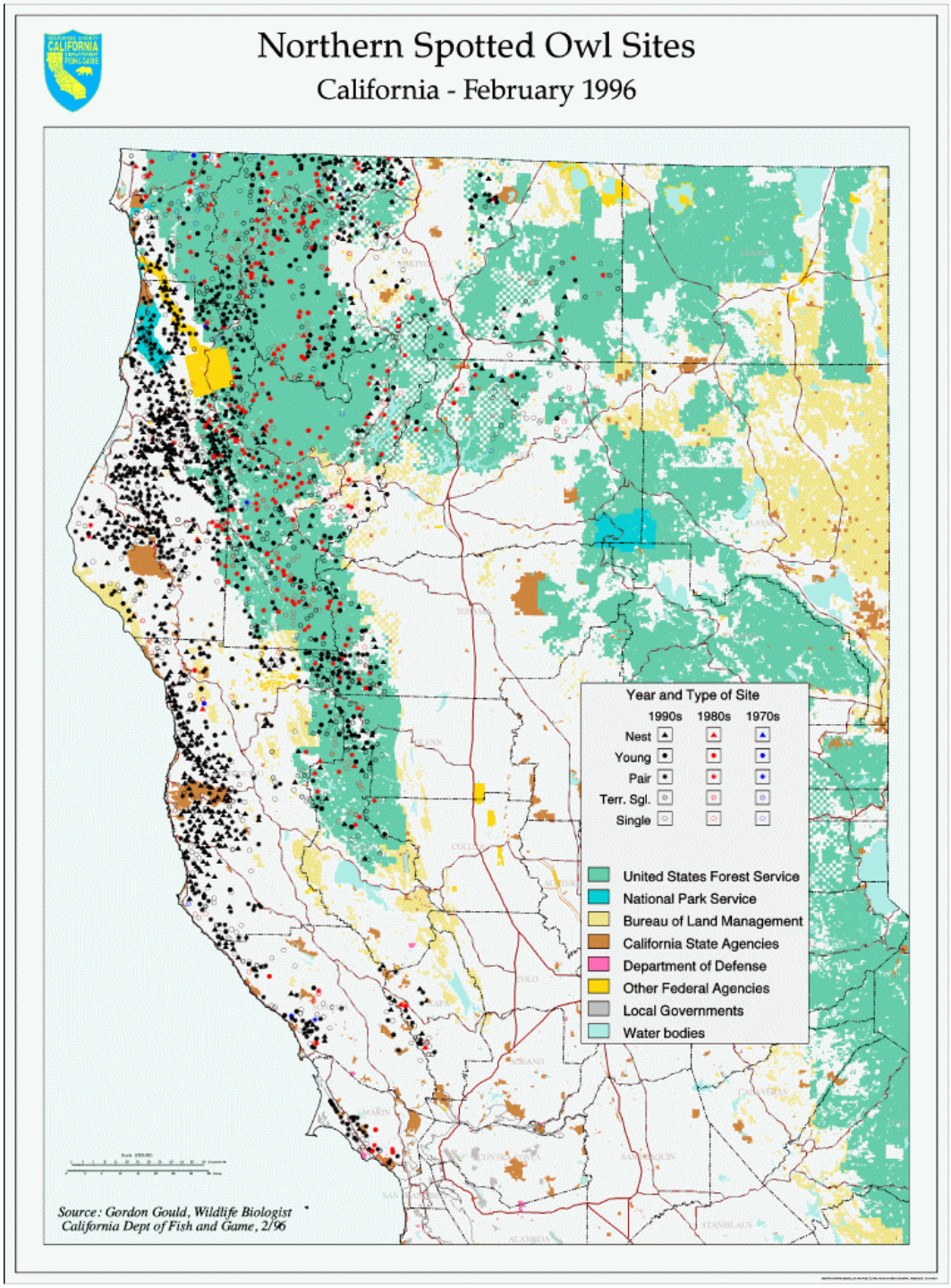


Figure 2: Northern Spotted Owl distribution in California (see legend for details).

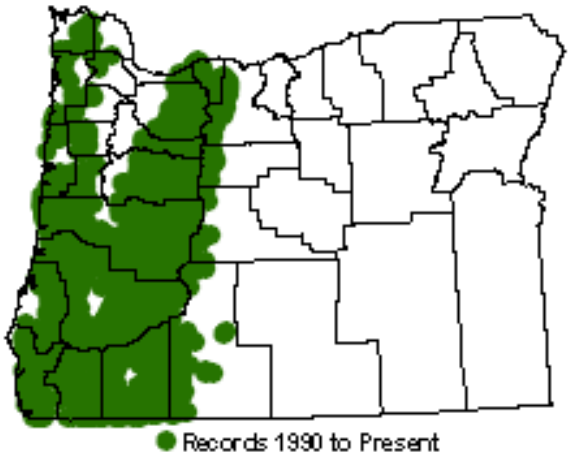


Figure 3: Northern spotted owl distribution in Oregon (green shaded area).

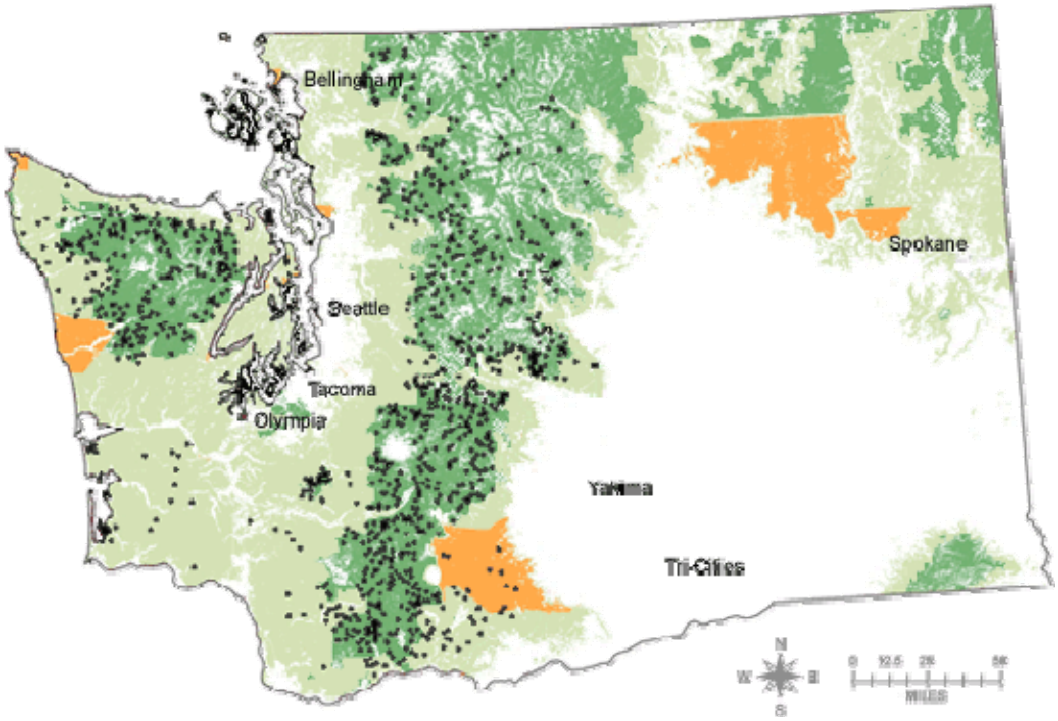


Figure 4: Northern Spotted Owl distribution in Washington (black dots).

C. Prey

Prey distribution and abundance plays a central role in the ecology of the northern spotted owl (Carey et al. 1992, Carey and Peeler 1995, Courtney et al. 2008). There is significant variation in the prey of the northern spotted owl across its range (Forsman et al. 2004, Courtney et al. 2008) and even within prey species, life history, and ecology vary geographically (Carey 2000, Lehmkuhl et al. 2006, Courtney et al. 2008). The northern portions of the owls' range lack several key prey species. For example, the red tree vole (*Aborimus longicaudus*) and dusky-footed wooded rat (*Neotoma fuscipes*) are not found north of the Columbia River (Carey et al.

1992, Carey 1999). However, southern Oregon provides some of the best remaining northern spotted owl habitat. In the margins of river valleys such as those along the Umpqua River, both the number of prey species and their abundance reaches a peak. In these areas, prey biomass may be the highest in the owl's entire range (Carey et al. 1992, Carey 1999). Ecotones between areas of older hemlock and mixed conifer forests may have three abundant prey species—red tree vole, bushy-tailed wood rat (*Neotoma cinerea*), and northern flying squirrel (*Glaucomys sabrinus*). Valley margins in southern Oregon often have these three prey species plus dusky-footed wood rat in abundance.

Carey et al. (1992) estimated the effect of the number of available prey species on the area needed to support a pair of northern spotted owls. In Douglas-fir (*Pseudotsuga menziesii*) / western hemlock (*Tsuga heterophylla*) forests in the southern Oregon Coast Range, when flying squirrels and bushy-tailed woodrats were available, 1,000 ha of old growth within a 2,000-ha area was sufficient to provide a high expectation of a pair surviving for one year. In more diverse nearby mixed conifer forests, with flying squirrels, bushy-tailed wood rats, dusky-footed wood rats, and red tree voles, owls needed less than half the area reported elsewhere. Cary et al. (1992) estimated that 500 ha of old forest within a 2,000-ha range could support a pair of northern spotted owls with a high probability of surviving for one year. In northern California, dusky-footed wood rat provides a major part of the northern spotted owl's diet (Courtney et al. 2008). The red tree vole is found in northwestern most California and is replaced by the Sonoma vole (*Arborimus pomo*) farther south.

While Courtney et al. (2004, 2008) provide a more extensive review of the diet of the northern spotted owl, little is known about the abundance and variability of prey populations. Owl demographic rates and population size may be influenced by prey abundance (Korpimäki 1992, Rohner 1996, Hakkarainen et al. 1997). Much of the high variation in northern spotted owl demographic rates may be explained, at least partially, by variations in prey abundance (Courtney et al. 2004).

D. Habitat Requirements

The best available science shows that relatively large areas of structurally complex, older forests provide the habitat necessary to support viable populations of northern spotted owls (Forsman et al. 2011). Spotted owls generally rely on older forested habitats because such forests contain the structures and characteristics required for nesting, roosting, and foraging, and dispersal. Forest characteristics associated with spotted owls usually develop with increasing forest age, but their occurrence may vary by location, past forest practices, and stand type, history, and condition. Although spotted owl habitat is variable over its range, some general attributes are common to the owl's life-history requirements throughout its range. To support northern spotted owl reproduction, a home range requires appropriate amounts of nesting, roosting, and foraging habitat arrayed so that nesting pairs can survive, obtain resources, and breed successfully. In northern parts of the range where nesting, roosting, and foraging habitat have similar attributes, nesting is generally associated with increasing old forest in the core area (Swindle et al. 1999). In some southern portions of the range, northern spotted owl survival is positively associated with

the area of old forest habitat in the core, but reproductive output is positively associated with amount of edge between older forest and other habitat types in the home range (Franklin et al. 2000). This pattern suggests that where dusky-footed woodrats (*Neotoma fuscipes*) are the primary prey species, core areas that have nesting habitat stands interspersed with varied types of foraging habitat may be optimal for northern spotted owl survival and reproduction. Both the amount and spatial distribution of nesting, roosting, foraging, and dispersal habitat influence reproductive success and long-term population viability of northern spotted owls. Population growth can occur only if there is adequate habitat in an appropriate configuration to allow for the dispersal of owls across the landscape. This includes support of dispersing juveniles, as well as nonresident subadults and adults that have not yet recruited into the breeding population. The survivorship of northern spotted owls is likely greatest when dispersal habitat most closely resembles nesting, roosting, and foraging habitat, but owls may use other types of habitat for dispersal on a short term basis. Dispersal habitat, at a minimum, consists of stands with adequate tree size and canopy closure to provide protection from avian predators and at least minimal foraging opportunities.

Large areas of older, structurally complex forests provide the habitat necessary to support viable populations of northern spotted owls. Extensive studies have supported the strong association of northern spotted owls and older forests. Northern spotted owls select older forests for nesting (Hershey et al. 1998, Swindle et al. 1999) and roosting and foraging (Forsman et al. 1984, Bart and Forsman 1992, Thomas et al. 1990, Herter et al. 2002, Glenn et al. 2004, Forsman et al. 2005). Nest site occupancy also is related to the presence of mature and old-growth forests throughout the owls' range although the nature of this relationship varies (Carroll and Johnson 2008). On private lands in northwestern California, northern spotted owls usually occur in the oldest forests available (Diller and Thome 1999). Understory structure characteristic of late-successional habitat is also important for northern spotted owls and their prey (Carey et al. 1992, Rosenberg and Anthony 1992, Buchanan et al. 1995, LaHaye and Gutiérrez 1999, Lehmkuhl et al. 2006).

Recruitment is positively related to the proportion of older forest habitat in owl territories, and higher levels of recruitment have been observed on federal lands with high proportions of old forest habitat (Forsman et al. 2011). Other studies have documented lower reproduction in areas with less old forest habitat. For example, pairs produced fewer fledglings in areas with less than 20 percent old forest habitat (average = 0.33 fledglings/pair) than in areas with greater than 60 percent old forest habitat (average = 0.93 fledglings/pair) (Bart and Forsman 1992).
Survival and fecundity are positively associated with the proportion of old forest surrounding nesting territories (Franklin et al. 2000, Dugger et al. 2005, Olson et al. 2004). In southern Oregon reproduction increased as the proportion of old forest within 730 m of activity centers increased (Dugger et al. 2005). Habitat may partially mitigate the effects of the invasive barred owl. The effects of barred owls increase with a decrease in old forest habitat (Dugger et al. 2011).

IV. Population Status

Forsman et al. (2011) determined that northern spotted owl populations declined on 7 of 11 study areas range-wide from 1985-2008. Overall population declines were documented throughout the range of the northern spotted owl at 2.9% annually, with estimates of population declines ranging from 5 to 15% in the Tyee, Klamath, Southern Cascades, and Hoopa study areas, and 40 to 60% in the Olympic, Cle Elum, Rainier, and Oregon Coast Range study areas (Forsman et al. 2011). See Table 1.

TABLE 1: Summary of trends in demographic parameters for northern spotted owls, from 11 study areas 1985-2008, adapted from Forsman et al. (2011).

Study Area	**Fecundity**	**Apparent survival**	**Population trend**
Washington			
Cle Elum	Declining	Declining	Declining
Rainier	Increasing	Declining	Declining
Olympic	Stable	Declining	Declining
Oregon			
Coast Range	Increasing	Declining since 1998	Declining
H.J. Andrews	Increasing	Declining since 1997	Declining
Tyee	Stable	Declining since 2000	Stationary
Klamath	Declining	Stable	Stationary
Southern Cascades	Declining	Declining since 2000	Stationary
California			
Northwestern California	Declining	Declining	Declining
Hoopa	Stable	Declining since 2004	Stationary
Green Diamond	Declining	Declining	Declining

Areas of primarily non-federal land support few or no owls and Forsman et al. (2011) state that too few northern spotted owls exist in these regions (i.e., southwestern Washington, the Coast Range of northwest Oregon, the California Cascades, and much of Washington's Olympic Peninsula) even to conduct a demographic study with their methods. It is likely that these declines will continue on both federal and especially on non-federal lands.

The effectiveness monitoring program of the NWFP confirms the dire trajectories reported in the studies discussed above. Analysis of data from government monitoring of owl populations on eight sites on federal lands (including sites in Washington, Oregon, and California) show a 2.8% decline per year. A 3.1% decline per year was calculated for the other three study areas (Davis et al. 2011). While these declines are dramatic, rates of decline are even more precipitous on non-federal lands (Anthony et al. 2006, Davis et al. 2011).

Funk et al. (2010) provide additional independent evidence that northern spotted owls continue to decline and document that the subspecies is experiencing a reduced effective population size. The loss of genetic variation in the spotted owl is an emerging threat not considered during the original listing. The evidence for recent genetic bottlenecks in northern spotted owls is based on a large genetic dataset. This study observes that the genetic bottleneck, in addition to field

evidence for demographic decline, highlights the increasing vulnerability of the northern spotted owl to extinction.

Demographic data from studies initiated as early as 1985 have been analyzed every 5 years to estimate northern spotted owl demographic rates and population trends (Franklin et al. 1999, Anthony et al. 2006, Davis et al. 2011, Forsman et al. 2011). The most current evaluation of population status and trends is based on data through 2008 (Forsman et al. 2011). Based on this analysis, populations on 7 of 11 study areas (Cle Elum, Rainier, Olympic Peninsula, Oregon Coast Ranges, H.J. Andrews, Northwest California, and Green Diamond) were declining (Forsman et al. 2011). Estimates of realized population change (cumulative population change across all study years) indicated that, in the more rapidly declining populations (Cle Elum, Rainier, and Olympic Peninsula), the 2006 populations were 40 to 60 percent of the population sizes observed in 1994 or 1995 (Forsman et al. 2011). Populations at the remaining areas (Tyee, Klamath, Southern Oregon Cascades, and Hoopa) showed declining population growth rates as well, although the estimated rates were not significantly different from stable populations (Forsman et al. 2011). A meta-analysis combining data from all 11 study areas indicates that rangewide the population declined at a rate of about 2.9 percent per year for the period from 1985 to 2006. Northern spotted owl populations on Federal lands had better demographic rates than elsewhere, but still declined at a mean annual rate of about 2.8 percent per year for 1985–2006 (Forsman et al. 2011). In addition to declines in population growth rates, declines in annual survival were reported for 10 of the 11 study areas (Forsman et al. 2011). Number of young produced each year showed declines at 5 areas (Cle Elum, Klamath, Southern Oregon Cascades, Northwest California, and Green Diamond), was relatively stable at 3 areas (Olympic Peninsula, Tyee, Hoopa), and was increasing at 2 areas (Oregon Coast Ranges, H. J. Andrews) (Forsman et al. 2011). The barred owl has emerged as a greater threat to the northern spotted owl than was previously recognized. The range of the barred owl has expanded in recent years and now completely overlaps that of the northern spotted owl (Crozier et al. 2006). The presence of barred owls has significant negative effects on northern spotted owl reproduction (Olson et al. 2004), survival (Anthony et al 2006), and number of territories occupied (Kelly et al. 2003; Olson et al. 2005). The determination of population trends for the northern spotted owl has become complicated by the finding that northern spotted owls are less likely to call when barred owls are also present; therefore, they are more likely to be undetected by standard survey methods (Olson et al. 2005, Crozier et al. 2006). As a result, it is difficult to determine whether northern spotted owls no longer occupy a site, or whether they may still be present but are not detected. The 2011 Revised Recovery Plan for the Northern Spotted Owl concludes that ‘‘barred owls are contributing to the population decline of spotted owls, especially in Washington, portions of Oregon, and the northern coast of California.’’ (USFWS 2011). British Columbia has a small population of northern spotted owls. This population has declined at least 49 percent since 1992 (Courtney et al. 2004), and by as much as 90 percent since European settlement (Chutter et al. 2004) to a 2004 breeding population estimated at about 23 birds on 15 sites (Chutter et al. 2004). Chutter et al. (2004) suggested immediate action was required to improve the likelihood of recovering the spotted owl population in British Columbia. In 2007, the Spotted Owl Population Enhancement Team recommended to remove spotted owls from the wild in British Columbia. Personnel in British Columbia captured and brought into captivity the remaining 16 known wild

spotted owls. Prior to initiating the captive-breeding program, the population of spotted owls in Canada was declining by as much as 35 percent per year (Chutter et al. 2004).

V. Nature, Degree and Immediacy of the Threat to Northern Spotted Owls in California

The following sections provide an overall summary of the threats to northern spotted owls throughout their range, including California. Taking all of the information together, it is clear that the species should be protected under CESA.

A. Present or threatened destruction, curtailment, or modification of habitat or range

The destruction of old-growth forests in the Pacific Northwest and northern California is the original reason why spotted owls are imperiled. The warning signs of extinction were first document in the 1970s, due to the heavy logging throughout the owl's range, especially on many federal lands that had escaped logging up until that point. Lower elevation forests throughout Washington, Oregon and California were clearcut and substantial amounts of spotted owl habitat was high-graded by logging the biggest trees first (USFWS 1990). Many of these areas have never recovered to a point that they support spotted owls, particularly in southwestern Washington and the coast ranges of Oregon. The patchily distributed federal lands present in these regions are insufficient to provide sufficient habitat to recover spotted owls. Therefore, the spotted owl has been extirpated from large portion of its historic range and it is unlikely that the habitat on these predominantly private lands will be recovered in the foreseeable future. Management of federal lands, while improved from before ESA-listing, continues to allow the removal and degradation of spotted owl habitat, even areas deemed critical to their conservation. The Revised Recovery Plan even contemplates continued habitat losses with Recovery Action 32 (USFWS 2011). This action provides protections for "high quality" habitat but not for suitable owl habitat – as a result, ongoing losses are anticipated for nesting, roosting, foraging, and dispersal habitat that is not determined to be "high quality" by the action agencies or through consultation with USFWS.

According to the USFWS, spotted owl habitat losses have continued across ownerships despite the "threatened" listing (Moeur et al. 2005, Raphael 2006, Courtney et al. 2004). See Table 2.

TABLE 2. Spotted owl habitat losses across ownerships, 1994 to 2004.

Area (acres)	Time	Ownership	Cause	Description	Citation
16,900	1994 to 2003	Federal	Logging	older forest	Moeur et al. 2005
141,300	1994 to 2004	Federal and non-	Stand-replacing fire	owl habitat	Raphael 2006

		Federal			
155,999	1994 to 2003	Federal	Logging	owl habitat	Courtney et al. 2004
583,500	1994 to 2004	Non-Federal	Logging	owl habitat	Courtney et al. 2004

According to Campbell et al. 2010, over 50% of the state's old-growth forests have been lost. From 1994 to 2003 in Oregon and Washington fragmentation of forests increased substantially, in some regions as high as five-fold (Davis and Lint 2005). Even if owl habitat has not been completely lost by clearcut logging, most other types of commercial logging remove important components of functional owl habitat. This simplification of forest ecosystems contributes the overall decline in habitat quality and the ability of owls to survive over the long-term. Within native forests with older-forest habitat, important components for owls and their prey such as standing dead trees, large down wood, multi-layered canopies, and other features have been lost throughout much of the owls' range and are in short supply particularly on nonfederal lands mainly because of lax forest practices. In many places, it will take centuries for forests to recover their former productivity even with the Northwest Forest Plan, and other measures in place due to the extensive ecological debt in late-seral habitat (Strittholt et al. 2006).

1. Ongoing and Threatened Habitat Loss in California

Within California alone, EPIC has identified numerous logging proposals on both private and public lands that will destroy or degrade spotted owl habitat. For example, on private lands owned by Sierra Pacific Industries, EPIC has identified over 27 timber harvest plans (THPs) that are currently ongoing or proposed that will destroy over 7,000 acres of spotted owl habitat. See Table 3. We provide the supporting information for the identified Sierra Pacific THPs, including the owl and habitat survey data with this petition to the USFWS.

TABLE 3: Sierra Pacific Industries' timber harvest plans (THPs) destroying northern spotted owl habitat in violation of the ESA Section 9 "Take" prohibition

THP number	**THP Name**	**Spotted Owl Habitat Destroyed (acres)**
1-09-054HUM	Roweisner	157
1-09-061HUM	Rerun	399
1-09-085HUM	Acer	371
1-10-025HUM	Green Mule	130
1-10-048HUM	Kragness	112
1-10-085HUM	Marvel	34
1-12-042HUM	Hiker's Parade	724
2-09-010TRI	Hogs	83
2-09-038TRI	Wilcox	727
2-09-041TRI	Halls	227
2-09-042SHA	Derby	68

2-09-078LAS	Big Widow	123
2-09-085TRI	Bowman	91
2-09-091TRI	Lowball	64
2-10-011TRI	Dyno	403
2-10-019TRI	Ebert	321
2-10-074TRI	Ranger	189
2-10-075TRI	Hinkey	22
2-11-004TRI	Llium	54
2-11-014TRI	3B's	138
2-11-035TRI	Bowtie	2
2-11-061TRI	Pappy	895
2-11-064TRI	Southern Star	271
2-11-070TRI	Thurman	426
2-11-076SHA	Tea Kettle	167
2-11-078SHA	Uncle	717
2-11-080TRI	Hay	173
		7088 acres destroyed in total

Notably, the ongoing destruction of northern spotted owl habitat by Sierra Pacific Industries is taking place without an incidental take permit as required under the ESA. Therefore, EPIC has formally notified Sierra Pacific Industries with letter of intent to sue over violations of the ESA (EPIC 2012). The Secretary and USFWS have been aware of this ongoing "take" since at least February 2012, but the federal authorities have failed to act. The overall habitat destruction on Sierra Pacific Industries and other private lands in northern California has resulted in the abandonment of dozens of historic spotted owl territories (USFWS 2009). Those that remain are mostly all severely deficient in suitable habitat, particularly nesting and roosting habitat made up of older forests.

2. Habitat Loss and the Decline of Preferred Prey Species

Northern Flying Squirrel

The northern flying squirrel northern flying squirrel (*Glaucomys sabrinus*) is an essential prey species for spotted owls, particularly in the Oregon and Washington. Carey (2003) determined that logging in forests of the Pacific Northwest and northern California has produced imbalanced mammal communities, with some species that were once common in natural forests (Carey, 1995; Carey and Johnson, 1995) no being low in abundance. In particular, northern flying squirrels are very rare in the industrial timber stands due to dense homogeneous tree plantations with simplified understory while also promoting excessively high and uniform chipmunk abundance (Carey 2003). Manning et al. (2011) determined that large-scale commercial thinning of Douglas-fir forests is detrimental northern flying squirrels, and brings into question many of the proposed thinning treatments in spotted owl habitat. A recent meta-analysis of effects of silvicultural practices on northern flying squirrels found that previous studies asserting a benefit or no effect of harvesting on squirrel populations lacked statistical power and support for those

assertions (Holloway and Smith 2011). The implication of Holloway and Smith's meta-analysis is that forest management practices that are currently widespread in the Pacific Northwest (thinning and clearcutting) have negative short-term and long-term impacts on northern flying squirrels (Manning et al 2011).

Tree Voles

Tree voles are small, mouse-sized rodents that live in conifer forests and spend almost all of their time in the tree canopy. Tree voles rarely come to the ground, and do so only to move briefly between trees. They are one of the few animals to persist on a diet of conifer needles, which is their principal food. Spotted owls in Oregon and California rely on heavily on tree voles as a main source of prey. Tree voles are endemic to the humid, coniferous forests of western Oregon and northwestern California. Recently, the USFWS has proposed listing the northwestern Oregon distinct population segment of red tree vole under the ESA. See 76 Fed. Reg. 198 (October 13, 2011). The status review found that despite federal protections afforded by the Northwest Forest Plan, that the red tree vole was threatened due to ongoing clearcutting and habitat destruction on private, state and federal lands. Id. The clear declines for red tree voles throughout the range of the spotted owl are another indication that the owl faces significant threats warranting an endangered listing.

B. Disease or Predation

West Nile Virus is a potential threat to the northern spotted owl (Blakesley et al. 2004). Large numbers of wild birds have been killed by West Nile Virus since its introduction in 1999 and subsequent spread across North America (McLean et al. 2001, Caffrey 2003, Marra et al. 2004, Blakesley et al. 2004). Owls are known to be susceptible to West Nile Virus (Fitzgerald et al. 2003) and a captive spotted owl has died of the virus (Gancz et al. 2004). In addition, recent examination of the rates of infection by blood parasites indicates that northern spotted owls have a high rate of infection by *Leucocytozoon* and other parasites (Ishak et al. 2008). In addition, a *Plasmodium* parasite was documented for the first time in a northern spotted owl. The observed discrepancy between prevalence of blood parasites in barred and spotted owls could be explained by a better host immune response to the parasites. This differential in blood parasite infection rates led Ishak et al. (2008) to speculate that barred owls on the West coast may have a competitive advantage over the potentially immune compromised spotted owls.

C. Predation

Northern spotted owls are subject to predation by great horned owls (*Bubo virginianus*), goshawks (*Accipiter gentilis*), and red tailed hawks (*Buteo jamaicensis*) (Forsman et al. 1984, Courtney et al. 2004). This natural predation has been severely exacerbated by the destruction and fragmentation of suitable habitat. Industrial forestry models across millions of acres of private lands that create dense tree plantations, coupled with ongoing habitat degradation on public lands has resulted in more open habitat suitable for predators of spotted owls (Courtney et

al 2004). Additionally, barred owls (*Strix varia*) physically attack (Livezey and Fleming 2007) and may prey upon spotted owls (Leskiw and Gutiérrez 1998). With the expansion of the barred owl's range (Livezey 2009) this source of predation is increasing.

D. Inadequacy of Existing Regulatory Mechanisms

The inadequacy of existing regulatory mechanisms has been repeatedly cited as a primary threat to northern spotted owls for more than 20 years (USFWS 1990, Franklin and Courtney 2004, USFWS 2004, USFWS 2011). The primary inadequacies are the lack of protections for spotted owls on non federal lands, especially large swaths of industrial forestry lands controlled by a few large corporations. The regulatory inadequacies on non-federal lands were reviewed by DellaSala (2011) and categorized as follows: variable and often inadequate protection given to owls and owl habitat; lack of landscape-scale planning, especially on non-federal lands; use of survey protocols and other standards that fail to incorporate current relevant science; prevalence of discretionary guidelines and/or unclear or unsuitable direction; failure to consistently require involvement of personnel with biological expertise in evaluating/assessing ecological information. On federal lands and despite the protections afforded by the Northwest Forest Plan, insufficient protections and a lack of recovery planning outside of late-successional reserves continues to plague the agencies involved in forest management. This petition and supporting documentation clearly show that existing regulatory mechanisms have not prevented the continued decline of northern spotted owls since the 1990 ESA listing.

1. Non-federal Lands

Private and state lands managed for intensive timber production, employing clearcutting and short rotation, mono-culture and herbicide use have been largely overlooked by state regulators. Even though such practices were the primary reason for the original ESA-listing, this major cause of the spotted owl's decline and continued imperilment is simply not adequately addressed by existing laws and regulations. Most attention has focused on federal forest management, primarily because federal authorities have refused to prosecute ESA violations. Because the USFWS has abandoned its clear duties to prosecute "take" under the ESA, the lack of adequate regulations non-federal lands continues to pose a threat to northern spotted owls. Rather than issue protective regulations or prosecute violations of the ESA, the USFWS has allowed individual state agencies with conflicting missions to issue inadequate regulations in an attempt to create a façade of conservation. The following sections describe the regulatory approach and inadequacies for California, Oregon and Washington.

a) California

The California Forest Practices Rules ("CA FPRs") are the primary state regulations affecting the management of the spotted owl on private lands in California. These regulations implement the Z'berg Nejedley Forest Practices Act of 1973 (4 Pub. Res. Code Ch. 8). Unbelievably, the State of California has never listed the spotted owl under the state's own California Endangered

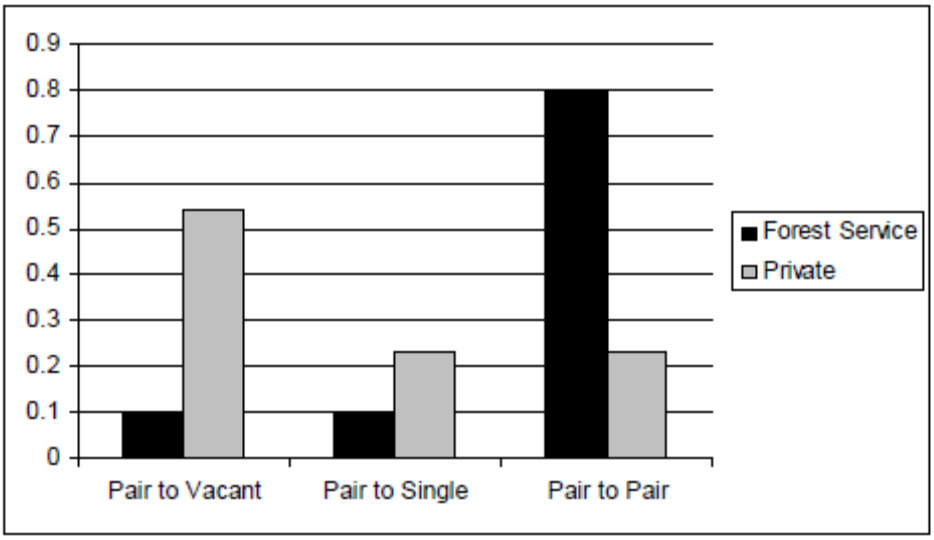
Species Act (CESA). Lacking any listing under CESA, the California Department of Fish and Game (CA DFG), the state agency charged with defending the public wildlife trust, is completely absent from conservation efforts. Therefore, the CA FPRs, as administered by the California Department of Forestry and Fire Protection (CalFire), are the state's only attempt at conserving spotted owls, and they are woefully inadequate. The CA FPRs require timber operators to prepare and submit a Timber Harvest Plan (THP) that is intended to serve as a substitute for the planning and environmental protection requirements of the California Environmental Quality Act of 1970 (Pub. Res. Code sections 21000-21177). The CA FPRs allow for the removal of spotted owl habitat below threshold guidelines for the avoidance of "take" set by the U.S. Fish and Wildlife Service (CA FPRs 2012, USFWS 2009).

The Yreka Field Office of the U.S. Fish and Wildlife Service completed an extensive analysis of the status of historical spotted owl activity centers on federal and private lands in interior northern California (USFWS 2009). The Service found that extensive losses of owl pairs occurred on private lands, which sharply contrasted with the persistence of owl pairs on federal lands. Yreka USFWS concluded:

> To quantify the pattern of territory loss identified during the technical assistance process, we compared results of protocol surveys conducted at verified NSO territories supporting at least one year of occupancy by paired owls on Forest Service lands (N=196) with similar data from private timberlands (N=75) in Shasta and Trinity counties. The data set consisted of activity center status records in the California Department of Fish and Game's Spotted Owl Database (CDFG-NSO database), supplemented with territory locations and recent survey records received during technical assistance. We first evaluated the validity of activity center records in the CDFG-NSO database, and eliminated 18 sites on private lands due to lack of verification of status. The remaining 57 private-land activity centers had verified NSO status in at least one year between 1989 and 2007; 44 of these sites had supported pairs during at least one year. Of these verified pair sites, 54% declined from pair status to no response, and an additional 23% declined from pair status to a territorial single owl during subsequent protocol surveys (Figure I.B.1). On Forest Service-administered lands, 80% of pair sites did not change status during the same time periods. While we recognize that annual variation in survey effort and results at this relatively coarse scale of resolution may influence this type of analysis, the strong differences in trends observed on private versus federal lands supports the contention that management on private timberlands is creating habitat conditions that do not support sustained occupancy by NSO.

(USFWS 2009: 11-12). The Service also created the figure below to illustrate the results of their analysis. Clearly, the California Forest Practice Rules are completely inadequate to protect spotted owls on private lands.

Figure I.B.1. Status of valid historical northern spotted owl activity centers (pair sites only) when resurveyed after 5-10 years. Data are from U.S. Fish and Wildlife Service technical assistance records and USFS monitoring records



The application of the limited protections contained in the CA FPRs depends upon prior identification of areas as "activity centers." If an activity center has not been identified, then no habitat protections nor surveys are required. In addition, the current database of activity centers is generally acknowledged to be out of date, poorly maintained, not well updated, and not reliable. Further, the definition of an "active nest site" or "pair activity center" in §919.9(g)(1-2) & 939.9(g)(1-2) (known as "Option G") is not inclusive enough to apply to all the sites entitled to protection under the Endangered Species Act. For known activity centers, the CA FPRs "Option G" only requires that a minimum amount of general spotted owl habitat be maintained, and makes no distinction as to whether the habitat must be nesting, roosting or foraging habitat. This critical deficiency means that logging operations may result in the complete removal of nesting and roosting habitat from an activity center, and still comply with the rules so long as enough foraging habitat remains. This on-the-ground reality is why the USFWS has found most activity centers on private lands have been abandoned since the early 1990s.

b) Oregon

Only a nest site and 70 acres of adjacent habitat is protected in Oregon, and the Oregon Department of Forestry does not consider foraging habitat to be a specific resource site, and therefore it is not protected under the Oregon forest practice rules (Oregon Administrative Rules (OAR) 665, Oregon Forest Practice Act Rulebook 2010). Nothing contained within the state rules reflects the best available science regarding the habitat needs for spotted owls. Even though the species is listed under the Oregon Endangered Species Act, the state has not developed a regulatory mechanism adequate to protect, much less recover, northern spotted owl habitat and populations.

c) Washington

Although the northern spotted owl has been listed as "endangered" under the Washington State Endangered Species Act since 1988, the subspecies has declined most precipitously in this state. There is no state recovery plan for spotted owls. Under the Washington State Forest Practice Rules, significantly different protections apply to northern spotted owls and their habitat depending on their location within or outside of designated Spotted Owl Special Emphasis Areas (SOSEAs). Conservation measures for northern spotted owls on private lands outside SOSEAs are "substantially less" than within SOSEAs (Ward 2006, Sweeden 2006). Even within SOSEAs, the designation does not prohibit detrimental forest practices so long as some environmental review takes place. The State of Washington and Weyerhaeuser Corporation were prosecuted for illegal "take" of northern spotted owls, resulting in a legal settlement that created a working group to recommend changes to Washington's Forest Practice Act. *See* Seattle Audubon Society v. Sutherland, 2:06−cv−01608−MJP, W.D. Washington. The federal court issued a preliminary injunction against further logging due to ongoing and threatened harm to spotted owls outside of SOSEAs. Id. The subsequent working group produced recommendations for changes to private lands logging in Washington to the state's forest practice board (Berg et al. 2009). The State of Washington's forest practice board has failed to act on those recommendations to the present day, and therefore spotted owls are still lacking adequate protections.

2. Federal Lands

While protections and conservation strategies are much better than on private and state lands, federal land management still poses many problems for spotted owls. All federal lands within the range of the northern spotted owl are currently managed under the provisions of the Northwest Forest Plan ("NWFP"). The NWFP was adopted in 1994, and it amended land management planning documents for nineteen National Forests and seven Bureau of Land Management districts throughout Washington, Oregon and California. The NWFP established a late-successional reserve (LSR) network and specified management standards and guidelines to further the recovery of northern spotted owls.

The 15-year report on the NWFP performance for spotted owls was recently released and it plainly shows that the plan is simply not enough to recover the species (Davis et al. 2011). The NWFP was based on overly optimistic assessments of spotted owl demographic performance (Franklin et al. 1999, Anthony et al. 2006). Demographic studies (Franklin et al. 1999, Anthony et al. 2006, Forsman et al. 2011, Davis et al. 2011) have demonstrated that the population declines are much greater rate than was anticipated across their range and particularly in Washington. In light of this decline, the Forsman et al. (2011) stressed the importance of retaining high quality owl habitat: "[i]n view of the continued decline of Spotted Owls in most study areas, it would be wise to preserve as much high quality habitat (i.e., late-successional forests) for Spotted Owls as possible, distributed over as large an area as possible."

The NWFP protected some of the remaining high quality owl habitat, but not the entirety of remaining high quality owl habitat was protected. In addition, recent estimates have shown that

only about 36% of late-successional reserves actually include late-successional forests, with the majority of the designated reserves expected to acquire such conditions over decades (Strittholt et al. 2006). Similarly, recent scientific literature suggests that the limited, bare minimum approach taken by the NWFP is inadequate to stabilize populations. Of particular note is the omission of all remaining nesting, roosting, and foraging habitat from reserves. While qualifying as late-seral the remaining nesting, roosting, and foraging habitat may not meet the standards of high quality habitat implicit in the Revised Recovery Plan (USFWS 2011). Thus, important owl habitat on federal lands will remain vulnerable to ongoing logging at a time when owl populations are declining more rapidly than anticipated, and risks are increasing from presumed competitive pressures from barred owls.

The NWFP noted that "certain thinning and salvage activities would be allowed in the reserves," however, thinning or other silvicultural treatments inside reserves theoretically are authorized "only if those treatments are beneficial to the creation of late-successional forest conditions" (USDA Forest Service and USDI BLM 1994). Some studies have indicated that spotted owls are somewhat resilient to low to mid-severity fire effects (Clark 2007, Bond et al. 2009). However, post-fire logging is often employed after fires, and a bigger threat to owls (Clark 2007, Bond et al. 2009, Hanson et al. 2010). Northern spotted owls remain vulnerable to post-fire logging even within late-successional reserves, as the NWFP is inadequate to protect owls from this threat. During the decades since original adoption of the NWFP, post-fire logging has become a more significant source of timber from federal lands, including late-successional reserves, and fire associated management (including thinning, suppression, and post-fire logging) has become a substantial emphasis of both the Forest Service and the Bureau of Land Management. As a result, supposedly protected owl habitat is at risk of fire-associated management (Hansen et al. 2009). This is particularly relevant on BLM lands in western Oregon, where the Secretary of Interior recently proposed a pilot process following active management guidelines in Johnson and Franklin (2009) that could extend thinning limits within reserves in dry forested regions from current 80-year limits to 120-years. Thus, active forest management designed to open forest canopies is increasing and could result in degrading additional owl habitat (Hanson et al. 2009, 2010).

E. Other natural or manmade factors affecting the continued existence of the species

1. Barred Owl

The barred owl (*Strix varia*), closely related species to spotted owls, has expanded its range from its original home in eastern North America into the Pacific Northwest, much to the detriment of spotted owls. (USFWS 2011, Campbell 1973, Hamer et al. 1994, 2001, Dark et al. 1998, Herter and Hicks 2000, Pearson and Livezey 2003, Livezey 2009a and 2009b). Recent studies report that barred owls have "increased dramatically" on the demographic study areas over the last two decades (Forsman et al. 2011).During the second half of the 20thcentury, barred owls expanded their range from eastern to western North America, and the range of the barred owl now completely overlaps that of the northern spotted owl (Gutierrez et al. 1995, Crozier et al. 2006).

Barred owls compete with northern spotted owls for habitat and resources for breeding, feeding, and sheltering, and the presence of barred owls has significant negative effects on northern spotted owl reproduction, survivorship, and successful occupation of territories. The loss of habitat has the potential to intensify competition with barred owls by reducing the total amount of resources available to the northern spotted owl and by increasing the likelihood and frequency of competitive interactions. Barred owls select very similar habitat to spotted owls for breeding, feeding, and sheltering, and loss of habitat has the potential to intensify competition between species. While conserving habitat will not alleviate the barred owl threat, Dugger et al. (2011) found that spotted owl occupancy and colonization rates decreased as both barred owl presence increased and available habitat decreased. These authors concluded that, similar to another case in which increased suitable habitat was required to support two potentially competing raptors, increased habitat protection for spotted owls may be necessary to provide for sustainable populations in the presence of barred owls (Dugger et al. 2011).

Maintaining high-quality habitat has been important since the northern spotted owl was initially listed as threatened in 1990, and this competitive pressure from barred owls has intensified the need to conserve and restore large areas of contiguous, high quality habitat across the range of the northern spotted owl (Dugger et al. 2011, Forsman et al. 2011, USFWS 2011). The Revised Recovery Plan states:

> Barred owls reportedly have reduced spotted owl site occupancy, reproduction, and survival. Limited experimental evidence, correlational studies, and copious anecdotal information all strongly suggest barred owls compete with spotted owls for nesting sites, roosting sites, and food, and possibly predate spotted owls. . . Because the abundance of barred owls continues to increase, the effectiveness in addressing this threat depends on action as soon as possible

(USFWS 2011, p. III-62). Barred owls initially proliferated in Washington and Oregon much more rapidly, but barred owls are becoming increasingly common in northern California (USFWS 2012, Dark et al. 1998, Kelly 2001, Kelly et al. 2003, Forsman et al. 2011).

The USFWS has recently embarked on a barred owl removal experiment, releasing a draft environmental impact statement in March 2012 that includes an exhaustive list of research and documentation outlining the threat posed by barred owls (USFWS 2012). While it encouraging that the USFWS will finally begin addressing the threat of barred owls, many researchers have questioned the utility of barred owl removal. Furthermore, given the landscape scale changes to Pacific Coast forests, and the rapid saturation of barred owls into these landscapes, a distinct question arises about USFWS' plans for addressing overall habitat changes in the range of the spotted owl. Regardless of whether the USFWS will address habitat loss and barred owls together, because it has taken 20 years for the USFWS to even begin addressing barred owls, whatever outcome may be too little too late for spotted owls across much of their historic range. Barred owls will likely always be present in the spotted owl's range, despite control efforts described by USFWS (2012).

Studies have clearly shown a negative impact on spotted owls due to direct displacement and occupancy of nesting sites and territories (Kelly et al. 2003, Olson et al. 2005). A negative impact on spotted owl fecundity (Olson et al. 2004). Forsman et al. (2011) found that the presence of barred owls has a negative effect on spotted owl recruitment, in turn affecting their survival and population trends. Of all the factors contributing to declines in the demographic rates of northern spotted owls, the presence of barred owls is the strongest and most consistent across study areas (Forsman et al. 2011, p. 75). Kelly et al. (2003) concluded that the presence of barred owls at historical northern spotted owl sites reduced spotted owl occupancy. Gremel (2005) determined that the presence of barred owls appeared to be reducing northern spotted owl occupancy at their historical sites and increasing the detection distance between spotted owls and their original site centers.

Crozier et al. (2006) showed that northern spotted owls have a reduced response rate in the presence of barred owls. While not the focus of the study, this provides evidence that barred owls may disrupt certain behaviors important to spotted owls. Vocalizations are an important part of the spotted owl's territorial behavior.

Barred owls will choose old or mature forests for nesting and compete for nest cavities with spotted owls (USFWS 2012, McGarigal and Fraser 1984, Mazur and James 1998, Carroll and Johnson 2008, Mazur et al. 1997, Buchanan et al. 2004). Barred owls prey upon the same species of small mammals that are the primary prey species of Spotted Owls (Forsman et al. 2001, Hamer et al. 2001). In addition, barred owls also prey upon a wider variety of prey not taken by spotted owls (Elderkin 1987, Bosakowski and Smith 1992, Hamer et al. 2001, Livezey et al. 2008). Further, annual home ranges of sympatric northern spotted owls were 3–4 times larger than those of barred owls in the western Cascade Mountains of Washington (Hamer 1988, Singleton et al. 2005), probably due to the more-varied prey base of barred owls (Hamer et al. 2001, Livezey 2007, Livezey et al. 2008). Barred owls also breed more regularly and have consistently larger broods than do spotted owls (Livezey and Fleming 2007).

Finally, barred owls are capable of exploiting younger forest stands, and semi-forested urban and suburban landscapes in the range of the northern spotted owl that are seldom used by spotted owls (Livezey and Fleming 2007) and use forests in the Pacific Northwest outside of the range of the spotted owl (Buchanan 2005). As a result, barred owls have large source populations that, with their greater dispersal capability (Gutiérrez et al. 2004, Livezey and Fleming 2007), can supplement numbers of barred owls within the range of the spotted owl. As expected, the overlap between barred and spotted owls in habitat and prey coupled with the larger size and more aggressive nature of the barred owl has resulted in significant concern for the long-term sustainability of the northern spotted owl. Livezey and Fleming (2007) concluded that barred owls have a competitive advantage over spotted owls.

VI. Recommended Management and Recovery Actions

- List the northern spotted owl as an endangered species within California under the California Endangered Species Act.

- Initiate a long-term planning process to create a northern spotted owl recovery plan based on the best available science. Such a plan should include the development of clear conservation goals for the recovery of northern spotted owls.

VII. Conclusion

Northern spotted owls are now facing extinction throughout a significant portion of their range. Continued habitat loss range-wide, the failure on non-federal lands to protect and restore spotted owl habitat, the invasion of the barred owl and additional threats listed above require that the California Fish and Game Commission immediately begin the process of listing the species as "threatened" or "endangered" under the CESA. Many populations of spotted owls have already been extirpated, and the remaining populations are reduced and declining. The best available scientific evidence is clear that the northern spotted owl is in danger of extinction throughout all or a significant portion of its range.

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The Northern Spotted Owl in California: Current Status and Threats

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Photograph courtesy of Peter Carlson.

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Introduction

This Independent Status Report was prepared pursuant to the California Endangered Species Act's (CESA) implementing regulations, specifically Cal. Code Regs., tit. 14, § 670.1 (h), which allows "interested parties . . . to submit a detailed written scientific report to the commission on the petitioned action." This same regulation explains that parties "may seek independent and competent peer review of this report prior to submission", and the author did so (see acknowledgements section at end of each chapter). Furthermore, to comply with the Fish and Game Code, section 2074.6, this report must be "based upon the best scientific information available."

This report was prepared by Wildlife Ecologist, Dan L. Hansen. His CV is attached, and a brief description of his qualifications is included herein (see *Project Author and Funding*).

This Independent Status Report was commissioned by the Environmental Protection Information Center (EPIC). However, its contents, conclusions, and management recommendations were exclusively developed by the author.

Executive Summary

This synthesis is organized into two parts. Part I consists of a single chapter: Status and Trends in California (Ch. 1). Part II covers four primary potential threats to northern spotted owls (*Strix occidentalis caurina*; NSOs) in California: Timber Harvesting (Ch. 2), Wildfires (Ch. 3), Barred Owls (Ch. 4), and Outdoor Marijuana Cultivation (Ch. 5). Following these chapters, a brief list of management recommendations is provided based on the information reviewed herein.

Chapter 1 is a review of the current status and trends of NSOs in California. Multiple types of information are available for evaluating the subspecies' status and trends in the state, including potential changes in its range, distribution, population densities, occupancy rates, demographic rates, metapopulation dynamics, and genetics. However, the most compelling information comes from long-term demographic studies in northwestern California (Forsman et al. 2011, Higley and Mendia 2013, Franklin et al. 2014, Green Diamond Resource Company 2014). These studies indicate that NSOs are declining in that portion of the state and that the rate of decline is accelerating. Competitive pressure from the congeneric barred owl (*S. varia*) appears to be the primary cause of increasing rates of population decline in the three demographic study areas. Occupancy data further support conclusions that NSOs in California's three demographic study areas are declining at an increasing rate and that the decline is largely driven by negative effects of barred owls (Franklin et al. 2014, Green Diamond Resource Company 2014). Less rigorous information is available for describing the NSO's current status and trends in California outside the state's demographic study areas. Only one published paper described occupancy in the eastern portion of the NSO's range in California (eastern Klamath and southern Cascades) (Farber and Kroll 2012). That paper described a substantial decline in occupancy by NSOs, which was likely associated with intensive timber harvesting and possibly, wildfires. Recent reports from demographic studies in southern Oregon further suggest that NSOs may be declining in relatively nearby and ecologically similar areas in California (eastern Klamath and southern Cascades) (Davis et al. 2013b, Dugger et al. 2014). Most of the other information for describing the subspecies' status and trends in California comes from monitoring reports by National Parks and industrial timber companies. NSOs appear to have been mostly displaced by barred owls in the Redwood National and State Parks (Schmidt 2013). In contrast, few barred owls have invaded National Park land in Marin County and occupancy by NSOs appears to be relatively stable in the area (Ellis et al. 2013). Industrial timber companies in California have uniformly concluded that NSO populations are stable on their lands (Calforests 2014). However, the available information for those ownerships does not support strong conclusions about the NSO's status or trends and some of the information actually appears to indicate at least gradual declines in occupancy.

Chapter 2 is a review of timber harvesting as a potential threat to NSOs in California. Habitat loss to timber harvesting was a primary impetus for listing the NSO under the federal Endangered Species Act (USFWS 1990). An estimated 60-88% of old forest was harvested within the NSO's range during the 19th and 20th centuries (USFWS 1990, Strittholt et al. 2006). Following federal listing of the NSO and adoption of the Northwest Forest Plan in the early 1990s, timber harvesting was dramatically curtailed on federal lands (Healey et al. 2008, Davis and Dugger 2011, Moeur et al. 2011, Kennedy et al. 2012). However, there is currently considerable interest among some ecologists, land managers, and agencies in use of widespread

forest thinning to reduce the risk of large severe wildfires on public lands (USFS and BLM 1994, USFWS 2008, 2011, 2012a, Franklin and Johnson 2012). The term thinning can encompass a wide array of silvicultural practices and prescriptions but the limited available evidence suggests that NSOs and their primary prey in California generally respond negatively to thinning and partial harvesting (see Ch. 2). Timber harvesting is still responsible for most habitat loss and degradation for NSOs on private lands (Davis and Dugger 2011). Habitat loss and degradation on private lands does not appear to be offset by habitat recruitment; even in California, which has more stringent habitat protection measures on private lands than do Oregon and Washington (Davis and Dugger 2011, Moeur et al. 2011). Although timber harvesting is generally accepted to have been the primary cause of the NSO's initial decline and federal listing, its effects on the subspecies are poorly known. Several rigorous studies in the southern part of the NSO's range, including in northwestern California, have found that the NSO's fitness (a function of survival and reproduction) is typically highest in landscapes with both a core concentration of mature and old forest and some degree of habitat heterogeneity (e.g., a moderate amount of habitat edge due to convoluted shapes of older forest patches) (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005, Schilling et al. 2013). Timber harvesting that substantially reduces either of these habitat attributes could negatively affect NSOs (USFWS 2009). The U.S. Fish and Wildlife Service (2009) concluded that current habitat retention guidelines for NSOs on industrial timberlands in interior California (CAL FIRE 2014) are inadequate and are not based on a current understanding of the subspecies' ecology.

Chapter 3 is a review of wildfire as a potential threat to NSOs in California. Several studies have investigated responses of NSOs to wildfires but their inferences are limited due to small sample sizes, short time frames, confounding effects of post-fire salvage logging, or pooling of data from all three subspecies. This information is supplemented in Chapter 3 with reviews of studies of effects of fire on California spotted owls (*S. o. occidentalis*) and Mexican spotted owls (*S. o. lucida*). Inferences from those studies are similarly limited by small sample sizes, short time frames, confounding effects of post-fire salvage logging, or pooling of different kinds of fire (prescribed fires, wildfires, and wildfires allowed to burn under specified conditions). Currently available information indicates that spotted owls respond in variable and complex ways to fire. The species appears to be generally resilient to low-, moderate-, and mixed-severity or patchy fires (Ch. 3: Table 3.1). It is possible that fires such as these sometimes benefit spotted owls by temporarily increasing access to prey that respond positively to fire (Ream 1981, Zwolak and Foresman 2007, Zwolak 2009, Bond et al. 2013). In contrast, spotted owls appear to generally respond negatively to extensive severe wildfires (Ch. 3: Table 3.1). While some spotted owls may preferentially forage in or near severely burned areas, they rarely nest and roost in such areas and may generally avoid foraging deep within them (Ch. 3: Table 3.1). The limited available information suggests that post-fire salvage logging negatively affects spotted owls (Clark 2007 and Clark et al. 2013, Lee et al. 2012, 2013). Salvage logging could reduce prey availability after fires by removing important structures, such as snags, logs, and shrubs. Habitat suitability modeling projected that wildfires caused substantial loss, degradation, and fragmentation of nesting and roosting habitat for NSOs on federal lands during the first 15 years of the Northwest Forest Plan (Davis and Dugger 2011). Most of these habitat changes were caused by a small number of extensive severe fires in southern Oregon and northern California. There is scientific debate regarding recent versus historical frequencies of high severity fire in southern Oregon and northern California (e.g., Hanson et al. 2009, 2010 vs. Spies et al. 2010).

Nonetheless, it is clear that large wildfires are now relatively common within the NSO's range in California (CAL FIRE 2008, Davis et al. 2011), and that some recent wildfires have severely burned very large areas (e.g., 2002 Biscuit Fire). Climate change research generally projects that large wildfires will become more common in California (Westerling et al. 2006, Lenihan et al. 2008, Westerling and Bryant 2008, Littell et al. 2009, Moritz et al. 2012, Stavros et al. 2014). It is reasonable to assume that some of these large wildfires will include extensive areas of high-severity fire and will therefore continue to be a source of habitat loss for NSOs.

Chapter 4 contains an evaluation of the barred owl as a potential threat to NSOs in California. The available information suggests that barred owls are currently the primary threat to NSOs throughout their range, including in California. Information from long-term demographic studies indicates that barred owls have contributed to the NSO's population declines in multiple study areas (Forsman et al. 2011) and that the barred owl's presence and negative impacts on NSOs are continuing to increase (Davis et al. 2013b, Higley and Mendia 2013, Franklin et al. 2014, Dugger et al. 2014). A large body of research conducted across much of the NSO's range has also shown that barred owls are associated with declines in occupancy rates by NSOs (Kelly 2001, Kelly et al. 2003, Pearson and Livezey 2003, Gremel 2005, Olson et al. 2005, Kroll et al. 2010, Dugger et al. 2011, Higley and Mendia 2013, Franklin et al. 2014, Green Diamond Resource Company 2014). Barred owls negatively affect NSOs by competing for space, habitat, and food (Gutiérrez et al. 2004, 2007, USFWS 2013, Wiens et al. 2014). The barred owl appears to be a superior competitor to the NSO due to its larger size, more aggressive behavior, higher reproductive potential, higher population densities, and broader ecological niche (e.g., USFWS 2013, Wiens et al. 2014). The available information suggests that lethal control of barred owls is a viable management option for some areas, although there is ethical and emotional resistance to this within some segments of society (Diller et al. 2013, Higley 2014). The negative effects of habitat loss and fragmentation on NSOs can be exacerbated by the presence of barred owls (Dugger et al. 2011). Thus, the barred owl threat magnifies the importance of habitat conservation for NSOs, rather than reducing it.

Chapter 5 is a review of outdoor marijuana cultivation as an emerging potential threat to NSOs in California. Marijuana is one of California's largest cash crops (Gettman 2006) but little is known about the environmental effects of its cultivation. Recent research in northwestern California has shown that both fishers (*Pekania pennanti*) and barred owls are regularly exposed to anti-coagulant rodenticides used to protect marijuana plants from rodents (Gabriel et al. 2012, 2014). Multiple fishers are known to have died due to poisoning from anti-coagulant rodenticides (Gabriel et al. 2012, 2013). Fishers and barred owls have overlapping distributions, habitat associations, and diets with NSOs so it is likely that many NSOs in California are likewise exposed to these toxicants. This was supported by recovery of a dead NSO in Mendocino County, which tested positive for exposure to anti-coagulant rodenticides (Calforests 2014). Marijuana cultivation could also negatively affect NSOs through habitat changes caused by illegal and poorly planned logging, road construction, pollution, and water diversion (Gabriel et al. 2013, Bauer et al. 2015). Marijuana cultivation can particularly impact riparian areas. These impacts could indirectly affect NSOs, which often show a preference for nesting, roosting, and foraging in riparian areas (e.g., Hamer et al. 2007, Irwin et al. 2012). Safety concerns about encounters with armed marijuana growers are resulting in reduced conservation research and

monitoring effort and efficiency for NSOs and other sensitive wildlife species in California (Keane et al. 2011, Gabriel et al. 2013, D. Hansen pers. obs.).

Overall, this synthesis supports conclusions that NSOs in California are declining at an increasing rate (Ch. 1) and that they face an array of threats to their persistence (Chs. 2-5). Barred owls appear to pose the greatest current threat to NSOs (Ch. 4). If conservation of NSOs is to remain a priority then widespread barred owl removal programs may be necessary. Habitat protection also remains an important aspect of NSO conservation. Listing under the California Endangered Species Act, substantial changes to the California Forest Practice Rules habitat retention guidelines, and greater involvement by knowledgeable spotted owl biologists in the Timber Harvest Plan review process may be necessary to adequately protect habitat for NSOs on private lands in the state. The available information suggests that large severe wildfires pose a threat to NSOs on federal lands in California (Ch. 3). Some ecologists and land management agencies have proposed widespread use of forest thinning and prescribed fire to reduce this risk. However, the available information also suggests that spotted owls often respond negatively to thinning (Ch. 2). It is important for land managers to consider potential tradeoffs in costs and benefits of thinning in landscapes occupied by NSOs. Thinning could potentially be focused in areas that generally receive the least use by spotted owls and that have the highest fire risk, such as upper and southwesterly slopes (see Ch. 3). The limited information currently available suggests that post-fire salvage logging negatively affects NSOs and their prey (Ch. 2). Further research of this topic is needed but this practice does not appear to be generally concordant with conservation of NSOs in California. Marijuana cultivation appears to pose a substantial emerging threat to NSOs in California; particularly trespass operations on federal lands (Ch. 5). Increased research, law enforcement, and site cleanup and restoration efforts are likely needed to protect NSOs from negative effects of outdoor marijuana cultivation in California.

Methods

The northern spotted owl (*Strix occidentalis caurina*; NSO) has been a focus of conservation concern and research for more than three decades (see reviews in Courtney et al. 2004 and USFWS 2011a). Although substantial habitat protection measures exist for NSOs on federal lands, the subspecies has continued to decline across much of its range (Forsman et al. 2011). Indeed, the U.S. Fish and Wildlife Service (2015) recently concluded that uplisting the NSO from 'threatened' to 'endangered' under the federal Endangered Species Act may be warranted. The California Fish and Game Commission will soon decide whether or not to list the NSO under the California Endangered Species Act. The large body of research and monitoring information concerning the NSO can be challenging for natural resource agencies and policymakers to evaluate. In order to inform the California Endangered Species Act listing decision and other policy and management actions, I have endeavored to synthesize much of the available scientific information concerning the NSO's current status, trends, and threats in the state.

While writing this synthesis, I reviewed information from a variety of sources but generally gave greater weight to peer-reviewed publications, particularly those based on more rigorous field and analytical methods. For example, in Chapter 1, I attempted to carefully consider all available information about the NSO's current status and trends in California but gave greatest weight to results of long-term demographic studies. Some topics related to the NSO's ecology and conservation are scientifically and politically contentious; for example, whether wildfire constitutes a threat to the subspecies and, if so, whether or not it should be addressed through active management approaches, such as forest thinning (see Ch. 3). In these situations, or when published information was limited (e.g., regarding effects of forest thinning on NSOs: see Ch. 2), I treated research results as 'case studies' and described each study's methods and findings in more detail than is common in these kinds of reviews. Although this approach could have underweighted peer-reviewed publications, it allowed me to thoroughly search for patterns among numerous studies, draw tentative conclusions based on those patterns, and highlight gaps in available information about the topic. I also felt that it was important to carefully consider all available sources of information, rather than peer-reviewed publications alone, due to the tremendous variation in ecology and management history that exists within the NSO's range in California. For instance, I felt that it was especially important to evaluate timber industry and National Park monitoring data for portions of California outside the area that includes the state's three demographic studies (see Ch. 1: Figure 1.22 or USFWS 2011a Appendix C for California ecoregional boundaries). In all cases, I was transparent about my approach and the strengths and weaknesses of the available information.

Project Author and Funding

Dan Hansen is a freelance wildlife ecologist (see attached CV). He has an M.S. in animal behavior (conservation biology track) from the University of California at Davis and a B.A. in biology (ecology, evolution, and behavior emphasis) from the University of California at Santa Cruz. He has worked as a contractor for the U.S. Fish and Wildlife Service (USFWS) and U.S. Forest Service (USFS) through the Humboldt State University Sponsored Programs Foundation for most of the last decade. During this period, he primarily coordinated, wrote, and edited scientific syntheses aimed at informing public policy and land management decisions. Documents that Dan contributed to include the USFWS revised recovery plan for the northern spotted owl (critical habitat modeling and effects of forest thinning), the USFS conservation assessment for the northern goshawk in California (a peer-reviewed book to be published in 2015), a USFWS peer-reviewed white paper supporting changes to the California Forest Practice Rules habitat retention guidelines for northern spotted owls in interior northern California, and a USFWS 12-month finding on a petition to list two salamander species under the Endangered Species Act. In addition to working as a technical coordinator, writer, and editor, Dan has worked in the field researching or monitoring spotted owls, golden eagles, bald eagles, peregrine falcons, northern goshawks, carnivores, small mammals, marine mammals, and other wildlife. Prior to working at Humboldt State University, Dan co-managed a large study of California spotted owls in the northern Sierra Nevada.

This document was funded by the Environmental Protection Information Center (EPIC), a non-profit organization focused on environmental issues in northwestern California. EPIC filed a petition with the California Fish and Game Commission in September 2012 to list the northern spotted owl as 'threatened' or 'endangered' pursuant to the California Endangered Species Act. Although EPIC funded the following synthesis, they provided minimal feedback during its writing and were supportive of Dan's goal of producing an unbiased, peer-reviewed synthesis concerning the northern spotted owl's current status and threats in California. All conclusions and management recommendations in this synthesis are the author's alone and do not necessarily reflect those of EPIC or any of the document's reviewers.

Part I, Ch. 1: Status and Trends in California

Introduction

Several lines of evidence are available for evaluating the northern spotted owl's (*Strix occidentalis caurina*; NSO) status and trends in California. These include changes in the subspecies' geographic range and distribution, density and abundance, occupancy and demographic rates, meta-population dynamics, and genetics. The most reliable information available for examining the NSO's status and trends is provided by long-term demographic studies. Data from these studies are periodically analyzed together in meta-analyses for describing larger demographic patterns within ecoregions and rangewide. A new demographic meta-analysis is expected to be released later this year. This document will provide the best available information for determining the NSO's current status and trends. However, only a small portion of the NSO's range in California occurs within demographic study areas and those study areas all occur in relatively productive forests in the northwestern part of the state. It is therefore important to consider other sources of information, such as data collected for monitoring NSOs in National Parks and on industrial timber company lands and results of demographic studies in areas that ecologically resemble portions of interior northern California. The NSO's status and trends likely vary among regions, forest types, and ownerships and could be influenced by a host of factors, such as differences in forest ecology, management history, and stressors such as competition with invasive barred owls (*Strix varia*). It is also important to remember that available sources of information for evaluating the NSO's status and trends in California vary substantially in terms of their purpose and scientific rigor.

Range

The current range of the NSO includes southwestern British Columbia and the Cascade Mountains, coastal ranges, and intervening forests of Washington, Oregon, and California (USFWS 2011a). In California, the NSO's range extends from the Oregon border through the Northern Coast Ranges to Marin County, across the Klamath Mountains, and down the southern Cascades to the vicinity of the Pit River, where it contacts the range of the California spotted owl (*S. o. occidentalis*) (Figure 1.1).

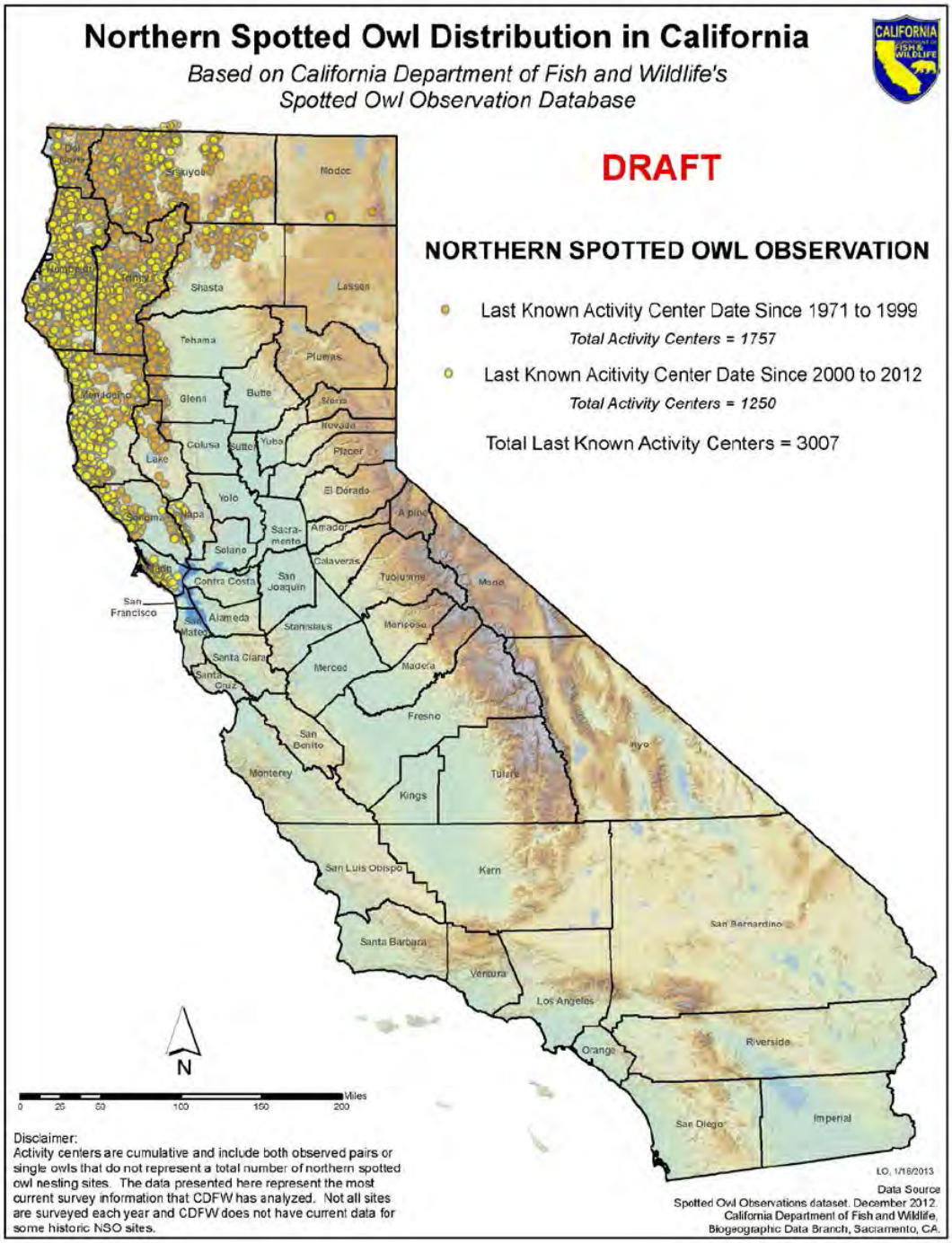
The precise historical range of the NSO is unknown. Thus, despite substantial loss, degradation, and fragmentation of NSO habitat (see Ch. 2 and 3), there is no evidence that the subspecies' range has contracted since Euro-American settlement (Thomas et al. 1990). However, British Columbia's NSO population has declined to very low numbers and is highly vulnerable to extirpation (Chutter et al. 2004). NSO populations in the Cascades and Olympic Peninsula of Washington and the Northern Coast Range of Oregon are also rapidly declining and may become vulnerable to extirpation (Forsman et al. 2011; see *Demography*, below). Loss of NSO populations could cause substantial contraction of the subspecies' range. For example, extirpation of NSOs from British Columbia alone would reduce the subspecies' range by approximately 8% (Cooper 2006).

Distribution

NSOs are thought to have been well distributed throughout most coniferous forests in the Pacific Northwest and northwestern California prior to Euro-American settlement (USFWS 2011a). The abundance and distribution of NSOs have likely declined due to removal of most (ca. 60-88%) old forest within its range (USFWS 1990; see Ch. 2). For example, the Puget Trough in Washington and the Willamette Valley in Oregon no longer support NSOs due to land conversion and timber harvesting and very few NSOs remain in British Columbia (Thomas et al. 1990, Courtney et al. 2004). The NSO's distribution has decreased in other areas of Washington and Oregon as well, due primarily to negative effects of timber harvesting, wildfires, and competition with barred owls (*Strix varia*) (Thomas et al. 1990, USFWS 2011a; see Ch. 2-4).

It is unknown if the NSO's distribution has changed in California. A difference is evident in the distribution of known historically (1971-1999) and recently (2000-2012) occupied activity centers (ACs) in the Eastern Klamath, Interior Northern Coast Ranges, and Southern Cascades regions of the state (Figure 1.1; see Figure 1.22 [left side] and USFWS 2011a Appendix C for ecoregional boundaries generally followed in this synthesis). It is unclear from these data, however, whether the distribution of NSOs has in fact decreased in these areas or if the apparent decline in distribution is due to some other factor such as decreased survey effort or reporting of detections. It is also possible that this difference is due to the greater number of years included in the historical period than in the recent period (29 vs. 13 yrs). However, the two periods are similar in length relative to federal listing of the NSO (10 vs. 13 yrs) when survey effort presumably became more intensive and widespread. Some portions of the Klamath, Interior Northern Coast Ranges, and Southern Cascades have experienced widespread intensive timber harvesting or large wildfires, which could have reduced the NSO's distribution (see Ch. 2 and 3). These forms of disturbance, along with competition with invasive barred owls, have likely contributed to declining occupancy by NSOs in some areas of California (see *Occupancy*, below). Nonetheless, the Klamath and Interior Northern Coast Ranges (but not the Southern Cascades) still appear to contain relatively large amounts of well connected suitable habitat and may function as crucial population sources for NSOs (Schumaker et al. 2014; see *Source-Sink Dynamics*, below). It is also possible that the distribution of NSOs has expanded at local or sub-regional levels in some portions of California due to increased distribution or density of suitable forest habitat in the absence of fire (Skinner 1995, Spies et al. 2006).

Figure 1.1: Distribution of northern spotted owl activity centers in the California Department of Fish and Wildlife's Spotted Owl Observation Database (from California Department of Fish and Wildlife 2013).



Density and Abundance

Species are rarely uniformly distributed across their range. Knowledge of variation in the density and abundance of NSOs is of potential conservation value because it can help identify areas where limited conservation resources should be focused. For example, while declines in low-abundance areas may be more likely to cause contraction of a species' range or distribution (see *Range* and *Distribution*, above), declines in high-abundance areas may disproportionately impact the species' probability of long-term persistence; particularly when high-abundance areas function as population sources (Pulliam 1988, Rodríguez 2002, Schumaker et al. 2014; see *Source-Sink Dynamics*, below).

Several studies have estimated either crude densities (owls or occupied territories per unit area) or ecological densities (owls per unit area of specified habitat class[es]) of NSOs in California (Blakesley et al. 2004; Table 1.1). These estimates are interesting in that they appear to reflect geographic variation in the ecology of NSOs (see below). However, they have limited utility for evaluating the NSO's status or trends in California. Available density estimates for the state are largely restricted to relatively mesic areas of northwestern California, which differ ecologically from drier interior forests (e.g., in terms of climate, forest productivity, and prey communities). Inferences from most density estimates are also limited because they are based on empirical counts of unmarked NSOs, which can bias estimates (Franklin et al. 1990, Diller and Thome 1999). Many of the currently available density and occupancy estimates for NSOs in California were provided by timber companies (Tables 1.1 and 1.2). While potentially useful for evaluating effects of management activities on timber company lands, these estimates do not describe population trends. Rigorous evaluation of NSO population trends require long-term statistically valid sampling designs from which estimates of abundance, or population growth rate with confidence intervals, can be repeatedly obtained within the same study area. In contrast, timber companies generally shift their NSO survey areas over time as timber harvest projects are completed in some areas and begun in others.

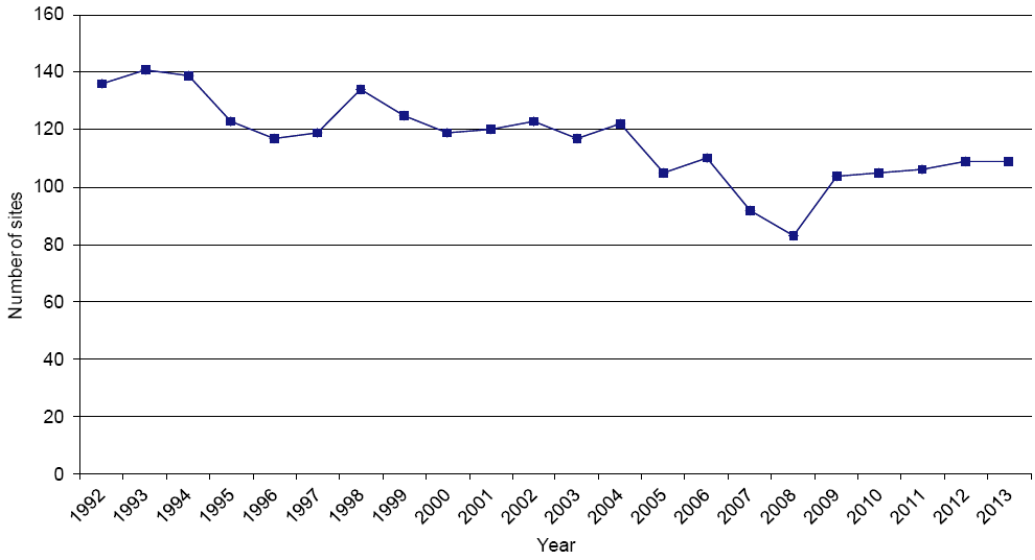
Based on limited information, both crude and ecological densities of NSOs appear to be substantially higher in northwestern California than in the Oregon Coast Ranges (Blakesley et al. 2004; Table 1.1). Lower densities in the Oregon Coast Ranges could be partially related to widespread intensive timber harvesting, which apparently contributed to a major decline in densities during the early 1990s (Thrailkill et al. 1998). Some areas of northwestern California have also experienced widespread intensive timber harvesting (see Ch. 2) but its effect on NSOs might have differed from that in the Oregon Coast Ranges. In general, NSOs in California primarily subsist on dusky-footed woodrats (*Neotoma fuscipes*) (in terms of biomass contribution to diets). NSOs that primarily subsist on dusky-footed woodrat often have smaller home ranges, and apparently occur at higher densities, than those that primarily rely on smaller-bodied prey (Carey et al. 1992, Zabel et al. 1995). Furthermore, in contrast with other primary prey species, such as northern flying squirrels (*Glaucomys sabrinus*) and tree voles (*Arborimus* spp.), dusky-footed woodrats seem to respond positively, albeit temporarily, to some forms of intensive timber harvesting (see Ch. 2).

Densities of NSOs are also thought to be higher in northwestern California than in the state's interior (Calforests 2014). However, there are apparently only two density estimates currently

available for interior northern California and both of these were for crude densities of occupied territories, rather than for individual owls as estimated by most studies in northwestern California (Table 1.1). These crude territory densities are substantially lower than those found on two timber companies' lands in the Redwood Region (Table 1.1). NSO densities may be relatively low in the Southern Cascades of California due to the prevalence of drier, less productive forests, a history of widespread intensive harvesting, and effects of recent large wildfires (see Ch. 2 and 3). Additional density estimates are needed for the Eastern Klamath of California. It is uncertain whether Sierra Pacific Industries' (2013) estimates are representative of densities across the region as a whole. Most ACs included in Sierra Pacific's density estimates were located near the margins of the company's lands or on adjacent ownerships, rather than within the interiors of the company's holdings (see Maps 2-5 in Sierra Pacific Industries 2013, which are copyrighted and cannot be reproduced without permission). This pattern suggests that densities could be higher on neighboring lands, such as the Shasta-Trinity National Forest, which have generally experienced less intensive management.

The California Forestry Association cited annual density estimates in timber company monitoring reports as evidence of stable or increasing NSO populations on private timberlands in the state (Calforests 2014). Reported crude densities on Humboldt Redwood Company, Mendocino Redwood Company, and The Conservation Fund lands in the Redwood Region were indeed relatively similar among years (Calforests 2014). However, it is unclear how changing survey methods and survey areas, as well as changing detectability of NSOs, influenced these companies' estimates over time (see Franklin et al. 1990). For example, recent adoption of survey protocols requiring more survey passes and use of electronic callers likely increased detection rates, and thus density estimates, on some of these lands. Estimates of crude densities of NSOs and numbers of ACs on Green Diamond Resource Company lands in the Redwood Region suggest that NSO densities have declined on that ownership (Figure 1.2; Table 1.1). The number of NSO ACs on Green Diamond lands briefly increased in 1998, apparently due to the company's acquisition of 70,000 acres of timberland that year (Green Diamond Resource Company 2014). Following a substantial decline during 2004-2008, the number of ACs began to gradually increase in 2009 (Figure 1.2). This increase appears to have been due to the company's adoption of a more rigorous survey protocol and implementation of a barred owl removal experiment during that same year (Green Diamond Resource Company 2014; see Ch. 4). Sierra Pacific Industries' (2013) density trends for its ownerships in the Eastern Klamath are difficult to evaluate and are therefore not included here. Sierra Pacific Industries' (2013) estimates are empirical, potentially influenced by changing survey effort and areas, mostly descriptive of ACs at the margin of or outside the company's ownership, and were compared among blocks of years, rather than annually.

Figure 1.2: Number of NSO activity centers ("sites") on Green Diamond Resource Co. lands during 1992-2013 (from Green Diamond Resource Co. 2014).



Rigorous ecological density estimates can be used to estimate population sizes for ecologically similar areas (Franklin et al. 1990). However, there are currently insufficient data for producing such an estimate for California or any of its regions. The California Forestry Association estimated that as many as 6,000 NSO territories currently exist in the state (Calforests 2014). This figure was based on an estimated statewide crude density of 0.28 territories per mile^2. This density estimate was, in turn, based on the cumulative number of known NSO ACs in California (see *Distribution*, above) and the proportion of "potential" habitat in the state that has been surveyed. The number of ACs known to have been recently occupied is substantially lower than the cumulative number that have been identified since the early 1970s (USFWS 2011a; see *Distribution*, above). This could be due to multiple factors, including declining occupancy rates (see *Occupancy*, below) and NSOs' use of different ACs over time. Thus, the timber industry's estimate provides little or no insight into the current number of NSOs or occupied ACs in the state. Furthermore, while reasonable projections of suitable habitat exist for NSOs in California (Davis and Dugger 2011, USFWS 2011a Appendix C, Schumaker et al. 2014), the California Forestry Association did not cite these data and it is unclear how it estimated the total and surveyed areas of suitable habitat in the state.

Table 1.1: Density estimates for NSOs in California and Oregon.

Study	Region	Owner	Method	Crude Density (owls/ mi²)*	Crude Density (occupied territories/ mi²)*	Ecological Density (owls/ mi²)**†
Diller and Thome 1999	N Redwood	Green Diamond	Mark-Recapture	0.54 (0.24-0.91)		0.97-2.72
Green Diamond Resource Co. 2014	N Redwood	Green Diamond	Empirical (marked)	0.34 (0.12-0.53)		
Tanner and Gutierrez 1995 cited in Diller and Thome 1999	N Redwood	Redwood National Park	Empirical	0.57		
Humboldt Redwood Co. 2013	N Redwood	Humboldt Redwood	Empirical	0.53-1.01	0.36-0.50	
Mendocino Redwood Co. 2014	N Redwood	Mendocino Redwood	Empirical	0.47-.077		
The Conservation Fund unpubl. data in Calforests 2014	N Redwood	The Conservation Fund	Empirical		0.29-.036	
Chow 2001	S Redwood	Public (Various)	Empirical	0.97		2.09
Franklin et al. 1990	W Klamath	Six Rivers National Forest, Other	Mark-Recapture	0.61		1.41-1.71
Sierra Pacific Industries 2013	E Klamath	Sierra Pacific Industries	Empirical		0.17-0.18	
Woodbridge and Cheyne 1995	So Cascades	Klamath National Forest	Empirical		0.05-0.20	
Thrailkill et al. 1998	OR Coast Ranges	Bureau of Land Management	Empirical	0.07-0.25		0.57-0.90
Anthony et al. 2000 cited in Blakesley et al. 2004	OR Coast Ranges	Oregon Dept. of Forestry	Empirical	0.13-0.27		

*Ranges = low-high survey areas (Woodbridge and Cheyn 1995, Thraillkill et al. 1998, Diller and Thome 1999, Anthony et al. 2000, Green Diamond Resource Co. 2014), low-high survey years (Humboldt Redwood Co. 2013, Mendocino Redwood Co. 2014). **Habitat definitions used to calculate ecological densities: Franklin et al. 1990: all conifer cover classes weighted by NSO use (based on telemetry), but mostly ≥20.6 in DBH; Diller and Thome 1999: all forest classes weighted by NSO use (based on nest locations) but mostly >40 yrs; Chow 2001: all forested area; Thrailkill et al. 1998: old, mature, old over young, mature over young. †Ranges of ecological densities: Franklin et al. 1990: with two different habitat definitions; Diller and Thome 1999: low-high survey areas.

Occupancy

NSO population trends are most directly evaluated with demographic data (see *Demography*, below). However, occupancy data are often more logistically and economically feasible to collect than demographic data and, with proper accounting of detection probability, can provide a useful index of spotted owl population rates (MacKenzie 2005, Olson et al. 2005, Mackenzie et al. 2012, Tempel 2014). Occupancy data that inadequately incorporate detection probabilities for spotted owls must be interpreted carefully since they can be strongly influenced by survey effort, habitat attributes, social and reproductive status of NSOs, presence of barred owls, and other factors (Mackenzie 2005, Olson et al. 2005). Recent research in NSO demographic study

areas suggests that competition with barred owls is driving NSOs to move large distances (several miles) between different territories within the same season (Davis et al. 2013, Higley and Mendia 2013). Higley and Mendia (2013) warned that occupancy estimates for unmarked populations may therefore be inflated (i.e., the same individual could appear to occupy multiple territories within the same season) and suggested using the presence of pairs, rather than individuals, to determine occupancy.

There is limited information available for describing occupancy trends for NSOs in California. Much of the available information is from annual monitoring reports provided by industrial timber companies (Table 1.2). These data show trends in annual proportions of known, surveyed, or previous year's ACs found to be occupied (see Table 1.2 footnote). It is important to acknowledge that much of the data presented in Table 1.2 provide only crude indices of occupancy in California and that most of them cannot be compared among ownerships due to differences in monitoring and analytical methods. Future efforts to evaluate the status of NSOs in California would benefit from greater consistency in occupancy monitoring and from reporting of modeled occupancy rates, which account for detectability of NSOs and other factors that can obscure occupancy trends (e.g., Figure 1.5).

Recent occupancy estimates are unavailable for the Redwood National and State Parks in the northern portion of the Redwood Region. The National Park Service has discontinued surveying most historical territories in these parks due to apparent widespread displacement of NSOs by barred owls (Schmidt 2013; see Ch. 4). In contrast with an apparently strong decline in occupancy in the Redwood National and State Parks, NSO occupancy rates on National Park Service lands in the southern portion of the Redwood Region have fluctuated annually but suggest a stable trend over time (Ellis et al. 2013; Table 1.2; Figure 1.3). Perhaps due to the area's geographic isolation, barred owls are still relatively uncommon the southern Redwood Region (Ellis et al. 2013; see Ch. 4). Occupancy by NSOs appears to be gradually declining on industrial timberlands in the northern Redwood Region (Table 1.2; Figures 1.2, 1.4, 1.5, and 1.7). Given the substantial and increasing presence of barred owls in NSO territories on these lands (see Ch. 4), it is surprising that more dramatic declines in NSO occupancy are not evident (e.g., see Table 1.2 for occupancy rates in Washington and Oregon). It is possible that NSOs respond differently to barred owls on these lands than elsewhere within their range. It is also possible that a more rapid decline is currently occurring than is indicated by the crude data presented in these companies' reports. Yet another possibility is that a more rapid decline will occur on these lands after a post-colonization lag period has elapsed or a critical threshold level of barred owl presence is reached (USFWS 2013).

NSO occupancy in the Northwestern California demographic study in the Western Klamath Region has declined dramatically in recent years (Franklin et al. 2013, 2014; Table 1.2). This decline has coincided with increasing barred owl presence in the study area, suggesting that NSOs are being displaced by barred owls (see Ch. 4). The recently increased rate of declining occupancy by NSOs in this study area appears to support the hypothesis that barred owls can have lag or threshold effects on NSO populations. Recent declines in occupancy in the Northwestern California study area may also be related to effects of multiple consecutive years of poor weather conditions on demographic rates (see *Demography*, below). Recent annual reports from the Hoopa demographic study did not include analyses of occupancy data for NSOs

(Higley and Mendia 2012, 2013). However, unmodeled occupancy rates in 2012 and 2013 were low (0.40 and 0.35, respectively). Low occupancy rates on the Hoopa Reservation may be related to substantial declines in numbers of NSOs, likely due to decreasing demographic rates (see *Demography*, below) and increasing numbers of NSO territories with barred owl detections (see Ch. 4). Greater declines in numbers of NSOs and increases in NSO territories with barred owl detections beginning in 2005 provide additional support for the hypothesis that barred owls have lag or threshold effects on NSOs.

There is currently no clear pattern in occupancy data available for the Eastern Klamath and Southern Cascades of California. Timber companies in those regions have reported evidence of stable occupancy rates (Sierra Pacific Industries 2013, Michigan-California Timber Company 2014; Figure 1.6; note: Sierra Pacific's estimates are not provided in Table 1.2 for reasons discussed in *Density and Abundance*, above). However, more rigorous, published research conducted primarily on industrial timberlands in the Eastern Klamath and Southern Cascades found substantial declines in both simple (total) and pair occupancy (Farber and Kroll 2012; Figure 1.7). The barred owl invasion appears to still be in the early colonization phase in the Eastern Klamath, where this study was primarily conducted (Farber and Kroll 2012; see Ch. 4). Thus, declining occupancy during the study was likely caused by some other factor, such as timber harvesting on the industrial timberlands that comprised much of the study area or wildfires on neighboring public lands (see Ch. 2 and 3). Research in other areas of the NSO's range indicates that occupancy can be negatively affected by habitat loss and fragmentation (Dugger et al. 2011, Sovern et al. 2014).

Table 1.2: Estimates and indices of occupancy by northern spotted owls in California, Oregon, and Washington.

Study	Region	Owner	Years	Number of Sites	Proportion Occupied (Total)	Proportion Occupied (Pairs)	Modeled Occupancy (Total)	Modeled Occupancy (Pairs)	Apparent Trend
Mendocino Redwood Company 2013	N Redwood	Private	2001-2013 (proportion); 2001-2008 (modeled)		0.75 - 0.69*		0.88 - 0.78*†		Declining (weak)
Humboldt Redwood Company 2014	N Redwood	Private	2003-2013		0.81 - 0.63*†				Declining (weak)
Green Diamond Resource Company 2014	N Redwood	Private	1999-2013 (no. sites); 2009-2013 (occupancy)	135 - 108*†	0.88 - 0.83*‡				Declining (weak)
Ellis et al. 2013	S Redwood	NPS	1999-2012		0.86 - 0.94*	0.72 - 0.87*			Stable
Franklin et al. 2002, 2003, 2010-2014	W Klamath	USFS, BLM, Private	2001-2013		0.67 - 0.37*	0.59 - 0.28*			Declining (strong)
Farber and Kroll 2012	E Klamath, S Cascades	Private, USFS	1995-2009				0.81 - 0.50*	0.75 - 0.46*	Declining (strong)
Michigan-California Timber Company 2014	E Klamath, S Cascades	Private	2000-2013		0.35 - 0.52 (2001-2013: 0.66 - 0.52)*†				Stable
Davis et al. 2013a	OR Klamath	BLM, State, Private	2001-2013		0.86 - 0.49*	0.62 - 0.30*			Declining (strong)
Dugger et al. 2011	OR S Cascades	USFS	1991/1992-2006				w/o barred owls: 0.86 - 0.71*†; w/ barred owls: 0.87 - 0.11*†		Declining (strong)
Kroll et al. 2010	WA E Cascades	NPS, USFS, Private	1990/1-2003				w/o barred owls: 0.83 - 0.64*†; w/ barred owls: 0.73 - 0.30*†	w/o barred owls: 074 - 0.36*†	Declining (strong)

*Start and end values. †Estimated from graph. ‡Occupancy of previous year's sites.

Figure 1.3: Occupancy status at monitored northern spotted activity centers on National Park Service lands in Marin County, California during 1999-2012 (from Ellis et al. 2013).

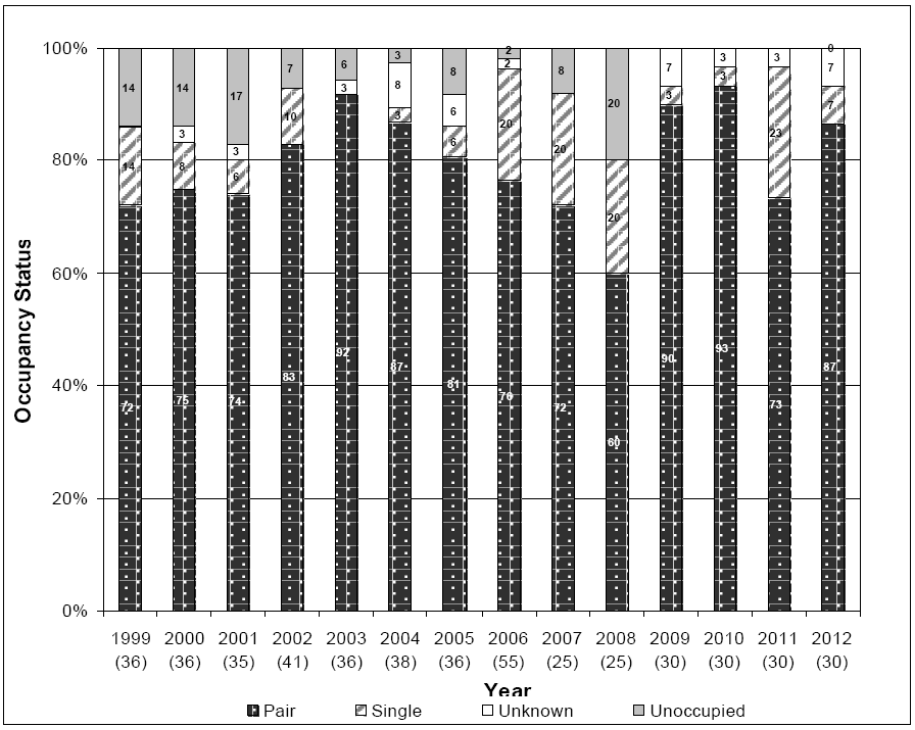


Figure 1.4: Annual numbers of known and occupied northern spotted owl activity sites (activity centers) on Humboldt Redwood Company lands during 2003-2013 (from Humboldt Redwood Company 2014).

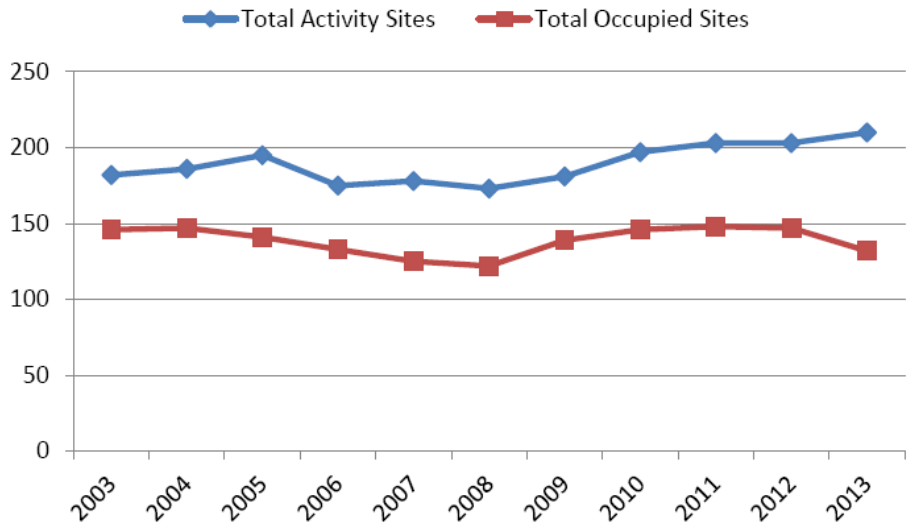


Figure 1.5: Annual proportion of northern spotted owl activity centers occupied (blue line) and modeled occupancy probability (red line) on Mendocino Redwood Company lands (from Mendocino Redwood Company 2013). Note the apparent decline in modeled occupancy compared with the lack of a clear trend in unmodeled occupancy.

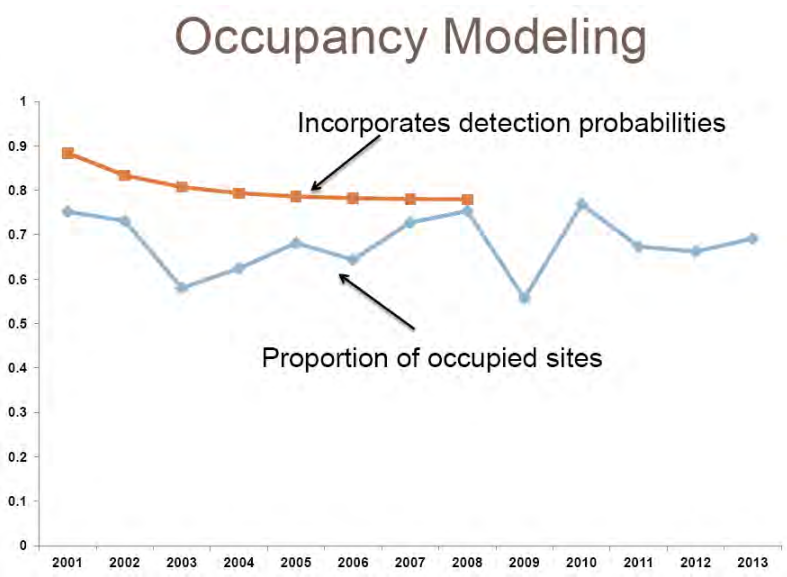


Figure 1.6: Percent of surveyed northern spotted owl sites occupied on Michigan-California Timber Company lands during 2000-2013 (from Michigan-California Timber Company 2014).

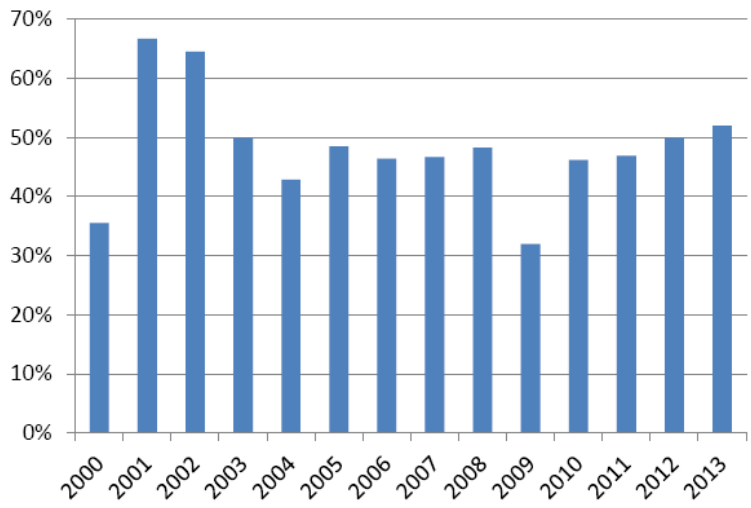
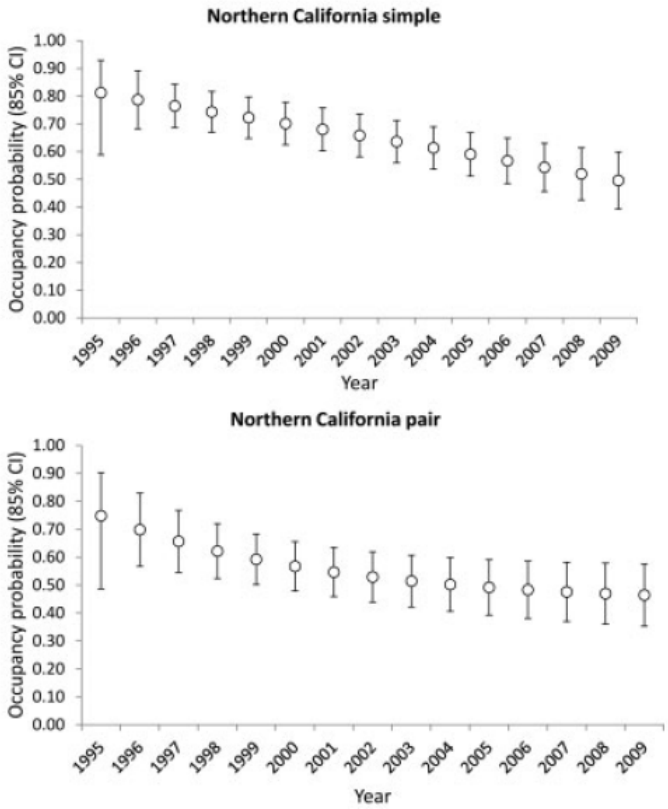


Figure 1.7: Estimated annual simple (total) and pair occupancy probabilities (with 85% confidence intervals) for northern spotted owls in the Eastern Klamath Region of California during 1995-2009 (from Farber and Kroll 2012).



Demography

Reproduction

Reproductive data are commonly collected as part of monitoring efforts for NSOs (e.g., Calforests 2014). They are easier and more cost-effective to obtain than those required for estimating survival or population trends. NSOs exhibit considerable annual fluctuations in reproduction (Forsman et al. 2011, Calforests 2014). Given often large annual fluctuations in reproduction, evaluation of trends in reproduction could require longer-term datasets than are available for many monitoring areas.

The 2011 demographic meta-analysis reported that fecundity of NSOs (number of female fledglings per female) significantly declined during 1985-2008 in four of 11 density study areas, may have declined in three other areas, and was stable in four areas (Forsman et al. 2011). Two of the four study areas with significant declines in fecundity were located in California (Northwestern California in the Western Klamath Region and Green Diamond in the Redwood Region). Two others were located in portions of southwestern Oregon (Klamath and South Cascades) that are nearby and ecologically similar to the Eastern Klamath and Southern Cascades of California (see USFWS 2011a Appendix C, USFWS 2012a, and Figure 1.22 [left side] for regions). Also, the one area in California with stable fecundity (Hoopa) had low fecundity estimates compared to other areas. Together these data, which represent the most

reliable evidence currently available, indicate that NSO reproduction could be declining across much of California and southwestern Oregon.

Annual fluctuations in fecundity were evident in all three demographic studies in California and were remarkably synchronous (Forsman et al. 2011; Figure 1.8). Forsman et al. (2011) found that variation in fecundity was associated with a variety of variables, including the age of breeding females, whether the year was even or odd, weather or climate (e.g., early nesting season temperature or precipitation), percent cover of suitable habitat, and the presence of barred owls. Franklin et al. (2013) noted a pattern of "good" and "bad" reproductive years in the Northwestern California demographic study area, which is likely associated with annual variation in weather during the early nesting season (also see Franklin et al. 2000). Franklin et al. (2013) also observed that particularly poor reproductive years have occurred in their study area at four-year intervals, suggesting that "some other extrinsic factor may be operating, such as seed production governing small mammal populations." Forsman et al. (2011) reported that barred owl presence was in the top models explaining fecundity in the Green Diamond study area, suggesting that competition with barred owls contributed to declining reproduction on that ownership. Reports from the Klamath and South Cascades demographic studies in southern Oregon noted negative associations between reproduction and rainfall during the early nesting season (Davis et al. 2013b, Dugger et al. 2014). Declining reproduction in these study areas also appears to be related to increasing presence of barred owls.

Following publication of the 2011 meta-analysis, California's demographic studies reported three consecutive years (2011-2013) of very low reproduction (Franklin et al. 2013, Higley and Mendia 2013, Green Diamond Resource Company 2014). This dip in reproduction might have been partially driven by high rainfall during the early nesting season during 2010-2012 (see below). Those three consecutive years of low reproduction exacerbated the negative long-term trend that was already occurring on Green Diamond lands (Green Diamond Resource Company 2014; Figure 1.9). Negative trends in reproduction also occurred in the Klamath and South Cascades demographic study areas subsequent to the end of the 2011 meta-analysis study period (Davis et al. 2013b, Dugger et al. 2014; Figures 1.10 and 1.11). Davis et al. (2013b) concluded that particularly poor reproduction during recent years "…may indicate potentially serious problems with maintaining a stable population. This is even more alarming since these results are following a long term downward trend."

Figure 1.8: Mean annual fecundity in California's three northern spotted owl demographic studies during 1985-2008 (from Forsman et al. 2011).

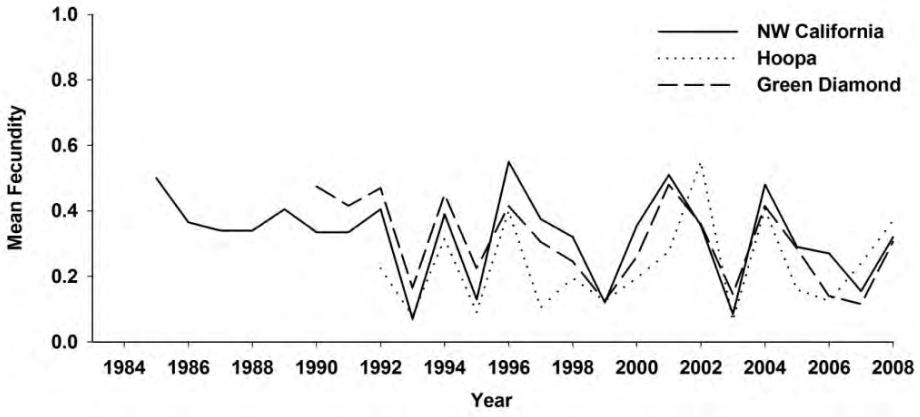


Figure 1.9: Number of fledglings produced per monitored pair of northern spotted owls on Green Diamond Resource Company lands during 1992-2013 (from Green Diamond Resource Company 2014).

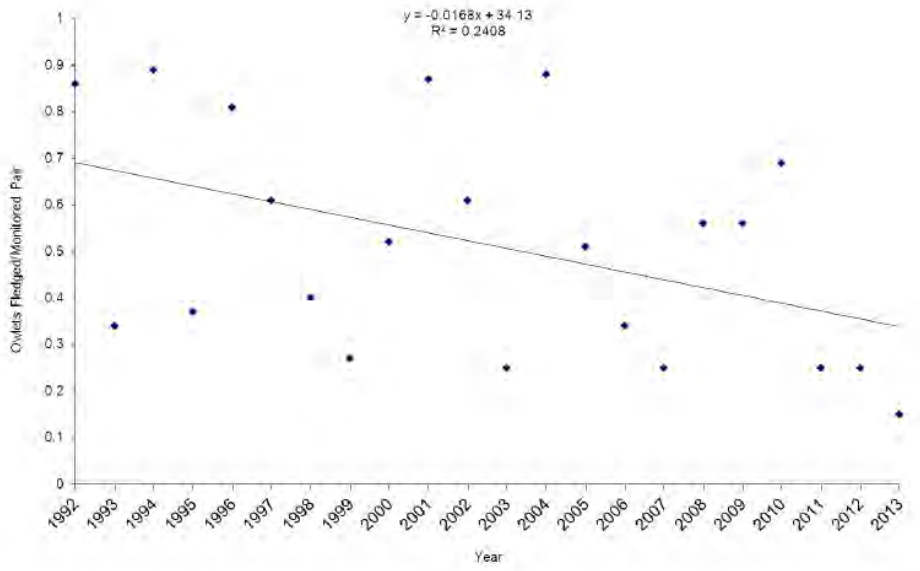


Figure 1.10: Fecundity of northern spotted owls ("STOC") in the Klamath demographic study area during 1990-2013 (from Davis et al. 2013a). Dashed line is a polynomial trend line ($r^2 = 0.419$). Vertical line represents the first year in which barred owls ("STVA") were detected in more than 10% of spotted owl territories.

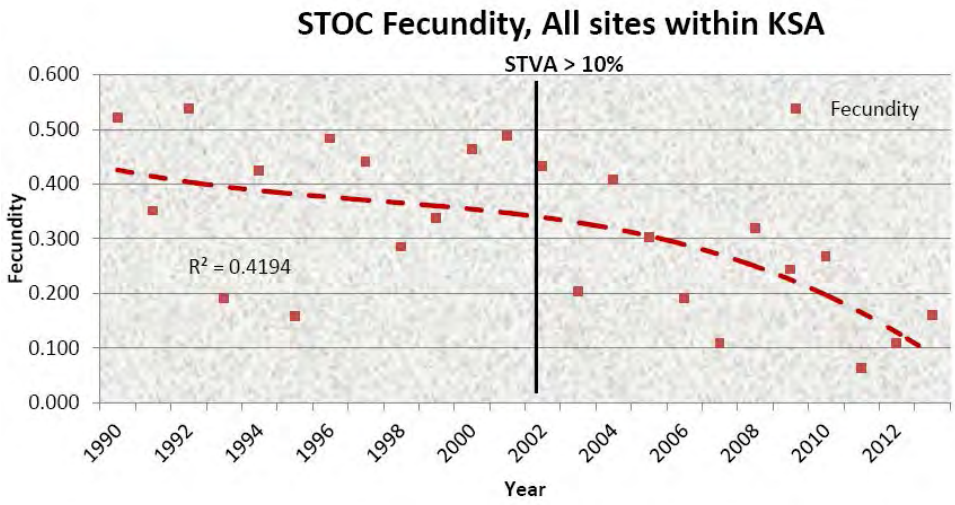
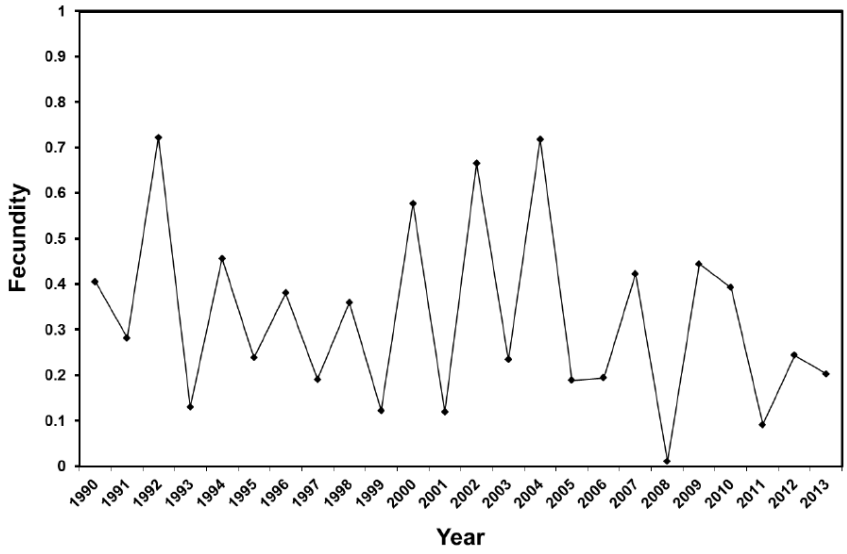


Figure 1.11: Fecundity of northern spotted owls in the South Cascades demographic study area during 1990-2013 (from Dugger et al. 2014).



Information is also available for describing recent trends in NSO reproduction in portions of California outside of demographic study areas. Ellis et al. (2013) found below average fecundity during 2007 and 2010-2012 on National Park Service lands in the southern Redwood Region (Figure 1.12). Humboldt Redwood Company (2013) and Mendocino Redwood Company (2014) likewise reported low reproduction during those years (Figures 1.13 and 1.14). These observations, along with those from demographic studies in California and southern Oregon described above, suggest that low reproduction during recent years was primarily driven by a factor that acted at a very large spatial scale, rather than at the scale of individual ownerships or ecological regions. As noted above, high rainfall during the early

nesting season was likely a primary cause of low reproduction during recent years. This apparent relationship is illustrated by the negative association between NSO reproductive success and early season rainfall observed on Mendocino Redwood Company lands (Figure 1.13).

Monitoring results suggest a stable long-term trend in reproduction on National Park Service lands in the southern Redwood Region (Figure 1.12). In the northern Redwood Region, Humboldt Redwood Company (2013) data likewise suggest little or no trend, although the period covered could be too short to capture long-term trends in reproduction (Figure 1.14). Mendocino Redwood Company (2014) provided a longer-term data set that suggests that a shallow decline in reproduction has occurred on their lands, primarily due to below average reproduction during seven of eight years during 2006-2013 (Figure 1.13). Data provided by the Fruit Grower's Supply Company (2014) suggests that a decline in reproduction occurred on their lands in the Eastern Klamath and Southern Cascades regions of California during 1990-2005 (Figure 1.15). It is important to note, however, that these are only descriptions of apparent trends based on patterns in relatively crude data. A more rigorous analysis of the data is needed to support strong conclusions about reproductive trends on industrial timberlands in California.

Figure 1.12: Fecundity of northern spotted owls on National Park Service lands in Marin County during 1999-2005 and 2007-2012 (from Ellis et al. 2013). The solid line indicates mean fecundity during these periods combined, the dashed lines are one standard deviation from the mean, error bars indicate ±1 standard error, and n is the total number of spotted owl territories.

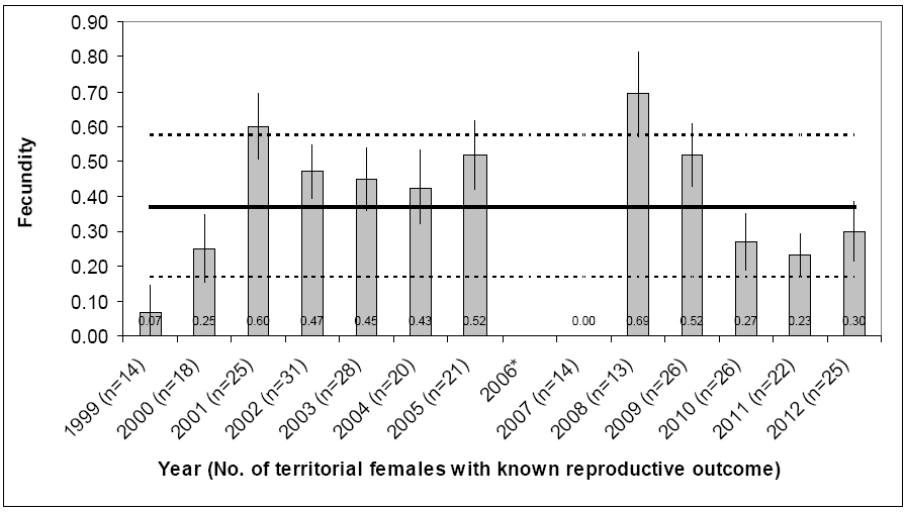


Figure 1.13: Reproductive success (average number of fledglings/pair) of northern spotted owls and amounts of rainfall during the early nesting season on Mendocino Redwood Company lands during 1989-2013 (from Mendocino Redwood Company 2014).

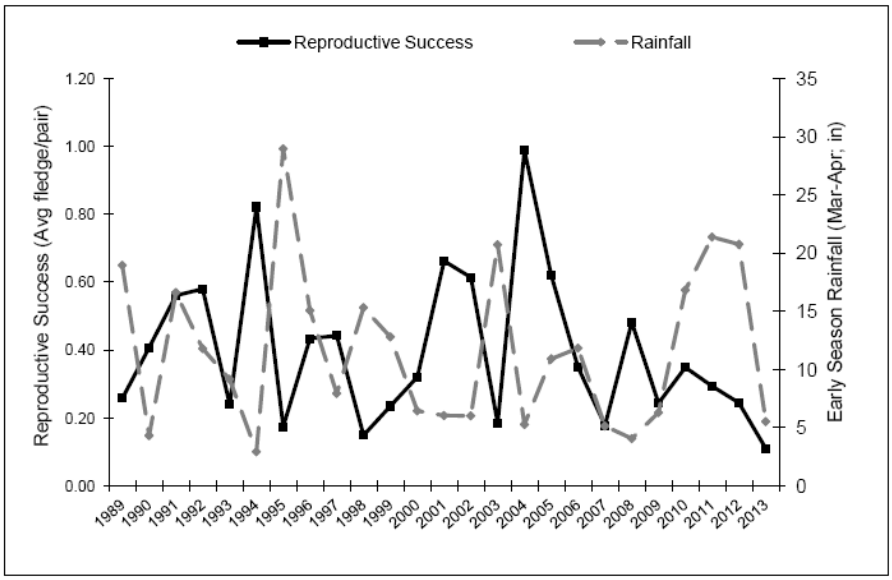


Figure 1.14: Reproductive rate and numbers of nesting pairs and juveniles on Humboldt Redwood Company lands during 2003-2012 (from Humboldt Redwood Company 2013).

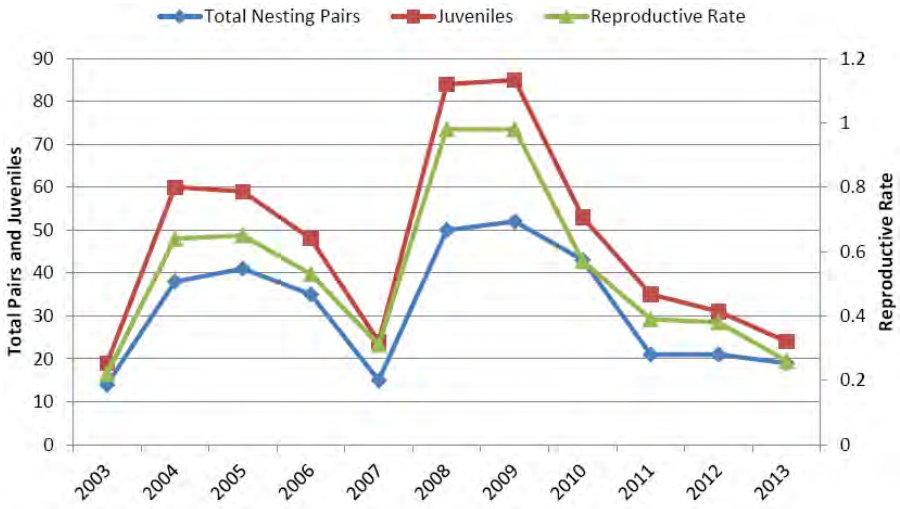
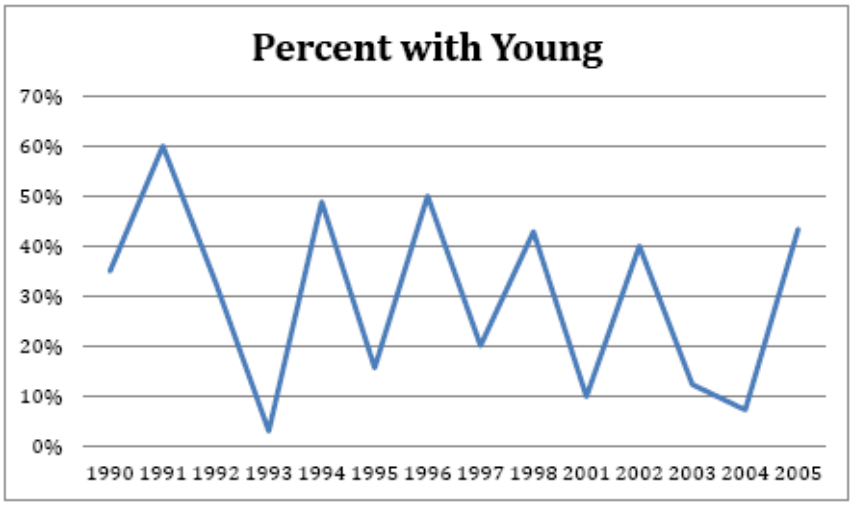


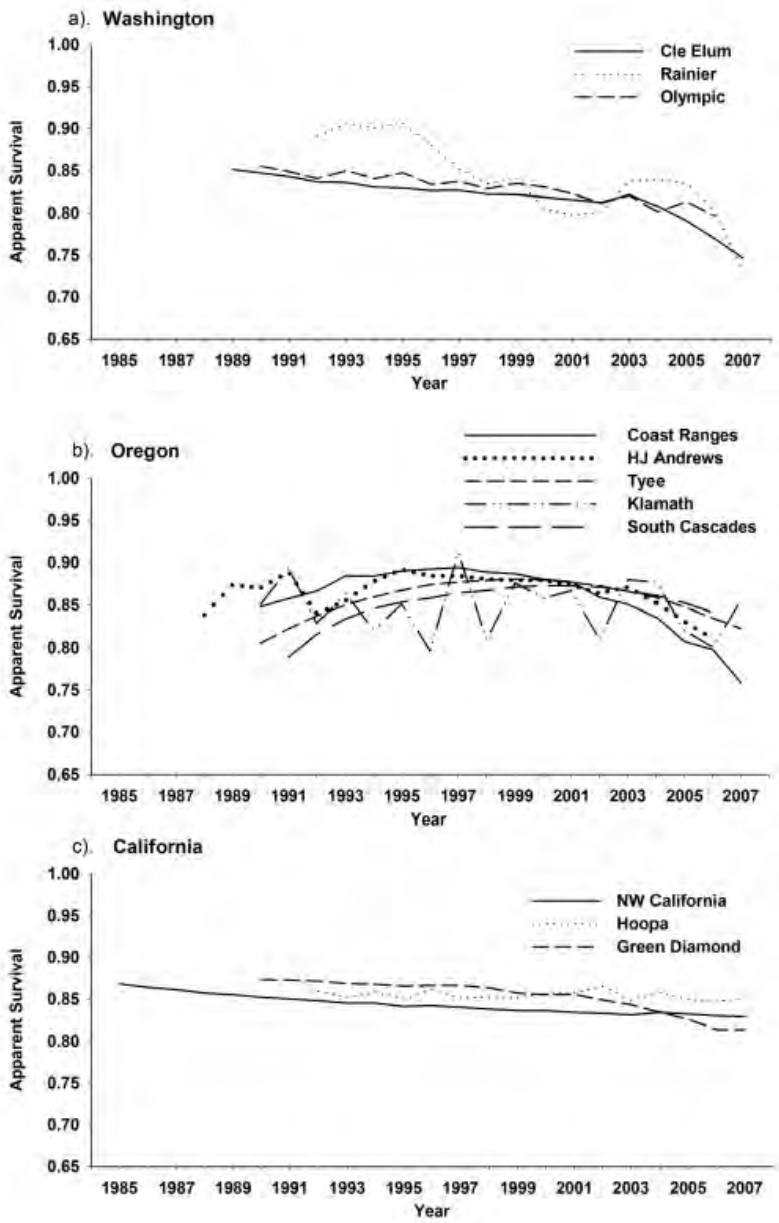
Figure 1.15: Fecundity of northern spotted owls on Fruit Growers Supply Company land during 1990-2005 (from Fruit Growers Supply Company 2014).



Survival

Available information concerning recent survival rates of NSOs is mostly limited to that provided in the 2011 demographic meta-analysis (Forsman et al. 2011). Survival data are not collected by timber companies other than Green Diamond Resource Company, which submits its data for analysis and reporting in the demographic meta-analyses. Forsman et al. (2011) reported statistically significant declines in apparent survival for 10 of 11 NSO demographic study areas, including all three study areas in California (Figure 1.16). Declines in many study areas were most precipitous during the last five years of the study period (i.e., 2003-2007 for survival; Figure 1.16). The Klamath in southern Oregon was the only study area that did not have a significantly declining survival rate through 2007. Forsman et al. (2011) stated that "collectively, the declines in apparent survival of Northern Spotted Owls across much of the subspecies' range are cause for concern because Spotted Owl populations are most sensitive to changes in adult survival rates (Noon and Biles 1990, Lande 1991)."

Figure 1.16: Model averaged estimates of apparent survival of adult female northern spotted owls three study areas in Washington (a), five study areas in Oregon (b), and three study areas in California (c) during 1985-2007 (from Forsman et al. 2011).



NSO demographic studies have largely deferred reporting of more recent survival data to the forthcoming meta-analysis, which is expected to be released in 2015. The limited information available prior to release of that meta-analysis suggests that survival has continued to decline since the 2011 meta-analysis study period. Davis et al. (2013b) reported that subsequent "…data regarding occupancy (in the Klamath study area) has shown a rapid decline, which suggests the stability of the survival rate may no longer be valid." Franklin et al. (2013) reported an alarming drop in apparent survival in 2011 on the Northwestern California demographic study area (Figure 1.17). Their subsequent annual report deferred reporting of 2012-2013 survival data to the forthcoming meta-analysis (Franklin et al. 2014). Higley and Mendia (2013) reported a statistically non-significant decline in survival of NSOs on the Hoopa Valley Indian Reservation in the Western Klamath (Figure 1.18). Their best model explaining survival of NSOs suggested that the decline was at least partially related to increasing numbers of barred owls in the study area.

Figure 1.17: Annual estimates (solid dots with 95% confidence intervals) of, and trend in (solid line), apparent survival for subadult and adult northern spotted owls in northwestern California during 1985-2012 (from Franklin et al. 2013).

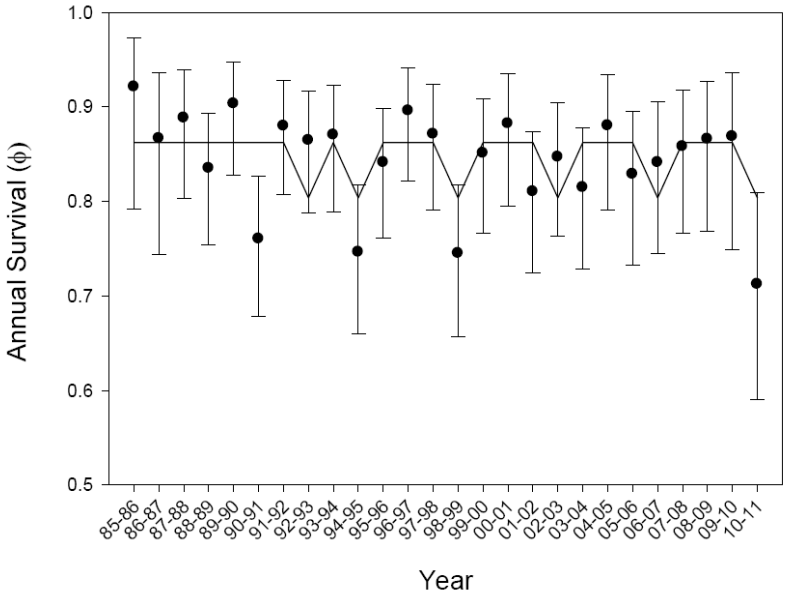
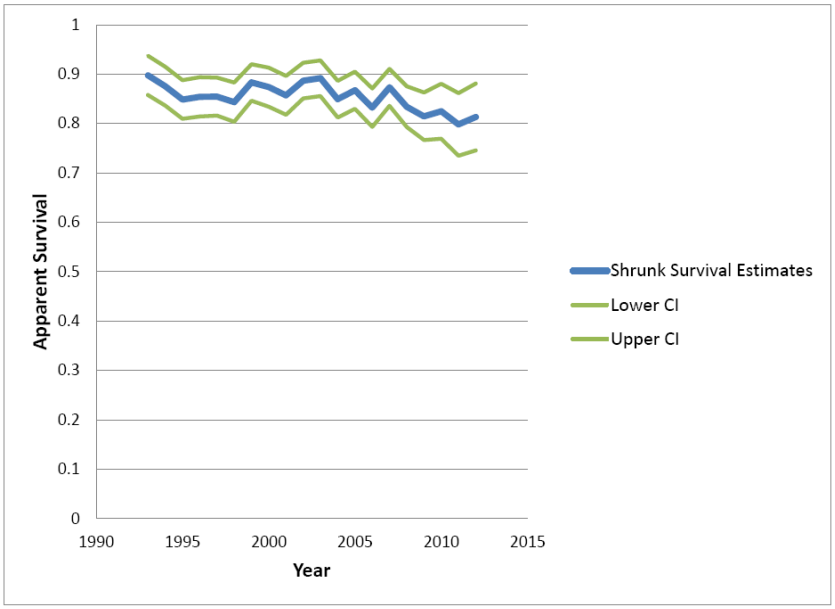


Figure 1.18: Estimates and 95% confidence intervals for NSO apparent survival on the Hoopa Valley Indian Reservation, Humboldt County, California during 1994-2012 (from Higley and Mendia 2013).



Forsman et al. (2011) reported that the presence of barred owls was included in the best model structures for several study areas, including the Green Diamond and Klamath, and was in a competitive model for Northwestern California (Forsman et al. 2011). Given evidence that barred owl presence continued to increase after the study period covered by Forsman et al. (2011) (see Ch. 4), it is likely that the forthcoming meta-analysis will report continued declines in apparent survival for many, if not all, demographic study areas. Franklin et al. (2013) noted that apparent survival in the Northwestern California study area, like reproduction, is influenced by annual variation in weather during the early spring. Thus, recent consecutive years with poor weather during the early spring further suggest that survival has likely continued to decline since the period analyzed by Forsman et al. (2011).

Population Change

A new demographic meta-analysis is expected to be released in 2015. Until then, the 2011 meta-analysis (Forsman et al. 2011) provides the most current available estimates of population change for NSOs across their range. Except for the Green Diamond Resource Company, which submits its data for analysis and reporting in periodic meta-analyses, timber companies do not estimate population change for NSOs. Forsman et al. (2011) stated that their results likely "…reflected conditions on federal lands and areas of mixed federal and private lands within the range of the Northern Spotted Owl because the study areas were (1) large, covering ≈ 9% of the range of the subspecies, (2) distributed across a broad geographic region and within most of the geographic provinces occupied by the owl, and (3) the percent cover of owl habitat was similar between our study areas and the surrounding landscapes." Only one of the study areas included in the meta-analysis was entirely located on private lands (Green Diamond). Thus, it is unclear whether results from the 2011 meta-analysis reflect demographic trends on private lands across the range of the NSO. Given weaker habitat conservation measures for NSOs on many private ownerships compared with federal lands, Forsman et al. (2011) stated that, "if anything, our results depict an optimistic view of the overall population status of the Northern Spotted Owl."

Forsman et al. (2011) reported estimates of the annual finite rate of population change (λ) for 11 study areas located across the NSO's range. Estimates of λ ranged from 0.929 to 0.996 (i.e., declines of 0.4 to 7.1% per year) for these study areas during the period of 1990-2006. There was strong evidence of population declines on seven of the study areas, including the Northwestern California (-1.7% per year) and Green Diamond (-2.8% per year) study areas in California. Negative population trends were also found on the Hoopa study area in California (-1.1% per year) and on the Klamath and South Cascades in southern Oregon (-1.0% and -1.8% per year, respectively) but they were not statistically significant. The weighted mean estimate of λ for all study areas combined was 0.971, indicating an average population decline of 2.9% per year during the study. Variables included in the best model in the meta-analysis of λ indicated effects of ecoregion (geographic location and major forest type) and the proportion of NSO territories with barred owl detections.

In addition to estimates of annual rate of population change, Forsman et al. (2011) provided estimates of realized population change, which describes population change over the study period (Figure 1.19). NSO populations in Washington and northern Oregon declined by approximately 40-60% during 1990-2006. Populations on the Northwestern California and Green Diamond study areas declined by 20-30% during the study period, although the 95% confidence intervals for these estimates slightly overlapped zero (Figure 1.19). Declines of 5-15% were evident on the Hoopa, Klamath and South Cascades study areas but these trends were not statistically significant (Figure 1.19).

Figure 1.19: Estimates of realized population change with 95% confidence intervals for northern spotted owls in California and southern Oregon (from Forsman et al. 2011).

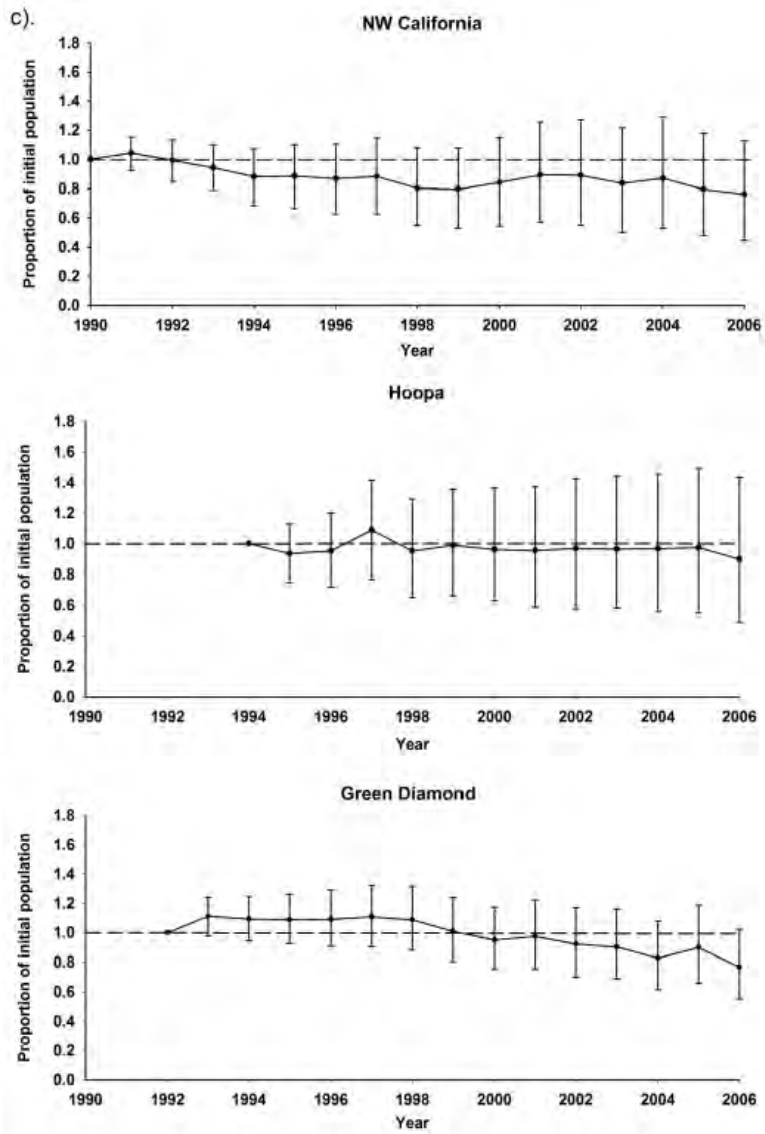
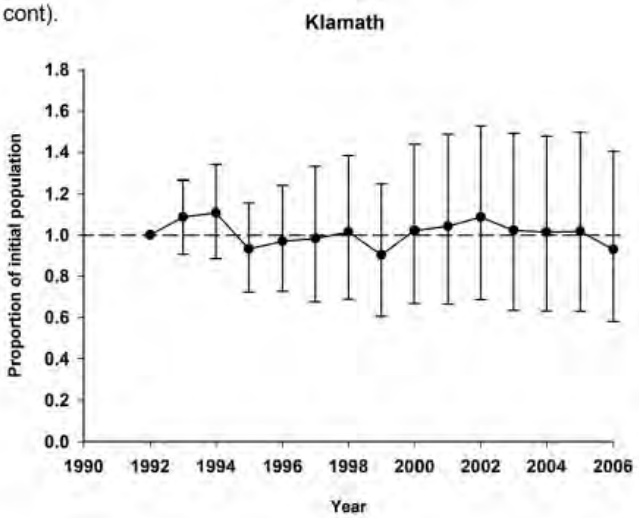
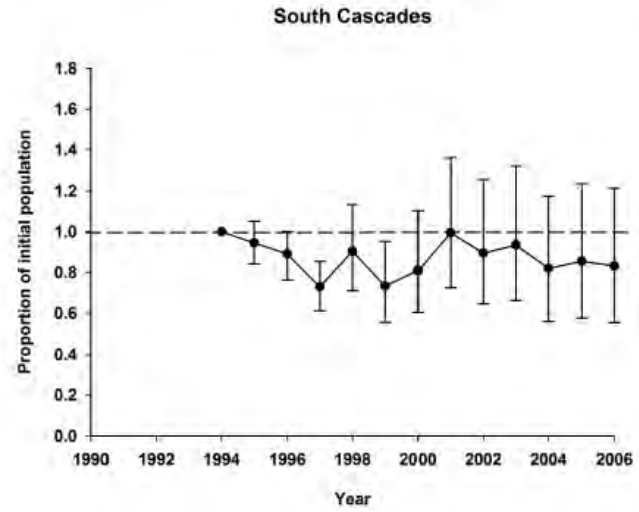


Figure 1.19 (cont.).

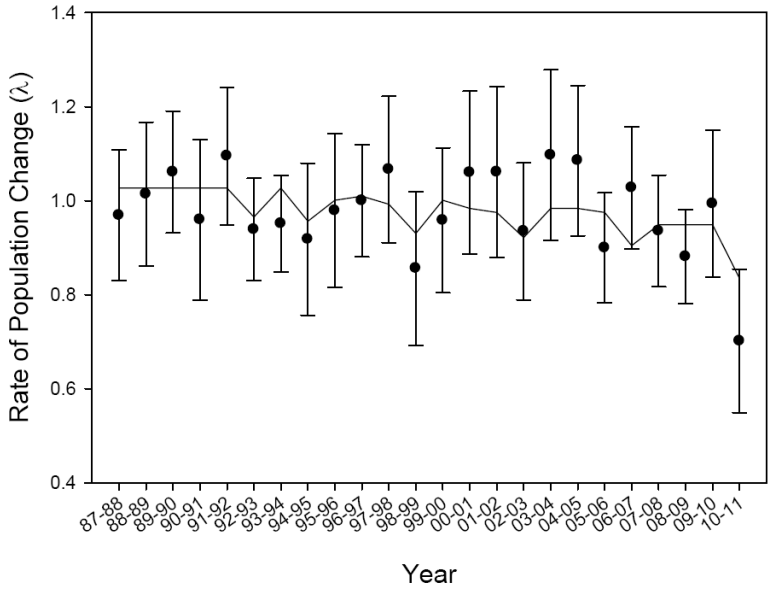
b cont).





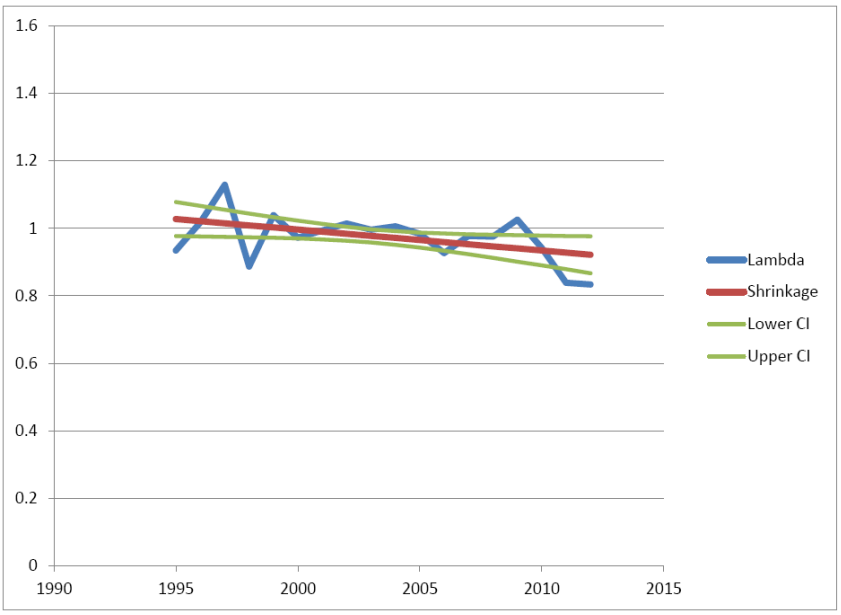
Following the 2011 meta-analysis study period (i.e., >2007), NSOs in the Northwestern California study area experienced a further decline in λ (mean = 0.978 or -2.2% per year) (Figure 1.20). The last year included in this analysis (2011) had the lowest annual estimate of λ found during the 24-year analysis period (Figure 1.20). The forthcoming meta-analysis should reveal whether the substantial drops in apparent survival and λ in the Northwestern California study area in 2011 were anomalous or indicative of an increased rate of population decline in the study area. Franklin et al. (2013) found that fecundity, apparent survival, and λ in the study area fluctuated during "good" and "bad" years, which was likely at least partially related to weather (see above). Annual rate of population change was also apparently negatively affected by increasing presence of barred owls. Given continued increases in barred owls (see Ch. 4), poor weather during the early spring during 2010-2012, and poor reproduction by NSOs during 2011-2013 (see above), it is likely that λ continued to decline on this study area and probably others in California and southern Oregon.

Figure 1.20: Annual estimates of (dots with 95% confidence intervals) and trend in (solid line) rate of population change in the Northwestern California study area (from Franklin et al. 2013).



Higley and Mendia (2013) reported that the estimate of λRJS (Jolly-Seber Capture-Recapture model) for the Hoopa demographic study during 1995-2012 was 0.977, indicating a mean annual population decline of 2.3%. The decline was statistically significant in 2011 and 2012 (point estimates of λRJS not included in the 95% CI; Figure 1.20). Higley and Mendia (2013) noted that "the recent decline in survival, the point estimate of λRJS and the actual number of birds detected this past season all point to a population that is in fact, declining. This apparent decline in spotted owls corresponds with an increase in total annual barred owl detections and proportion of spotted owl territories with barred owl detections." They further noted that the forthcoming meta-analysis will show that it is "...very clear that northern spotted owls are in decline across all 11 study areas and that in many cases the decline is accelerating."

Figure 1.21: Trend in rate of population change on the Hoopa Valley Indian Reservation, Humboldt County, California during 1994-2012 (from Higley and Mendia 2013).



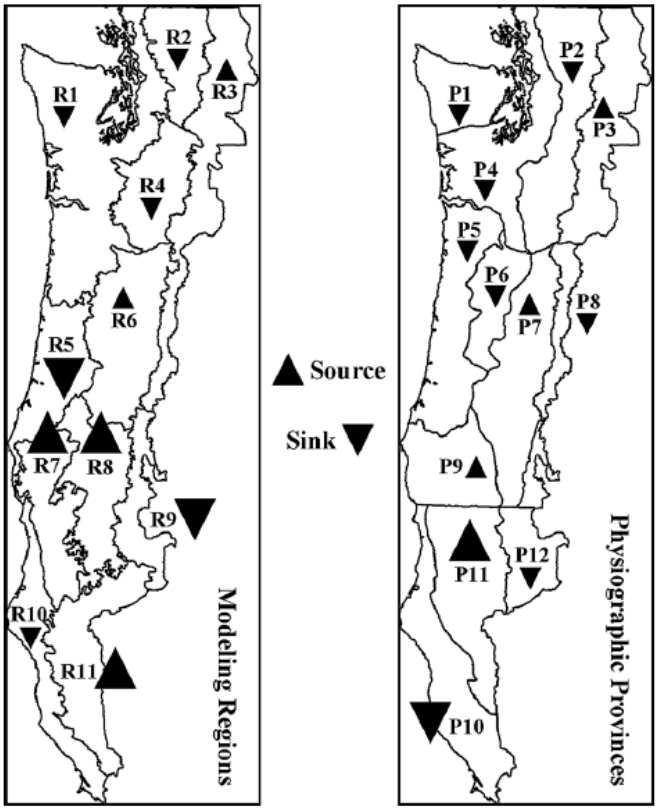
Source-Sink Dynamics

As described by Gutiérrez and Harrison (1996), source-sink dynamics exist for species "…that occupy both high-quality habitats (sources) where populations grow and produce emigrants, and low-quality habitats (sinks) where populations cannot sustain themselves in the absence of immigration." Population sinks potentially function as reservoirs for repopulation of sources that go extinct but may also reduce population growth rates (Pulliam 1988, Gutiérrez and Harrison 1996). Identifying source and sink areas is therefore, an important component of conservation research and planning. For example, identification of population sinks might be useful for determining where to focus habitat restoration or barred owl removal efforts. Empirical studies of relationships between NSO fitness and habitat attributes (Habitat Fitness Potential *sensu* Franklin et al. 2000) provide a rigorous measure of sources and sinks but only at the territory scale and within a given study area, rather than at population or regional levels (see Ch. 2 and 3 for further discussion of Habitat Fitness Potential). In the absence of direct empirical measures of large-scale source-sink dynamics, it may be useful to evaluate the results of source-sink simulation modeling based on empirical data.

Schumaker et al. (2014) recently published a rangewide study of source-sink dynamics for NSOs at the spatial scales of ecological regions and physiographic provinces. Their source-sink simulation modeling incorporated an array of regional data for NSO movement distances and rates, life history attributes, habitat suitability and connectivity, encounter rates with barred owls, and environmental stochasticity. Source-sink dynamics in this study emerged from simulated interactions between individual NSOs and landscapes, rather than being predefined based on habitat suitability as was done in previous studies. The simulation models by Schumaker et al. (2014) predicted that most ecological regions and physiographic provinces currently function as population sinks for NSOs (Figures 1.22 and 1.23). The study's results projected that the Klamath Provinces of California and Oregon and the Interior Northern Coast Ranges of California are the subspecies' strongest population sources (Figure 1.23). The Klamath

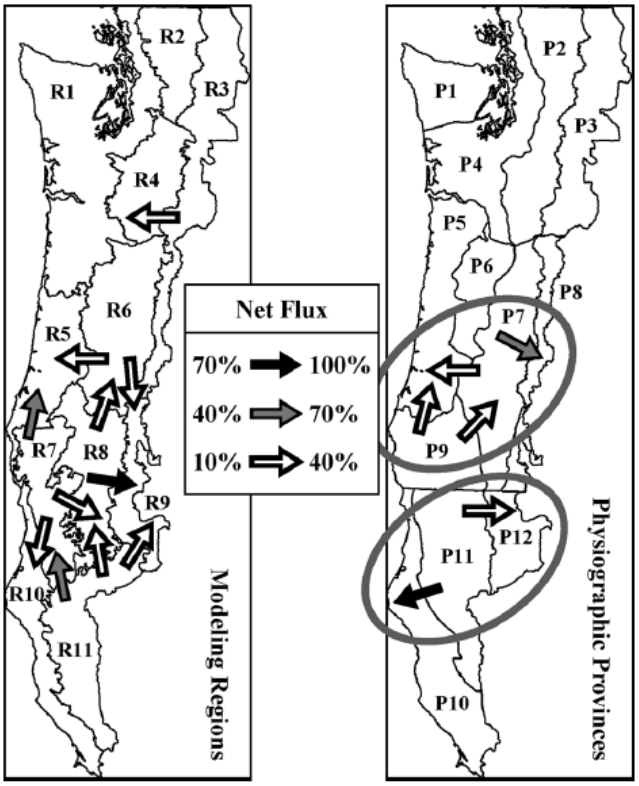
Provinces may be particularly important for maintaining NSO population stability due not only to being net population sources but to their high levels of population connectivity with multiple surrounding regions (Schumaker et al. 2014; Figure 1.23). The Redwood and Southern Cascades regions in California were both classified as moderate population sinks. Schumaker et al. (2014) identified the Klamath Provinces and California Cascades as areas in which it could be particularly important to focus habitat protection and restoration efforts, respectively.

Figure 1.22: Relative source and sink values in northern spotted owl modeling regions and physiographic provinces (from Schumaker et al. 2014). The sizes of symbols denote major versus minor or moderate sources and sinks.



R7: Klamath West, R8: Klamath East, R9: Eastern Cascades South, R10: Redwood Coast, R11: Inner California Coast Ranges, P10: California Coast Range, P11: California Klamath, P12: California Cascades. See Schumaker et al. (2014) for other modeling regions and physiographic provinces.

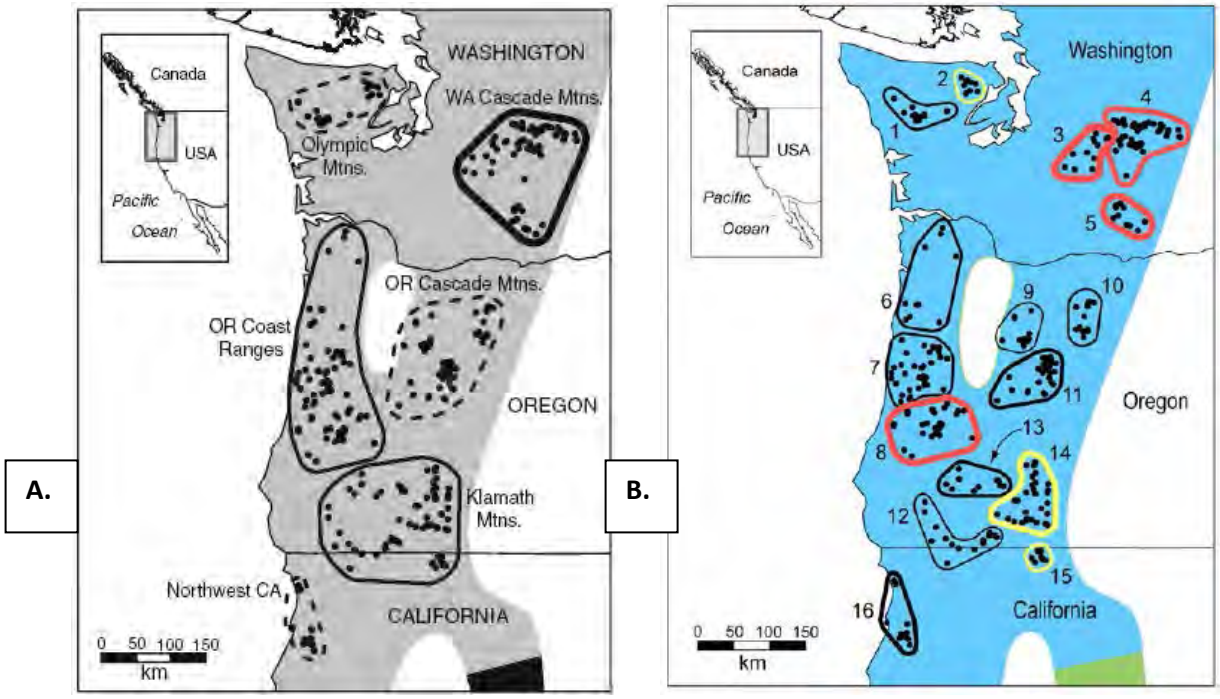
Figure 1.23: Graphical representation of net movement ("Net Flux") of individual (simulated) northern spotted owls from one modeling region or physiographic province to another (from Schumaker et al. 2014). The largest Net Flux values are shown in black, intermediate values in gray, and smallest values in white. Gray ovals highlight two areas with strong patterns of Net Flux.



Genetics

Funk et al. (2010) found statistically significant evidence that NSOs have experienced genetic bottlenecks during recent decades in the Washington Cascades, Oregon Coast Ranges, and "Klamath Mountains" of Oregon and California (Figure 1.24). An earlier report on this study indicates that evidence of a bottleneck in the Klamath Mountains analysis area was primarily driven by data from the southern Cascades of Oregon and California, rather than from the Klamath Provinces (Funk et al. 2008; Figure 1.24). Evidence of recent genetic bottlenecks in the Washington Cascades, Oregon Coast Ranges, and southern Cascades are concordant with recent demographic declines in these regions (Forsman et al. 2011; see *Demography*, above). Surprisingly, Funk et al. (2010) did not find evidence of a genetic bottleneck in the Olympic Mountains of Washington, where NSOs have recently experienced dramatic population declines (Forsman et al. 2011). However, they noted that their small sample size for this region limited their power to detect a genetic bottleneck if one occurred. Funk et al. (2010) did not find statistically significant evidence of a recent genetic bottleneck in northwestern California (Western Klamath and Redwood regions). They suggested that this could likewise have been due to low statistical power or to the relatively gradual population declines reported for that area at the time (see *Demography*, above). The analyses of Funk et al. (2010) did not address whether genetic bottlenecks were solely a result of population declines or were also contributing to them. Genetic declines can contribute to reduced demographic rates through effects of inbreeding depression and loss of adaptive genetic variation (reviewed in Funk et al. 2010).

Figure 1.24: Recent population bottlenecks in NSOs. Points represent 352 individual owls included in the analysis which are grouped into six (A) and 16 (B) regions. Statistically significant bottlenecks are represented by solid lines (A) or yellow (p = 0.05) and red (p = 0.01) lines (B). (A) represents significant bottlenecks under 5, 10, and 15% multi-step mutation models as solid bold lines and under 10 and 15% multi-step mutation models as finer solid lines (see Funk et al. 2010). (B) indicates greater magnitude bottlenecks with bolder lines. From Funk et al. 2010 (A) and 2008 (B).



Summary of Current Status and Trends

Rigorous long-term research has indicated that NSO populations are dramatically declining in Washington and northern Oregon and more gradually declining in southern Oregon and California (Forsman et al. 2011). Yet, while less precipitous than those in the northern portion of the NSO's range, the rapidity of population declines in southern Oregon and California are cause for grave concern regarding the subspecies' status and trends. A new demographic meta-analysis, which is due for public release during 2015, will replace the 2011 meta-analysis and provide the most reliable information for evaluating the NSO's current status and trends. Based on information available in annual research reports, it is clear that the forthcoming meta-analysis will show that populations in southern Oregon and California are declining more rapidly than was evident in the 2011 meta-analysis (Davis et al. 2013a, Franklin et al. 2013, Higley and Mendia 2013, Dugger et al. 2014, Green Diamond Resource Company 2014).

The NSO's status and trends are less clear in portions of California outside the state's three demographic study areas. Much of the information for these areas is provided by industrial timber companies, which have uniformly concluded that NSO populations on their lands are stable (Calforests 2014). However, the data provided by these companies are insufficient for drawing strong conclusions about the NSO's status and trends, and may in fact indicate declines in occupancy and reproduction on some ownerships (see *Occupancy* and *Demography*, above). Forsman et al. (2011) suggested that, due to weaker habitat

protection, NSO demographic trends could generally be worse on non-federal lands than on the federal and mixed federal/non-federal lands on which most demographic studies are conducted. This appears to be true in California, where NSOs experienced greater declines on Green Diamond Resource Company lands than on nearby tribal and Forest Service lands (Forsman et al. 2011; see *Occupancy* and *Demography*, above). However, the degree to which these differences were due to variation in land management, effects of competition with barred owls, or other factors is unclear.

It is likewise unclear if demographic trends in California's three demographic study areas accurately represent those in drier, less productive forests in the state's interior. An occupancy study in California's Eastern Klamath and Southern Cascades (Farber and Kroll 2012) and demographic studies in ecologically similar areas of southern Oregon (Davis et al. 2013a, Dugger et al. 2014) could provide the most reliable information currently available for evaluating NSO's status and trends in interior California (see *Occupancy* and *Demography*, above). These studies indicate that NSOs are currently declining in at least some portions of the Eastern Klamath and Southern Cascades regions (note: these regions cover portions of both California and southern Oregon as they are ecologically rather than politically defined; see USFWS 2011a Appendix C and Figure 1.22 [left side]). Evidence of population declines in the Klamath regions (Forsman et al. 2011, Farber and Kroll 2012, Davis et al. 2013a, and Franklin et al. 2013) are particularly concerning in light of the critical contributions these areas may provide to the NSO's long-term persistence (Schumaker et al. 2014; see *Source-Sink Dynamics*, above).

Although the Redwood Region is projected to currently function as a population sink, it still retains high densities and abundances of NSOs and is therefore important to the subspecies' conservation (Schumaker et al. 2014; see *Density and Abundance* and *Source-Sink Dynamics*, above). There is limited information available for evaluating the NSO's status and trends in portions of the Redwood Region outside of Green Diamond's lands. Monitoring on National Park Service lands and adjacent ownerships suggest that the population in Marin County is stable while NSOs in the Redwood National and State Parks have substantially declined. These differences appear to be largely due to negative effects of high barred owl densities in the Redwood National and State Parks and the relatively slow rate of the barred owl invasion in Marin County (see *Occupancy*, above). In contrast with the Green Diamond Resource Company, other timber companies in the northern portion of the Redwood Region have concluded that their NSO populations are stable (Calforests 2014). It is possible that NSOs have indeed fared better on these ownerships than on Green Diamond lands; for example, due to less intensive timber harvesting or more recent colonization by barred owls. However, the data provided by these companies are insufficient for drawing firm conclusions about the NSO's status and trends on these lands, and actually appear to indicate at least gradual declines in some areas. More consistent and rigorous monitoring (e.g., consistent survey areas and protocols; reporting of modeled occupancy rates) would assist future evaluations of the NSO's status and trends on industrial timberlands in California.

Acknowledgements

I am extremely grateful to Lowell Diller for his helpful review of this chapter and to Jeff Dunk for his comments on the *Source-Sink Dynamics* section.

Part II: Threats to Northern Spotted Owls in California

Forsman et al. (2011) concluded that habitat loss was partly responsible for declines in NSO fecundity, apparent survival, and/or populations observed in most demographic study areas. Due to a lack of a suitable habitat map at the time, they did not include a habitat variable in models for California. However, a substantial body of research has shown that stand- and landscape-level habitat attributes influence habitat selection, densities, occupancy, reproduction, survival, and metapopulation dynamics of NSOs in California and southern Oregon (e.g., Carey et al. 1992, Gutiérrez et al. 1998, Hershey et al. 1998, Thome et al. 1999, Franklin et al. 2000, Zabel et al. 2003, Carroll and Johnson 2008, Schumaker et al. 2014). Loss of approximately 60-88% of all old forest within the NSOs range during the 19th and 20th centuries was a primary reason for the subspecies' federal listing (USFWS 1990, Strittholt et al. 2006). Despite greater habitat protection following federal listing and implementation of the Northwest Forest Plan, intensive timber harvesting and large wildfires have continued to cause a downward trend in suitable habitat for NSOs and thus, continue to threaten the subspecies (Davis and Dugger 2011, USFW 2011). Yet, NSOs in California and southern Oregon may have complex relationships with these disturbances. For example, low-to-moderate or mixed severity wildfires could sometimes benefit NSOs in these areas by contributing to prey diversity and abundance, provided they do not excessively remove nesting and roosting habitat. In-depth reviews of these topics are provided in Chapters 2 and 3 of this volume.

Demographic analyses indicate that worsening NSO population declines in California and southern Oregon have been driven to a large degree by increasing competitive pressure from invasive barred owls (Forsman et al. 2011, Davis et al. 2013a, Franklin et al. 2013, Higley and Mendia 2013, Dugger et al. 2014, Green Diamond Resource Company 2014). A large body of quantitative and anecdotal information indicates that barred owls negatively affect NSOs in a variety of ways and that they currently pose one of the primary threats to the NSO's long-term persistence (USFWS 2013). These topics, with particular emphasis on information from California, are reviewed in Chapter 4.

Outdoor marijuana cultivation has dramatically increased in recent years and has emerged as a serious potential threat to NSOs in California (Gabriel et al. 2013, Calforests 2014). There is little quantitative information concerning impacts of outdoor marijuana cultivation on NSOs. However, published research of fishers (*Pekania pennanti*), which have overlapping home ranges, habitat associations, and diets with NSOs, suggests that anti-coagulant rodenticides and other pesticides used in outdoor marijuana cultivation currently pose a widespread risk to NSOs in California (Gabriel et al. 2012, 2013, Thompson et al. 2014). In addition to potential behavioral and demographic effects of pesticides on NSOs, outdoor marijuana cultivation could impact the subspecies through suppression of prey populations; ecological changes due to water diversion, clearcutting, and pollution; or habitat loss to wildfires ignited by growers (Gabriel et al. 2013, Bauer et al. 2015). Marijuana cultivation could also impact conservation of NSOs by reducing the ability of biologists to safely and efficiently conduct conservation research and monitoring (Gabriel et al. 2013). These topics are further discussed in Chapter 5.

The apparent effects of weather and climate variables on NSO demographic rates suggest that anthropogenic climate change could pose a major threat to the subspecies (Glenn et al. 2010). This hypothesis is further supported by projections of increased numbers of large wildfires in California under plausible climate change scenarios (see Ch. 3). Climate change could also impact NSOs in California through other climate or weather effects (e.g., increased frequency of droughts), outbreaks of insects and pathogens, large-scale redistribution of major vegetation types, and unpredictable effects on

prey communities (reviewed in USFWS 2012b). Due to limited time and funding, and the complex and ever-increasing body of science covering these topics, a synthesis of this information is not included in this document. State and federal agencies should thoroughly evaluate climate change as a potential threat to NSOs and other species prior to determining their conservation status.

Although not reviewed herein, the stressors described above and in the remainder of this document could have cumulative and interactive impacts on NSOs. For example, Dugger et al. (2011) found that barred owls and habitat fragmentation had an additive negative effect on NSO occupancy rates in southern Oregon. This finding suggests that habitat loss and fragmentation due to timber harvesting or severe wildfires can increase competitive pressure from barred owls. Decreasing population sizes, apparently due primarily to habitat loss and competition with barred owls, can increase risks posed to NSOs by other factors. For example, small NSO populations may become vulnerable to extinction due to chance events such as epidemics or extreme weather or climate events (Franklin et al. 2000). Decreasing population sizes may also have negative genetic effects on NSOs. For example, genetic bottlenecks could further reduce demographic rates through inbreeding depression and loss of adaptive variation (Funk et al. 2010). Also, hybridization between NSOs and barred owls could become more frequent in the future as NSOs become less able to find conspecific mates (Gutiérrez et al. 2007). Policymakers and land managers should acknowledge that, despite limited research of the topic, multiple past and current stressors for NSOs could have important cumulative and interactive impacts on the subspecies.

Ch. 2: Timber Harvesting

Introduction

Timber harvesting was a primary impetus for federal listing of the NSO and is still regarded as one of the major threats to the subspecies (Thomas et al. 1990, USFWS 1990, Courtney et al. 2004, USFWS 2011a). Timber harvesting can directly impact NSO populations by removing, degrading, or fragmenting habitat for them or their prey (reviewed below). Harvesting might also indirectly affect NSOs by increasing effects of other stressors, such as competitive pressure from barred owls (*Strix varia*) (Forsman et al. 2011, USFWS 2011a; see Ch. 4). However, timber harvesting likely has complex effects on NSOs in the southern part of their range due to divergent effects of habitat conditions on survival versus reproduction (Franklin et al. 2000, Olson et al. 2004, Diller et al. 2010). The information reviewed herein suggests that some forms and amounts of harvesting may be sustainable in northern California but that large-scale removal or fragmentation of habitat around activity centers can have strong negative impacts on NSOs (reviewed below and in USFWS 2009).

The kinds of habitat concentrations associated with high survival and fitness of NSOs may be limited in some parts of the subspecies' range due to removal of the majority of old forest during the 19th and 20th centuries (USFWS 1990, Strittholt et al. 2006). Harvesting has been substantially curtailed on federal lands since implementation of the Northwest Forest Plan (Healey et al. 2008, Davis and Dugger 2011, Moeur et al. 2011, Kennedy et al. 2012). However, removal of suitable NSO habitat continues on federal lands and is occurring at higher rates on non-federal lands (Davis and Dugger 2011). On non-federal lands, habitat loss to logging is only partially offset by recruitment of new habitat (Davis and Dugger 2011, Moeur et al. 2011; reviewed below). This is cause for concern since non-federal lands contain a considerable portion of remaining suitable breeding habitat for the subspecies (e.g., >30% of older forest in the Pacific Northwest and northwestern California currently exists on non-federal lands: Moeur et al. 2011) and because recovery of the NSO could partially depend on voluntary conservation efforts on these lands (USFWS 2011a). The timber industry has cited relatively strict harvest regulations in California as evidence that listing of the NSO under the California Endangered Species Act is unnecessary (Calforests 2014). Yet, contemporary harvesting has still resulted in a net loss of suitable breeding habitat for NSOs on non-federal lands in California (reviewed below). Furthermore, the U.S. Fish and Wildlife Service (2009) recently concluded that California's regulations for avoiding "take" of NSOs inadequately protect the subspecies and do not reflect the best available science. Inconsistent or poor implementation of existing regulations could further weaken protections for NSOs on private timberlands in California (reviewed below).

Responses of NSOs to Timber Harvesting

<u>Interior of Northern California and Southern Oregon</u>

NSOs in interior northern California show a strong general preference for relatively old, structurally complex forest. This is illustrated by studies describing both small-scale plots around NSO locations (Solis and Gutiérrez 1990, Rissler 1995, White 1996, Hershey et al. 1998; but see Irwin et al. 2013) and landscape-scale analysis areas around activity centers (Chávez-León 1989, Solis and Gutiérrez 1990, Hunter et al. 1995, Gutiérrez et al. 1998). This body of research can be used to inform conservation measures for NSOs in interior northern California (e.g., for evaluating appropriate habitat definitions in take-avoidance guidelines: USFWS 2009). However, the following review is focused on studies of associations between landscape-scale habitat attributes and NSO demography in interior forests

(Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005, Schilling et al. 2013). These studies are based on rigorous demographic data and provide the best available insight into potential effects of timber harvesting on NSO populations (USFWS 2009). This review is supplemented with information from studies of associations between landscape-level habitat characteristics in southern interior forests and NSO home range sizes and probability of occurrence (Carey et al. 1992, Carey and Peeler 1995, Zabel et al. 2003, Carroll and Johnson 2008, Schilling et al. 2013).

In the California Klamath, Franklin et al. (2000) found that NSO survival was highest when estimated breeding core areas (390 ac) contained large amounts of both interior (>326 ft from edge) older forest (conifer or mixed forest with conifer QMD ≥21 in and canopy cover ≥70%) and edge with other vegetation classes. In contrast, reproduction was typically highest with lower amounts of interior older forest and greater amounts of edge. Estimated breeding core areas supporting high fitness for NSOs (a function of both survival and reproduction) contained both a large concentration of interior older forest and considerable habitat edge provided by a mosaic of other vegetation patches with convoluted shapes. Franklin et al. (2000) emphasized the difference between total area of older forest versus area of interior older forest. For example, they noted that large amounts of older forest edge cannot occur with low total amounts of older forest. This study did not directly address effects of timber harvesting on NSOs. Vegetation other than older forest was combined into a single class and edges occurred wherever that class and older forest met. Franklin et al. (2000) noted, however, that the dominant silvicultural system in their study area at that time was large-scale clearcutting, which they concluded was unlikely to contribute to the kinds of habitat mosaics found in territories supporting high fitness.

In an unpublished report, Matthews et al. (2008) evaluated the demography of NSOs on the Hoopa Valley Indian Reservation in the California Klamath. Their best performing model explaining NSO survival indicated that survival increased with greater amounts of interior mature or old forest (>80 yrs with "heavy" canopy cover, ≥328 ft from edge) up to about half of a 200-acre analysis area around activity centers and then slightly declined with higher proportions. Survival also increased with increasing amounts of brushy pole-timber forest (conifer stands 10-20 yrs with a "heavy brush component", meant to represent dusky-footed woodrat [*Neotoma fuscipes*] habitat) within estimated territories (917 ac) up to about 16% of the area and then leveled off. Survival was negatively associated with pre-commercial thinning (prescription not described) of brushy pole-timber forest, which Matthews et al. (2008) attributed to a negative long-term effect of thinning on dusky-footed woodrat populations. The best performing model explaining patterns of NSO reproduction indicated that the influence of woodrat habitat on reproduction depended on whether it was a high or low reproduction year and on amounts of mature and old forest. During years with high reproduction, productivity was highest at sites with moderate amounts (19%) of woodrat habitat in a larger core analysis area around activity centers (517 ac), whereas woodrat habitat had little influence on NSO reproduction during low reproduction years. Furthermore, high amounts of mature and old forest apparently offset negative effects of low amounts of woodrat habitat on reproduction; possibly by providing access to alternative prey (e.g., northern flying squirrels) or greater protection from predators or inclement weather (Matthews et al. 2008).

In the interior of the Oregon Coast Range, Olson et al. (2004) found that NSO survival was positively associated with greater amounts of both "mid-seral" (9.5-31.5 in DBH) and "late-seral" (>31.5 in DBH) forest in landscapes around activity centers (≤4,921 ft) and lower amounts of early-seral forest and non-forest (<9.5 in DBH). Reproduction, in contrast, was negatively associated with area of mid- and late-seral forest and positively associated with edge between early-seral and non-forest and other vegetation classes. Olson et al. (2004) encountered technical difficulties with the habitat fitness potential portion of

their modeling but noted that territories supporting high fitness must contain attributes associated with both high survival and high reproduction. This was supported by diagrams made from aerial photos of landscapes around activity centers, which showed remarkably similar habitat mosaics to those presented by Franklin et al. (2000).

Dugger et al. (2005) found a positive association between NSO survival in the Oregon Klamath Province and greater amounts of mature and old forest (≥100 yrs) within estimated breeding core areas (413 ac) and a moderate amount of non-habitat (non-forest, early-seral vegetation, and older forest with harvest entries ≥40% basal area) in the landscape beyond the core area (3,430-ac ring). The specific contribution of timber harvesting (and of different harvest types and intensities) to the non-habitat class and thus, its effects on NSO fitness, were not reported. This study's findings differed from others in that reproduction was positively, rather than negatively, associated with greater amounts of older forest within estimated core areas. These findings suggest that widespread harvesting of older forest within NSO core areas would negatively affect both survival and reproduction in this area but that some level of harvesting might be sustainable in the broader landscape (to the degree that it contributes to "optimal" amounts of non-habitat in the 3,430-ac ring surrounding estimated core areas).

Schilling et al. (2013) found additional evidence of a positive influence of both older forest and habitat heterogeneity on NSO survival in the Oregon Klamath. Their best performing model indicated that monthly survival probabilities for NSOs were highest when home ranges (based on radio-telemetry) contained more patches of mature and old forest (≥20 in DBH and ≥40% canopy cover). The second best performing model indicated a positive association between survival and clustering of (i.e., close distances between) older forest patches. Unlike other studies, they did not find an association between survival and total amount of older forest. They noted that this could have occurred due to their small sample size or because most NSO home ranges in their study had amounts of mature and old forest (mean = 72%) that exceeded threshold amounts required for survival. A third competitive model suggested that survival was also positively associated with a moderate amount of edge between forest (mean DBH ≥5 in) and other cover classes; thus providing additional support for the value of habitat heterogeneity for NSOs in southern interior forests.

Zabel et al. (2003) modeled probability of NSO occurrence (i.e., habitat suitability) across interior northern California based on habitat conditions at an estimated core area scale (500 ac). The best performing model in their study indicated that the probability of NSOs occurring in a given location was highest with large amounts of suitable nesting-roosting habitat (generally ≥17 in DBH and canopy cover ≥60%) and intermediate amounts of foraging habitat (≥10 in DBH and canopy cover ≥40%) at the core area scale. The second and third best performing models at the core area scale included habitat edge. The results of this modeling study provide further support for conclusions that a combination of both a large concentration of suitable habitat and some form of habitat heterogeneity is important to NSOs in interior northern California.

Carroll and Johnson (2008) also modeled probability of NSO occurrence in interior northern California. Based on their best model, predicted abundance of NSOs in the area was highest when most of the landscape (5,930-ac areas) consisted of mature and old forest (>50 yrs). However, predicted abundance slightly declined when area of mature and old forest increased beyond about 80% of the landscape. This study therefore, provides evidence of at least a slight positive effect of other vegetation classes on probability of NSOs occurring in a given area. These results contrasted with the study's findings for more northern parts of the NSO's range, where the probability of occurrence continued to increase (albeit diminishingly) with greater amounts of older forest.

Studies of home range sizes provide another line of evidence concerning habitat and harvesting influences on NSOs in interior southern forests. Home range studies in the Oregon Klamath found that home range size increased with habitat fragmentation (Carey et al. 1992, Schilling et al. 2013). NSOs in the area are known to use regenerating harvest units for foraging, particularly when closer to the activity center or outside the breeding season (Carey and Peeler 1995, Irwin et al. 2013). However, Carey and Peeler (1995) concluded that the energetic benefit of increased access to dusky-footed woodrats in heavily fragmented forest is often outweighed by the energetic cost of increased travel.

In summary, studies in interior northern California have found that NSOs in the region benefit from both large amounts of older forest concentrated around activity centers and some form of habitat heterogeneity (Franklin et al. 2000, Zabel et al. 2003, Carroll and Johnson 2008, Matthews et al. 2008). Similar results have been found in the Klamath (Dugger et al. 2005, Schilling et al. 2013) and interior Coast Range of Oregon (Olson et al. 2004). These findings suggest that NSO populations in southern interior forests can tolerate some level of timber harvesting provided suitable breeding habitat is retained in sufficiently large concentrations around activity centers (USFWS 2009). However, whether and how timber harvesting contributes to beneficial habitat heterogeneity in interior southern forests is unclear. Available studies differed in their findings of types, amounts, and locations of beneficial heterogeneity and did not directly evaluate whether timber harvesting contributed to it. In contrast, it is clear from research of associations between landscape-level habitat attributes and the demography, presence, and home range sizes of NSOs that harvesting within core concentrations of suitable habitat has the potential to negatively affect populations in southern interior forests (USFWS 2009).

Redwood Province

Most of the literature concerning NSOs in the Redwood Province pertains to research on intensively harvested lands owned by the Green Diamond Resource Company. Studies on these lands found a preference among NSOs for landscapes with greater amounts of intermediate-age or older forest than expected based on general availability of those forest classes (Thome et al. 1999, Folliard et al. 2000, Keithley and Motroni 2000, Gonzales 2005, Diller et al. 2010). However, site fidelity and reproduction on these lands were positively associated with presence of younger forest classes and measures of habitat heterogeneity (e.g., edge) (Thome et al. 1999, 2000, Diller et al. 2010). Studies of the habitat associations of dusky-footed woodrats on these lands appear to provide additional support for the value of younger forest and habitat heterogeneity to NSOs in the area (Hamm et al. 2007, Hamm and Diller 2009). Unpublished but relatively rigorous modeling of associations between landscape-level habitat attributes and NSO fitness and population growth rate has confirmed that NSOs on Green Diamond lands have complex relationships with timber harvesting (Diller et al. 2010). NSOs on Green Diamond lands indeed appear to benefit from some level of habitat heterogeneity, which is currently maintained through “small-patch” ($\leq$20 ac) clearcutting (Diller et al. 2010). Yet, habitat quality on these lands (measured as habitat fitness potential, *sensu* Franklin et al. 2000) is positively associated with protection of suitable breeding habitat, and both habitat quality and population growth rate are negatively associated with harvesting of suitable habitat (Diller et al. 2010). Thus, appropriate management of NSOs on Green Diamond lands appears to include avoiding take, setting aside suitable habitat from harvesting, and focusing economically-driven harvest requirements in relatively homogeneous blocks of unsuitable forest created by past large-block clearcutting. Diller et al. (2010) did not describe habitat conditions associated with habitat fitness potential $\geq$1 (i.e., conditions associated with NSOs replacing themselves or contributing to a population surplus). Peer reviewed reporting of these conditions could

be used to refine current take-avoidance guidelines for the Redwood Province (see USFWS 2011b, CAL FIRE 2014).

There does not appear to be any published information concerning the ecology and appropriate management of NSOs on other ownerships within the Redwood Province. Habitat conditions available to and selected by NSOs appear to differ among public and private ownerships (Keithley and Motroni 2000), industrial timber company ownerships (Appendix 2.1), and industrial versus non-industrial timberland ownerships (K. Hoffman, pers. comm.). This variability could reflect differences among forest types (e.g., redwood vs. mixed-evergreen), management regimes (e.g., intensive even-age, intensive uneven-age, and low-intensity uneven-age), and natural disturbance regimes (e.g., pre-settlement fire return intervals in northern vs. southern forests) (see Stuart and Stephens 2006, Sawyer 2007).

The USFWS (2011a, 2012a) recently conducted habitat suitability modeling based on attributes of landscapes (494 ac) surrounding 392 activity centers distributed across much of the Redwood Province. The model selected for the region included a suite of habitat variables and performed well in terms of its ability to discriminate between areas around NSO activity centers and random sites. The resulting map of relative habitat suitability was incorporated into the USFWS (2012a) process for designating critical habitat for NSOs but has limited utility for characterizing habitat selection by the subspecies. However, "deconstruction" of the habitat suitability modeling outputs (cf. Dunk and Hawley 2009, Woodbridge et al. 2012, Zielinski et al. 2012) allows evaluation of associations between habitat suitability and the full range of candidate variables, including ones not included in the best performing model. Deconstruction of the habitat modeling output for the Redwood Province shows that the probability of NSOs occurring in a given area in the region increases with larger amounts of forest with relatively dense canopy cover and large diameter trees (Appendix 2.2). Compared with those in the lowest suitability class, landscapes in the highest suitability class contained an average of 1.8 times more nesting-roosting habitat; 2.4 times higher basal area of conifers $\geq$20 inches DBH; 2.3 times higher basal area of live trees $\geq$30 inches DBH; and 2.0, 1.8 and 1.9 times higher densities of conifers $\geq$20, 30, and 39 inches DBH, respectively. There was a high degree of variability (standard deviation) in terms of structural attributes within habitat suitability classes, particularly for rare habitat elements such as very large diameter trees. As noted above, this variability likely reflects the high diversity of forest types, management histories, and natural disturbance regimes in the region (see Stuart and Stephens 2006, Sawyer 2007). Nonetheless, consistent patterns of association between habitat suitability and mean amounts of these variables are evident. In addition, variability in amounts of many of these habitat attributes (coefficient of variation) declined with increasing habitat suitability, further indicating that they are often important to NSOs in the province. These results suggest that timber harvesting that reduces availability of these structural attributes would generally reduce the probability of NSOs occurring in a given area within the Redwood Province. Changes in availability of these structural attributes can occur with a variety of silvicultural approaches and are not solely caused by even-age harvesting.

Effects of Uneven-Age Harvesting and Thinning

Some private landowners in northern California currently emphasize uneven-age regeneration or management, which typically cause less visually dramatic changes to forests than does even-age harvesting. These forms of harvesting, particularly intensive uneven-age regeneration, nonetheless have the potential to cause substantial changes to forest structure or composition. For example, intensive selective logging of Douglas-fir (*Pseudotsuga menziesii*) has resulted in extensive conversion of mixed-evergreen forest to hardwood-dominated forest in parts of the Redwood Province (Sawyer 2006).

Relatively little harvesting has occurred on federal lands within the NSO's range since adoption of the Northwest Forest Plan (Davis and Dugger 2011, Moeur et al. 2011, Kennedy et al. 2012; see below). However, federal agencies have expressed support for widespread thinning to reduce wildfire risk, restore wildlife habitat, and meet economic objectives in the Plan area (USFS and BLM 1994, USFWS 2011a, 2012a).

Effects of contemporary uneven-age harvesting and thinning on NSOs are difficult to evaluate due to the paucity of rigorous research on the topic. Most of the available information about NSO responses to these silvicultural systems is based on the behavior of very small numbers of telemetered owls and was gathered in an opportunistic fashion during studies of other topics (reviewed in Hansen and Mazurek 2010, USFWS 2011a; see below). Evaluation of this topic is further complicated by poor descriptions of harvest methods, locations and intensities and, perhaps more importantly, post-harvest habitat conditions. The terms uneven-age harvesting and thinning encompass a tremendous variety of harvest types, objectives, and effects (e.g., Graham et al. 1999). Harvesting described in relation to NSO telemetry consisted of a variety of commercial thinning or partial harvesting (leaving residual trees) prescriptions, including understory thinning of various intensities, removal of most trees up to a relatively large diameter class, and shelterwood harvests prior to or without removal of residual trees (see Hansen and Mazurek 2010). The effects of thinning and uneven-age harvesting on NSOs may also be influenced by the condition of the landscape surrounding the harvest unit (e.g., amount, contiguity, and location of suitable NSO habitat), which could be affected by climate, soils, natural disturbance regimes, and past harvesting.

In a synthesis prepared for the 2011 revised recovery plan for the NSO (USFWS 2011a), Hansen and Mazurek (2010) provided detailed summaries of data concerning responses of both NSOs and California spotted owls (*S. o. occidentalis*; CSOs) to uneven-age harvesting, partial harvesting, and thinning. This information was gleaned from both peer-reviewed and gray literature and was based on small sample sizes. The authors therefore, opted to review each data source as a "case study" so that relatively detailed descriptions of harvesting and post-harvest conditions could be provided and so that the methodological strengths and weaknesses of studies could be evaluated. Their review is summarized below, with the addition of thee citations: Matthews et al. 2008, Gallagher 2010, and Tempel et al. *in press*.

All of the reviewed studies that described habitat use patterns by NSOs or CSOs documented at least some use of areas harvested with uneven-age harvesting, partial harvesting, or thinning. At least four of the studies found owls nesting in harvest areas (Forsman et al. 1984, Zabel et al. 1992, King 1993, and Buchanan et al. 1995) and at least five recorded roosting in them (Solis 1983, Sisco 1990, King 1993, Hicks et al. 1999, and Meiman et al. 2003). It is important to note, however, that older-forest structural attributes had been retained or regenerated in most of the harvest areas used for nesting or roosting. Three of the four studies that documented nesting in harvest areas described the nest stands as mature or old forest or an equivalent classification (USFS Region 5 "suitable habitat"; "understory reinitiation phase…of stand development"). The other study did not describe the harvest area used for nesting (King 1993). Harvest areas used for roosting in three studies likewise were either classified as mature or old forest (Solis 1983) or contained some older-forest structural characteristics, such as relatively high basal area or dense canopy cover (King 1993, Meiman et al. 2003). Two studies observed roosting in harvested stands that appeared to differ from this pattern; but one of the authors thought that the deaths of three spotted owls that roosted in them were due to higher predation risk in the more open stands (Sisco 1990, Hicks et al. 1999).

Most of the reviewed studies found that spotted owls foraged to some degree in uneven-age harvested, partially harvested, or thinned areas. Irwin et al. (2005, 2008) stated that some NSOs in their study areas selectively used certain harvest units but not others. However, they did not provide quantitative comparisons of prescriptions, post-harvest conditions, or proximities of harvest units to activity centers. Two other studies found that spotted owls generally avoided foraging in areas that recently experienced moderate to intensive partial harvesting or thinning, whereas use of lightly harvested areas varied among individuals (Anthony and Wagner 1999, Gallagher 2010). Anthony and Wagner (1999) found that NSOs (n = 15) in southern Oregon foraged in heavy and moderate partial-cuts less than expected (old stands with ≥30-40% of the original basal area removed and ≥"moderate" canopy cover reduction [not described]). Light partial-cuts (old forest with ≤20% of the original basal area removed and "small" reductions of "crown cover" [not described]) were used more than expected by two owls, as often as expected by five, and less than expected by eight. In the northern Sierra Nevada, Gallagher (2010) found that CSOs (n = 9) used heavily thinned "defensible fuel profile zones" (canopy cover reduced to 40%, removal of trees <30 in DBH, reduction of tree density and ladder and surface fuels) less than expected based on availability. She also reported a near-significant tendency ($p = 0.08$, n = 5) for avoidance of areas recently treated with understory thinning. Use and availability of harvest areas varied among individuals. Most individuals exhibited avoidance of defensible fuel profile zones and areas treated with understory thinning but one male showed strong selection for thinned areas (primarily understory thinning). It is possible that understory thinning improved prey availability or otherwise benefited this male. However, Gallagher (2010) noted that thinning treatments were located unusually close to this male's activity center, which potentially increased his likelihood of using them due to central place foraging. She also noted that an unusually large proportion of understory thinning units in the male's home range were also treated with prescribed fire, which could have temporarily increased abundances of deer mice (*Peromyscus* spp.) or other prey that tend to respond positively to fire (see Ch. 3).

The limited available information suggests that thinning and uneven-age harvesting causes some spotted owls to increase their home range sizes, which could impose energetic costs on individuals (Meiman et al. 2003, Gallagher 2010). Meiman et al. (2003) reported that a male NSO's breeding season home range in the Oregon Coast Range was slightly larger before commercial thinning than afterward but that its nonbreeding season home range was 2.3 times larger afterward. The individual also appeared to shift its breeding season core area to include less of the thinned area. In the northern Sierra Nevada, Gallagher (2010) found that the home range sizes of CSOs (n = 9) significantly increased with greater total area of fuels treatments (defensible fuel profile zones and understory thinning). She also reported near-significant trends of increasing home range size with greater area of defensible fuel profile zone ($p = 0.08$) and group selection harvesting ($p = 0.06$).

Four studies reported that thinning or partial harvesting near nests or roosts displaced spotted owls from those areas (Forsman et al. 1984, King 1993, Hicks et al. 1999, Meiman et al. 2003; also J. Reid, pers. comm.). The only study to describe this effect for more than two NSOs suggested that pairs' responses to harvesting near their nests depended on the intensity of the harvest, whether or not habitat in the nest area was excluded from harvesting, and whether or not suitable alternative habitat was available within the home range (Forsman et al. 1984).

At least two studies have evaluated potential relationships between spotted owl demographic rates and forest thinning. On the Hoopa Indian Reservation in the Western Klamath region of California, Matthews et al. (2008) found a negative association between survival of NSOs and pre-commercial thinning (prescription not described) of brushy-poletimber forest (conifer forest 10-20 yrs with a dense

brush layer). The researchers attributed this finding to a long-term negative effect of thinning on dusky-footed woodrat populations in the area (see below regarding timber harvest effects on spotted owl prey). Tempel et al. (*in press*) examined associations between CSO demographic rates at 70 territories in the central Sierra Nevada and area of "medium-intensity" harvesting (generally, retention of trees ≥30 in DBH and 40% mean DBH, reduction of fuels). Their best performing model explaining reproduction included a negative effect of medium-intensity harvesting, although evidence for this was statistically weak (95% CI of the beta coefficient broadly overlapped zero).

A recent study modeled recruitment of habitat for NSOs under a particular wildfire and forest thinning scenario in the Klamath and "dry Cascades" regions and concluded that negative effects of thinning on NSOs will outweigh potential benefits to the subspecies due to reduced risk of severe wildfire (Odion et al. 2014). Some of this study's assumptions do not appear to reflect the current scientific understanding of spotted owl-habitat relationships and wildfire and thinning effects on the species. For example, recruitment of NSO habitat was broadly defined in the study (recruitment of forest with basal area ≥120 ft^2/ac) and does not reflect the subspecies' relationships with other structural attributes, such as canopy cover, canopy layering, and large diameter trees. This study was also based on an assumption that commercially thinned and severely burned areas are always unsuitable for NSOs. NSOs are known to nest, roost, and forage in thinned areas (see above) and patchy severe fire appears to benefit NSOs in some areas, provided it does not result in extensive loss or degradation of nesting and roosting habitat (see above and Ch. 3). This study was further based on an assumption that federal agencies will blindly apply thinning to landscapes, including substantial areas of NSO habitat, rather than strategically locating treatments in areas more likely to burn at high severity and less likely to be used by NSOs (e.g., upper slopes, southwesterly aspects, densely-canopied young forest: Skinner and Taylor 2006, Skinner et al. 2006, Irwin et al. 2012). Modeling simulations have suggested that thinning can be strategically applied to relatively small portions of landscapes to reduce fire risk while minimizing negative short-term effects on spotted owls (Ager et al. 2007, Lehmkuhl et al. 2007, Prather et al. 2008).

Federal agencies have expressed support for widespread thinning to reduce the risk of severe wildfire in dry forests within the NSO's range (USFS and BLM 1994, USFWS 2011a, 2012a). The review provided in Chapter 3 suggests that spotted owls are often resilient to wildfire, and may benefit from some amount of low-to-moderate severity, mixed severity, or patchy fire in interior forests in southern Oregon and California, but that extensive severe fire can negatively affect the species by reducing amounts and contiguity of nesting and roosting habitat. This conclusion might appear to support widespread thinning to reduce the risk of large severe fires in NSO home ranges. However, preliminary findings of negative effects of thinning on spotted owls and the overall lack of reliable information on the topic suggest that rigorous research is needed to determine how best to balance tradeoffs for habitat conservation and fuels reduction objectives. If thinning is applied prior to conducting rigorous research of its effects on NSOs, research of the subspecies' habitat and prey relationships suggests that it should generally be located well away from activity centers and focused in young, closed-canopy stands with poorly developed brush layers. Thinning in these stands has the potential to increase habitat heterogeneity and accelerate development of complex, older-forest structure for NSOs and their prey (Carey 2006; but see below regarding effects of thinning on primary prey species). Planning of treatments should also integrate regional or local information about relationships between wildfires and topography (see Ch. 3), the composition of NSO diets or prey communities, and other ecological factors that could influence how thinning affects wildfires and NSOs.

Timber Harvest Effects on Prey

The primary prey for NSOs in California are dusky-footed woodrats, northern flying squirrels (*Glaucomys sabrinus*), and tree voles (*Arborimus* spp.) (Zabel et al. 1995, White 1996, Ward et al. 1998, Farber and Whitaker 2005, Diller et al. 2010, Klamath National Forest, unpubl. data). Other important prey in the state (either in terms of frequency or biomass contributions to diets) include other voles (*Myodes californicus*, *Phenacomys* spp., and *Microtus* spp.), deer mice (*Peromyscus* spp.), pocket gophers (*Thomomys* spp.), broad-footed moles (*Scapanus latimanus*), and juvenile brush rabbits (*Sylvilagus bachmani*) and snowshoe hares (*Lepus americanus*). These species have a broad array of habitat associations and thus, likely respond quite differently to timber harvesting and other forest disturbances. The review below focuses solely on timber harvest effects on the three primary prey species for NSOs in California. It is important to acknowledge, however, that NSOs typically have broad diets (see diet studies cited above) and that other prey species may also influence spotted owl demographic rates (Ward and Block 1995, Rosenberg et al. 2003).

Dusky-footed woodrats can occur in relatively high abundances in old forest, particularly in riparian areas and other locations with a well developed understory or brush layer (Carey et al. 1992, 1999). However, they generally reach their highest abundances in stands of brushy poletimber that develop following severe disturbances (Carey et al. 1992, 1999, Sakai and Noon 1993, Anthony et al. 2003, Hamm et al. 2007). Thus, intensive harvesting of intermediate-age stands could potentially result in temporary increases in abundance of dusky-footed woodrats. There is little information regarding effects of less intensive harvesting on dusky-footed woodrats. Hamm and Diller (2009) rarely found dusky-footed woodrats in thinned stands on Green Diamond Resource Company lands in the Redwood Region. They suggested that thinning without prescribed burning was insufficient for promoting growth of the disturbance-adapted shrubs locally favored by the species (see Ch. 3 regarding short-term effects of fire on prey). Matthews et al. (2008) did not directly evaluate effects of thinning on dusky-footed woodrats in the California Klamath. However, they suggested that the negative association between NSO survival and pre-commercial thinning of brushy-poletimber forest in their study was likely due to long-term declines in woodrats following thinning.

Densities and demographic rates of northern flying squirrels are positively associated with habitat elements found in forests (e.g., arboreal lichens, truffles, and snags: Rosenberg and Anthony 1992, Carey 1995, Waters and Zabel 1995, Gomez et al. 2005, Meyer et al. 2005, Lehmkuhl et al. 2006). Thus, they are likely to respond negatively to intensive forms of timber harvesting (e.g., Waters and Zabel 1995). Northern flying squirrels are also generally sensitive to habitat fragmentation caused by intensive harvesting (Smith 2007). For example, Rosenberg and Raphael (1986) found that densities of northern flying squirrels in the California Klamath Province were substantially lower in the smallest and most insular habitat patches (due to surrounding clearcut harvesting) than in the largest and best connected patches.

Research concerning the effects of thinning and other lower-intensity forms of harvesting on northern flying squirrels has generated inconsistent results (e.g., Carey 2000, Ransome and Sullivan 2002, Ransome et al. 2004, Gomez et al. 2005, Manning et al. 2012). Some of the inconsistency appears to be due to whether treated young stands are compared with structurally simple young stands (e.g., Gomez et al. 2005), structurally complex young stands (e.g., Carey 2000), or stands that have not recently experienced harvesting (Holloway and Smith 2011). The available research suggests that treated stands are more likely to contain relatively low abundances of northern flying squirrels when compared with structurally complex or mature and old stands, whereas they may exhibit similar or even higher

abundances when compared with structurally simple young stands. Harvest intensity and levels of retention appear to be another major determinant of thinning effects on northern flying squirrels, with higher intensity thinning (lower retention levels) having stronger negative effects (Meyer et al. 2007, Holloway and Smith 2011, Manning et al. 2012; but see Ransome et al. 2004). Whether thinning is patchy or uniform (in terms of location and intensity) might also be important. For example, thinning can reduce the availability of truffles, the northern flying squirrel's primary food, for more than 10-20 years; but variable-density thinning appears to be less harmful than commercial thinning (Waters et al. 1994, Colgan et al. 1999, Luoma et al. 2003, Meyer et al. 2005).

Tree voles generally occur at higher densities in old forests than in young forests (reviewed in Sztukowski and Courtney 2004, USFWS 2011c) and selectively use forests containing higher concentrations of habitat elements typically found in older stands (e.g., older stand age, larger diameter downed wood, greater basal area: Dunk and Hawley 2009). Tree voles are thought to be highly vulnerable to logging and other disturbances that reduce the extent and contiguity of old forests (Carey 1991, Huff et al. 1992, Hayes 1996, Adam and Hayes 1998, USFWS 2011c). Some tree vole populations occur in intensively managed landscapes with little or no old forest (e.g., Thompson and Diller 2002). However, the U.S. Fish and Wildlife Service (2011b) noted that "the limited evidence available suggests that tree vole occupation of younger forest stands may be relatively short-lived (Diller 2010, pers. comm.) or intermittent (Hopkins 2010, pers. comm.)." Based on the natural histories of these species, reducing or fragmenting older forest could negatively affect them; but retention of older Douglas-fir (*Pseudotsuga menziesii*) trees and patches of well-connected canopy might ameliorate those impacts (Hayes 1996, Adam and Hayes 1998, USFWS 20011b). Clear-cutting and other severe disturbances should have the strongest effects on tree voles, due to the species' diet, nesting habitat associations, arboreal mode of travel, and apparently poor mobility (USFWS 2011c). However, for these same reasons, thinning could also negatively affect tree voles (Wilson and Forsman 2013).

Habitat Lost to Past Timber Harvesting (1800s to 1994)

Rigorous research has shown that the fitness of NSOs in the southern part of their range is highest in landscapes with large concentrations of suitable breeding habitat (reviewed above). The following review shows that the current availability of suitable breeding habitat was strongly affected by past timber harvesting, which removed or modified the majority of old forest that existed historically.

There do not appear to be any existing estimates of the amount of suitable NSO habitat that existed at the time of Euro-American settlement (early to mid-1800s). Nesting-roosting habitat for NSOs generally occurs in relatively old, structurally complex conifer forest (Blakesley 2004). It is therefore, reasonable to evaluate historical trends in old conifer forest as a rough proxy for changes in amounts of suitable NSO habitat (USFWS 1990). Estimates reviewed for the NSO's federal listing determination indicated that approximately 18-24 million acres of old forest existed in western Oregon and Washington and northwestern California during the early to mid-1800s (USFWS 1990). These estimates did not include all regions or potentially suitable forest types within the subspecies' range. After including all regions and conifer forests, Strittholt et al. (2006) estimated that about 40 million acres of old conifer forest (>150 yrs) existed at the time of Euro-American settlement (Table 2.1). This is a crude approximation, as it is based on incomplete historical information and an assumption that nearly all pre-settlement conifer forest was old (i.e., had not experienced severe disturbance within the previous 150 years). However, Strittholt et al. (2006) noted that their regional estimates closely matched previous estimates for similar regions and forest types, suggesting that they provide a reasonable baseline for comparison with contemporary forest conditions.

Using satellite imagery, Strittholt et al. (2006) estimated that 11.5 million acres of old conifer forest existed in 2000 (Table 2.1). Thus, an estimated 72% of old conifer forest was lost in the Pacific Northwest during the 19th and 20th centuries (Table 2.1). This estimated post-settlement loss of old conifer forest is similar to earlier estimates of 60-88% reviewed in the NSO's federal listing determination (USFWS 1990). Strittholt et al. (2006) did not provide estimates of old forest declines for California alone. Old conifer forests declined by 62% in the Klamath provinces ("Klamath-Siskiyou Forests") and 79% in the eastern Cascades provinces ("Eastern Cascades Forests"), both of which substantially overlap with the NSO's range in northern California. Other than in two small regions surrounding major population centers in Washington and Oregon, declines in old conifer forest were primarily caused by widespread intensive logging (Strittholt et al. 2006). Mountainous terrain in the Klamath and eastern Cascades limited timber harvesting compared with more accessible areas but major losses of old conifer forest nonetheless occurred in those areas (Strittholt et al. 2006). Strittholt et al. (2006) did not evaluate trends in amounts of old forest for the Redwood Province but other sources estimated that 85-96% of old redwood forest was lost to intensive timber harvesting during the post-settlement period (USFWS 1992).

Table 2.1: Area (ha) of Pacific Northwest ecoregions and estimated historical (early to mid-1800s) and contemporary (2000) extents of old (>150 yrs) and mature (50-150 yrs) conifer forest within them (from Strittholt et al. 2006).

	Cascade Mountain Leeward Forests	*North Cascades Forests*	*Puget Lowland Forests*	*Central Pacific Coastal Forests*	*Central & Southern Cascades Forests*	*Eastern Cascades Forests*	*Klamath-Siskiyou Forests*	*Willamette Valley Forests*
Ecoregion area	1,600,444	1,278,056	1,719,726	4,267,988	4,481,279	5,398,139	5,033,181	1,487,769
Historical old conifer area	960,279	766,844	1,289,794	3,627,790	3,361,005	3,238,883	2,516,625	371,942
Percentage of ecoregion	60	60	75	85	75	60	50	25
Current old conifer area	420,394	511,396	67,353	668,281	1,328,796	687,836	946,394	34,993
Percentage of historical old conifer	44	67	5	18	39	18	38	9
Percent change	−56	−33	−95	−82	−61	−79	−62	−91
Mature conifer area	285,441	203,994	229,634	683,098	899,266	947,215	1,239,586	270,362
Percentage of historical old conifer	30	27	18	19	27	25	49	73
Combined area	705,835	715,391	296,987	1,351,379	2,228,063	1,635,051	2,185,980	305,355
Percentage of historical old conifer	74	93	23	37	66	43	87	82

Strittholt et al. (2006) reported that the majority of old (78%) and mature (50%) conifer forest in 2000 existed on public lands. Nearly all of the remaining old redwood forest likewise occurs on public lands, such as California state parks. Much of the current difference among ownerships in amounts of older forest and suitable breeding habitat is due to past timber harvest rates. For example, loss of forest to harvesting during the 1970s through early 1990s occurred at substantially higher rates on private timberlands than on federal lands (e.g., >2 times faster in western Oregon) (Cohen et al. 2002, Staus et al. 2002, Healey et al. 2008). Nonetheless, an estimated 32% of suitable breeding habitat for NSOs occurred on non-federal lands at the time of the Northwest Forest Plan's implementation (1994), so conservation efforts for NSOs on non-federal lands remain important.

Although timber harvesting was substantially curtailed on federal lands following implementation of the Northwest Forest Plan (Healey et al. 2008, Kennedy et al. 2012; reviewed below), biologists noted the possibility that NSOs would continue to decline for many years due to lag effects of past harvesting (Courtney et al. 2004). The NSO has a relatively low reproductive rate and might therefore be unable to

immediately recover following removal or reduction of threats (Noon and Biles 1990). Furthermore, substantial recruitment of old forest and suitable nesting-roosting habitat could take multiple decades in areas that formerly experienced widespread intensive harvesting (Moeur et al. 2011; see below). Past harvesting could therefore be among the causes of continuing poor demographic performance of some NSO populations (Courtney et al. 2004). Forsman et al. (2011) noted, however, that some populations are declining on lands not previously subjected to widespread intensive timber harvesting (e.g., some National Parks). Based on this observation, they concluded that lag effects of past timber harvesting poorly explain continuing population declines. Yet, it is possible that historical timber harvesting does continue to contribute to population declines but that this effect is obscured by that of other stressors, such as competition with invasive barred owls (see Ch. 4). Regardless of potential lag effects of historical harvesting on NSOs, timber harvesting continues to occur at high rates on private lands and is one of the primary sources of habitat loss for the subspecies (Davis and Dugger 2011, Moeur et al. 2011, Kennedy et al. 2012; reviewed below).

Habitat Lost to Contemporary Timber Harvesting (1994-2007)

Davis and Dugger (2011) estimated NSO habitat trends following implementation of the Northwest Forest Plan. Their analyses were mostly limited to federal lands within the Plan area but they also estimated habitat trends on non-federal lands, as reported in the 2011 revised NSO recovery plan (USFWS 2011a). In addition to these analyses, the following review includes results of research by Moeur et al. (2011), which provide additional insight into recent habitat trends for NSOs on non-federal lands. This review does not include habitat trend estimates based on federal ESA Section 7 consultation records (Bigley and Franklin 2004, USFWS 2012b). These records provide a less consistent and complete data source than those used by Davis and Dugger (2011) (see Bigley and Franklin 2004). They may also overestimate habitat changes since they evaluate effects of planned projects, which may be greater than what is actually implemented (Bigley and Franklin 2004).

Davis and Dugger (2011) used remotely sensed (satellite imagery) and forest inventory plot vegetation data to model changes in habitat suitability for NSOs during the first 15 years of the Northwest Forest Plan (1994-2007 in California and 1996-2006 in Oregon and Washington). They modeled habitat suitability based on habitat attributes surrounding thousands of NSO pair locations. Suitable breeding habitat was defined as having both a probability of owl presence greater than expected based on random chance and environmental conditions typical of those found around nesting and roosting pairs. Habitat loss was defined as a change in suitability rank from suitable or highly suitable to marginal or unsuitable due to vegetation changes caused by forest disturbances. Davis and Dugger (2011) did not estimate recruitment of, or net changes, in breeding habitat. They felt that their remotely sensed data poorly captured the kinds of slow and subtle habitat changes that occur during development of intermediate-aged and older stands. However, Moeur et al. (2011) estimated trends in mature and old forests during the same time period, which could provide insight into net changes in breeding habitat for NSOs.

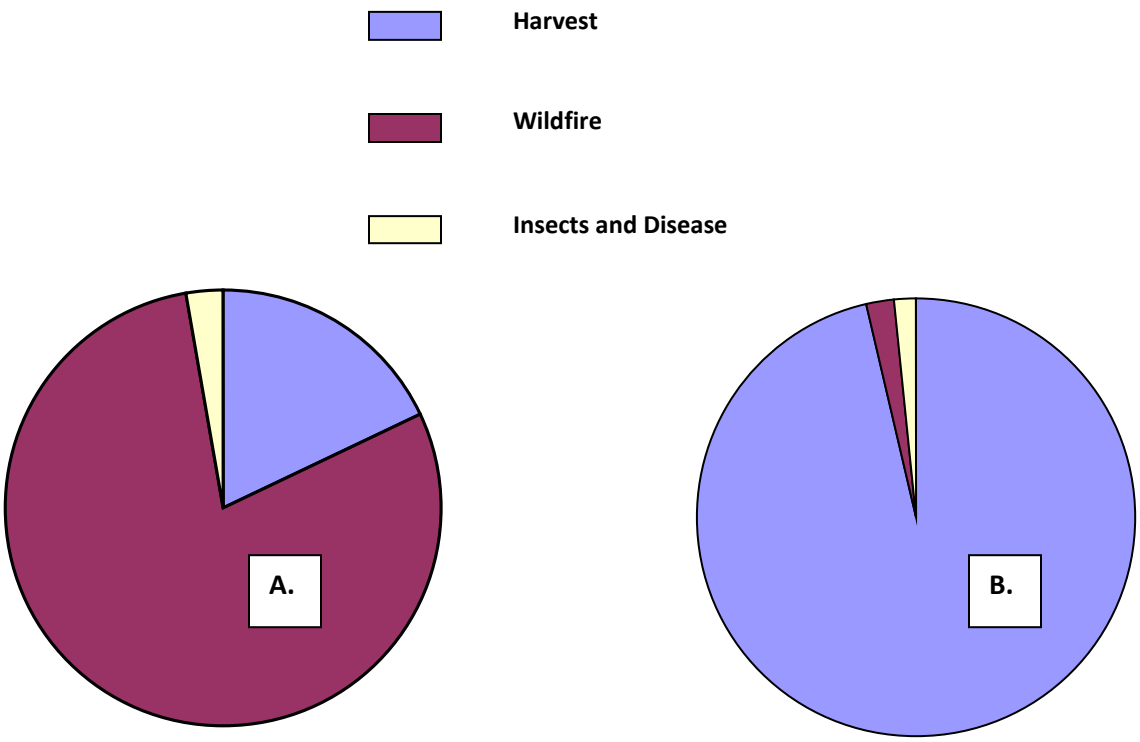
Table 2.2 shows estimated gross losses of suitable NSO breeding habitat to timber harvesting on federal and non-federal lands during the first 15 years of the Northwest Forest Plan (Davis and Dugger 2011, USFW 2011a). Timber harvesting was responsible for a gross loss of about 54,000 acres (0.6%) of suitable breeding habitat on federal lands. This loss likely had little rangewide effect on NSOs but could have impacted the subspecies at local or regional scales. For example, harvesting resulted in a 3% gross loss of suitable breeding habitat on federal lands in the California Cascades, where habitat was already relatively limited. Approximately 92% of total suitable breeding habitat lost to timber harvesting occurred on non-federal lands. In contrast with federal lands, nearly all estimated gross habitat loss on

non-federal lands was due to timber harvesting rather than natural disturbances (Figure 2.1; see Ch. 3). In just 11-13 years, timber harvesting caused an estimated rangewide gross loss of 625,600 acres (15%) of suitable breeding habitat on non-federal lands. The largest losses on non-federal lands occurred in Oregon (301,200 ac, 22%) and Washington (234,200 ac, 19%). Non-federal lands in California experienced lower gross losses of suitable breeding habitat to harvesting (90,200 acres, 6%). Nonetheless, losses in all three states were substantial given the short time frame during which they occurred and the likelihood that little of the loss was offset by recruitment of suitable breeding habitat during that period (see below).

Table 2.2: Estimated gross losses of suitable NSO breeding habitat on federal and non-federal lands due to timber harvesting during 1994-2007 in California and 1996-2006 in Oregon and Washington (adapted from Davis and Dugger 2011, USFWS 2011a).

State	Ownership	Province	1994/1996 Ac	Harvest Ac	Harvest %
California	**Federal**	CA Cascades	213,200	6,500	3.0%
		CA Klamath	1,489,800	4,400	0.3%
		CA Coast	145,400	300	0.2%
		CA Federal Total	**1,848,400**	**11,200**	**0.6%**
	Non-Federal		**1,556,700**	**90,200**	**5.8%**
	Combined		**3,405,100**	**101,400**	**3.0%**
Oregon	**Federal**	OR Coast Range	611,200	3,300	0.5%
		Western OR Cascades	2,258,700	13,900	0.6%
		Eastern OR Cascades	402,900	5,800	1.4%
		Willamette Valley	3,400	100	2.9%
		OR Klamath	985,000	6,800	0.7%
		OR Federal Total	**4,261,200**	**29,900**	**0.7%**
	Non-Federal		**1,382,400**	**301,200**	**21.8%**
	Combined		**5,643,600**	**331,100**	**5.9%**
Washington	**Federal**	Olympic Peninsula	763,100	500	0.1%
		Eastern WA Cascades	673,600	8,100	1.2%
		Western WA Cascades	1,283,000	3,700	0.3%
		Western WA Lowlands	24,700	400	1.6%
		WA Federal Total	**2,744,400**	**12,700**	**0.5%**
	Non-Federal		**1,258,900**	**234,200**	**18.6%**
	Combined		**4,003,300**	**246,900**	**6.2%**
Rangewide	**Federal**		**8,853,800**	**53,800**	**0.6%**
	Non-Federal		**4,198,000**	**625,600**	**14.9%**
	Combined		**13,051,800**	**679,400**	**5.2%**

Figure 2.1: Proportions of suitable breeding habitat loss attributed to harvesting, wildfire, and insects and diseases on (A) federal lands and (B) non-federal lands during 1994-2007 (adapted from Davis and Dugger 2011 and USFWS 2011a).



The USFWS (2011a) and Davis and Dugger (2011) did not describe regional habitat trends for non-federal lands. However, insight into regional habitat trends on non-federal lands can be obtained from trends in mature and old forest during the same time period. Moeur et al. (2011) reported substantial gross losses of mature and old forest (mean DBH ≥20 in) on non-federal lands during the first 15 years of the Northwest Forest Plan. The largest gross losses, in terms of acreage, occurred in the Western Washington Lowlands (387,200 ac, 49%), Oregon Coast Range (362,500 ac, 50%), and California Coast Range (259,000 ac, 35%). All provinces and states within the NSO's range experienced large proportional losses, ranging from 31% in the Eastern Washington Cascades to 48% and 52% in the Klamath and Eastern Cascades of Oregon. Confirming the results of Davis and Dugger (2011; Figure 2.1), Moeur et al. (2011) found that gross losses of mature and old forest on non-federal lands were almost entirely due to timber harvesting (also see Kennedy et al. 2012).

Moeur et al. (2011) reported that gross loss of mature and old forest was substantially offset by recruitment into that habitat class. They noted, however, that given the short length of the monitoring period (10-14 yrs), recruitment was "likely due to incremental stand growth over the 20-in diameter threshold, or from understory disturbances that removed smaller diameter trees and raised the average stand diameter above the threshold, rather than from an increase in forests of much larger and older trees." Thus, it is unlikely that there was substantial recruitment of suitable and highly suitable breeding habitat for NSOs during this time period. This conclusion is supported by Davis and Dugger (2011), who found that most of the detectable habitat recruitment during their monitoring period occurred in the marginal suitability class, which more closely resembled their definition for dispersal habitat than for breeding habitat. Even if all mature and old forest recruited during the first 15 years of the Plan provided suitable breeding habitat for NSOs, non-federal lands in California still experienced a net decline in area of mature and old forest during that period, and those in Washington and Oregon fared substantially worse (Moeur et al. 2011).

Future Harvesting in California

It is impossible to provide reliable projections of future timber harvesting or its effects on NSOs in California. Federal agencies have expressed support for widespread thinning to address wildfire risk on public lands in the state but there do not appear to be any projections of future harvest volume or effects on NSOs from these activities (USFS and BLM 1994, USFWS 2011a, 2012a). Documents associated with Habitat Conservation Plans for private timberlands in California project substantial impacts of harvesting on some ownerships and relatively low impacts on others. Many landowners, in the state, including some large industrial timber companies, conduct timber harvesting outside of Habitat Conservation Plans. The state requires evaluation of potential environmental impacts of all Timber Harvest Plans but both landowners and responsible agencies have used inconsistent methods for conducting these evaluations. For example, some entities have strictly adhered to the state's Forest Practice Rules (CAL FIRE 2014), others have relied on poorly described and vetted variants of those rules (e.g., "option g+"), and still others have opted to follow the Yreka or Arcata U.S. Fish and Wildlife Service Offices' (2009, 2011b) recommendations. Based on an in-depth review of research concerning the NSO's habitat and spatial relationships, the U.S. Fish and Wildlife Service Yreka Office (2009) recommended sweeping changes to NSO habitat retention guidelines in the Forest Practice Rules for California's northern interior. These recommendations are more scientifically supportable than are habitat retention guidelines in the Forest Practice Rules (CAL FIRE 2014), as they incorporate the large body of research of NSO-habitat relationships conducted since 1992 when guidelines in the Forest Practice Rules were created. In addition they were designed to enable CAL FIRE personnel lacking expertise with NSO-habitat relationships to properly determine if take would occur. However, the state

has not officially adopted these recommendations or any other changes that incorporate the tremendous body of research and biological expertise concerning NSO-habitat relationships developed since 1992 (USFW 2009). Furthermore, since 2008, when the US Fish and Wildlife Service largely ceased providing technical assistance with timber harvest reviews in northern California, relatively few Timber Harvest Plans have been reviewed by personnel with sufficient biological expertise to evaluate whether or not take will occur. Lacking reliable harvest and take projections, and barring a major change in the legal or regulatory framework protecting NSOs, there is currently no reason to conclude that timber harvest effects on NSOs in California will substantially decline in the near future.

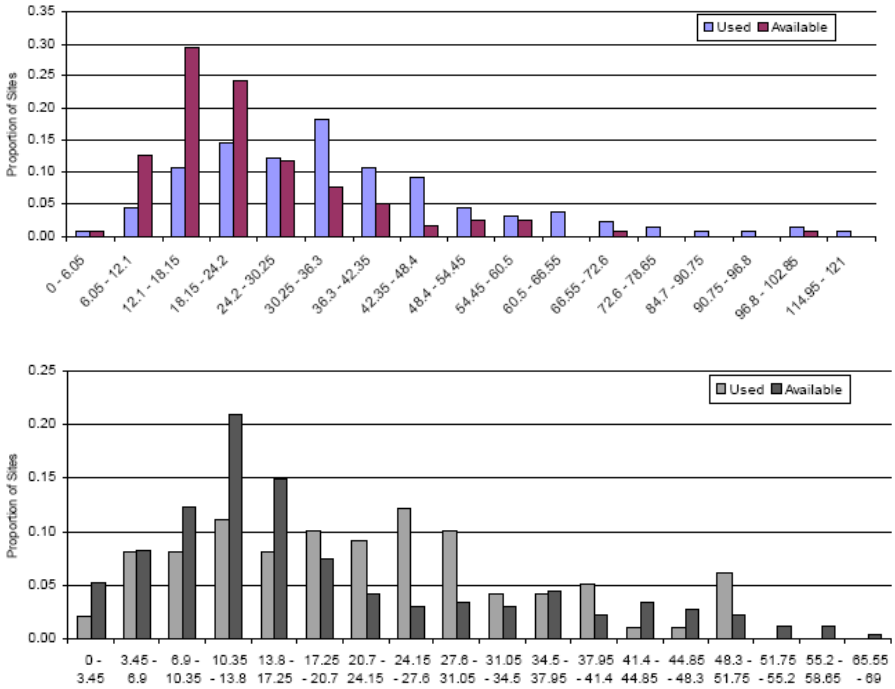
Acknowledgements

I am grateful to Ray Davis and Ken Hoffman for their insightful reviews of this chapter.

Appendix 2.1

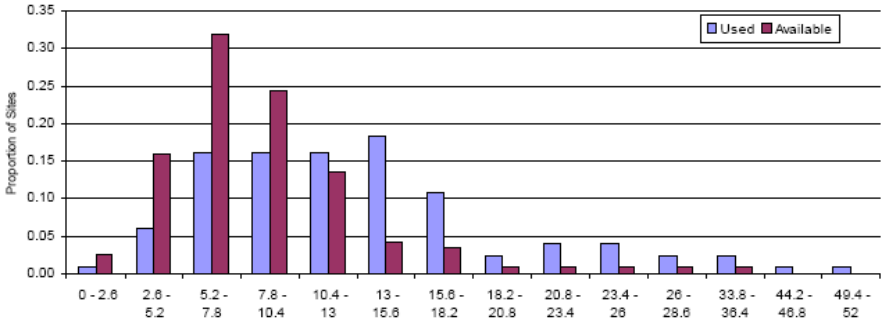
USFWS GNN (see USFWS 2011a) histograms showing use by NSOs versus availability of select habitat attributes at a landscape-scale (200 ha, 494 ac) on Mendocino Redwood Co. (left column) and Green Diamond Resource Co. lands (right column).

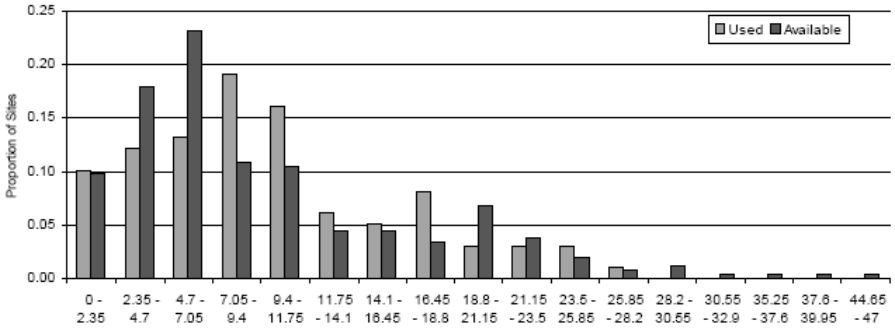
Live conifer trees per hectare ≥20 inches DBH:



Appendix 2.1 (continued)

Basal area of live conifers ≥20 inches DBH:

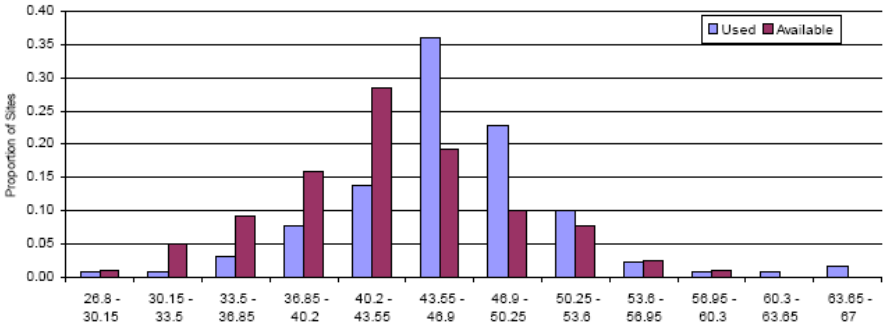


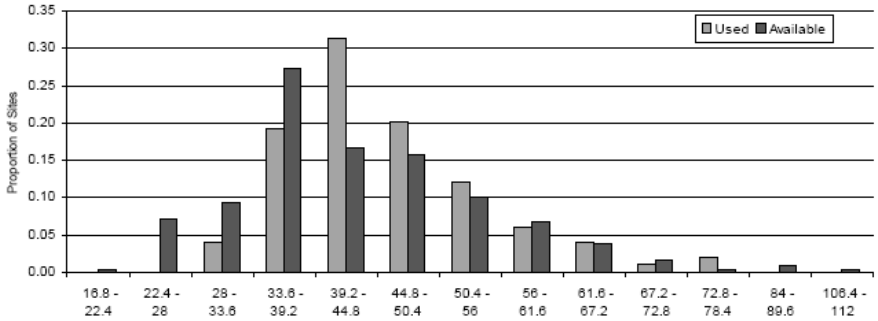


Appendix 2.1 (continued)

USFWS GNN (see USFWS 2011a) histograms showing use by NSOs versus availability of select habitat attributes at a landscape-scale (200 ha, 494 ac) on Mendocino Redwood Co. (left column) and Green Diamond Resource Co. lands (right column).

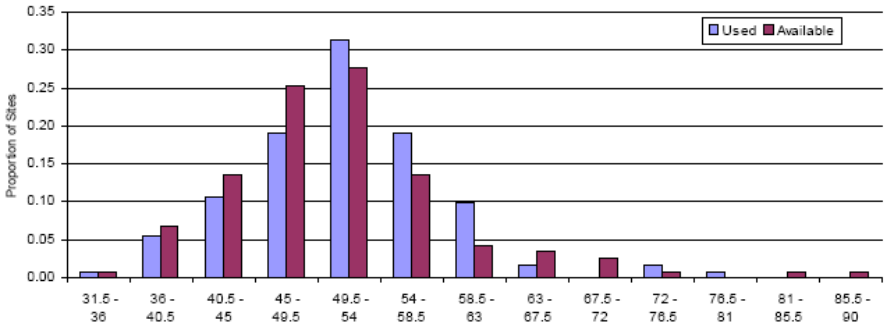
Basal area weighted mean diameter of all live conifers:

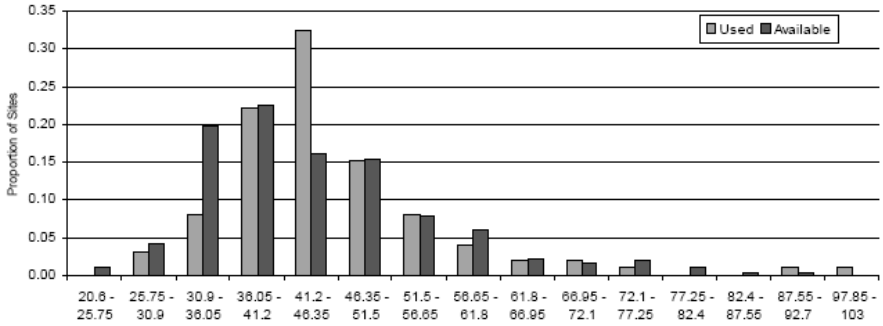




Appendix 2.1 (continued)

Basal area weighted stand age:

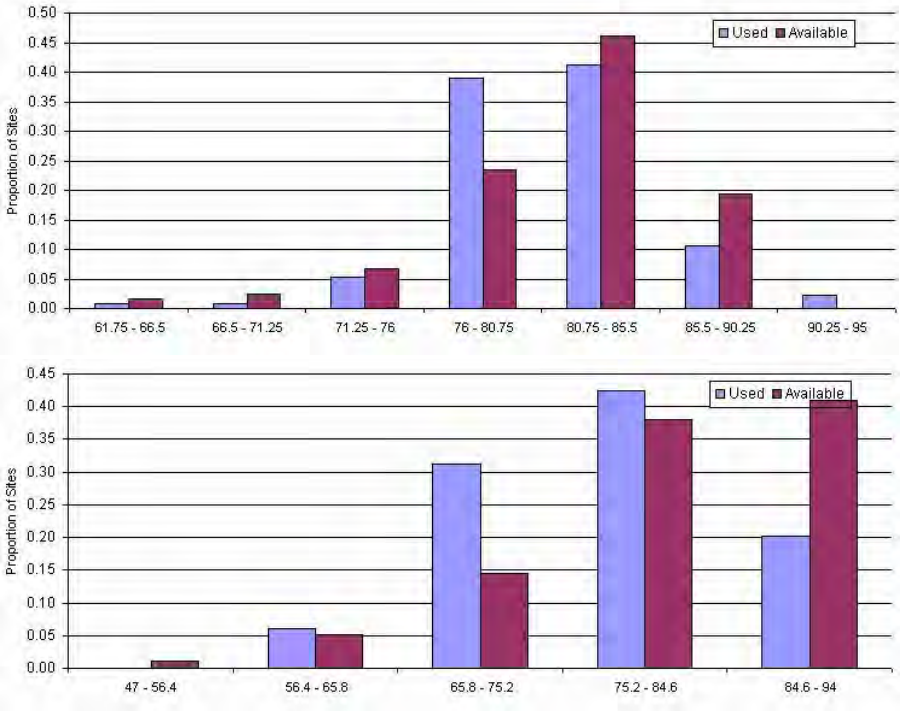




Appendix 2.1 (continued)

USFWS GNN (see USFWS 2011a) histograms showing use by NSOs versus availability of select habitat attributes at a landscape-scale (200 ha, 494 ac) on Mendocino Redwood Co. (left column) and Green Diamond Resource Co. lands (right column).

Canopy cover:



Appendix 2.2

"Deconstructed" habitat suitability modeling (see text) for NSOs in the Redwood Province showing mean (SD, CV) values of select habitat structural attributes at the 200 ha (494 ac) scale by relative habitat suitability rank (USFWS 2011a, unpubl. data).

Variable	Relative Habitat Suitability					
	Very Low	**Low**	**Med. Low**	**Med.**	**Med. High**	**High**
Strength of Selection*	-9.2	-2.9	-1.3	1.6	3.2	8.6
Percent of Region	16.3	24.5	26.2	22.4	9.7	0.9
Nesting-Roosting (ha)	57.9 (43.2, 75)	69.4 (40.8, 59)	79.9 (37.3, 47)	87.6 (33.6, 38)	94.3 (31.1, 33)	105.5 (30.8, 29)
Canopy Cover All Trees (%)	71.2 (23.2, 33)	75.2 (20.7, 28)	78.9 (18.1, 23)	81.0 (16.2, 20)	82.1 (15.5, 19)	82.9 (15.7, 19)
Canopy Cover Conifer (%)	43.9 (31.8, 72)	48.8 (30.0, 61)	53.4 (28.3, 53)	57.4 (27.2, 47)	61.4 (26.5, 43)	64.6 (26.4, 41)
BA Conifers ≥50 cm (m^2/ha)	10.6 (20.7, 195)	12.5 (23.0, 184)	14.1 (24.8, 176)	15.2 (25.6, 168)	17.6 (30.1, 171)	25.2 (45.9, 182)
BA Live Trees ≥75cm (m^2/ha)	7.3 (17.6, 241)	8.5 (20.1, 236)	9.3 (21.8, 234)	9.3 (22.4, 241)	10.4 (27.1, 261)	17.0 (44.0, 259)
Density Trees ≥50 cm (no./ha)	32.3 (37.3, 115)	36.1 (38.4, 106)	39.8 (40.0, 101)	42.5 (42.1, 99)	45.4 (44.5, 98)	50.0 (46.1, 92)
Density Trees ≥75 cm (no./ha)	8.2 (14.8, 180)	9.2 (15.6, 170)	9.9 (16.0, 162)	10.0 (15.5, 155)	10.4 (15.3, 147)	12.8 (16.8, 131)
Density Conifers ≥50 cm (no./ha)	22.1 (34.7, 157)	25.5 (36.4, 143)	28.9 (38.3, 133)	32.6 (40.7, 125)	37.3 (43.6, 117)	43.1 (45.6, 106)
Density Conifers ≥ 75 cm (no./ha)	6.6 (14.5, 220)	7.6 (15.4, 203)	8.4 (15.7, 187)	8.7 (15.2, 175)	9.4 (15.1, 161)	12.0 (16.7, 139)
Density Conifers ≥100 cm (no./ha)	2.5 (7.7, 308)	2.9 (8.4, 290)	3.2 (8.8, 275)	3.1 (8.3, 268)	3.2 (8.5, 266)	4.7 (10.4, 221)
Mean DBH Conifers by BA (cm)	42.8 (34.5, 81)	48.5 (35.5, 73)	51.7 (35.4, 68)	52.1 (34.0, 65)	52.9 (36.1, 68)	60.8 (51.1, 84)
QMD Dominant/Codominant Conifers (cm)	35.7 (29.1, 82)	40.2 (29.9, 74)	42.7 (29.7, 70)	42.6 (28.3, 66)	42.7 (29.7, 70)	48.1 (41.5, 86)

*Calculated as the proportion of activity centers in a habitat suitability class divided by the proportion of the modeling region in that class.

Ch. 3: Wildfire and Salvage Logging

Introduction

Recent status reviews have identified wildfire as a primary threat to the recovery of the NSO (Courtney et al. 2004, Davis et al. 2011, USFWS 2011a). Much of this concern was based on recent loss of suitable breeding habitat to wildfires and to the risk of extensive severe fires occurring in the future (Davis and Dugger 2011, USFWS 2011a). Other researchers and stakeholders have questioned the scientific basis of claims that wildfires pose a threat to NSOs and have expressed distrust of agency recommendations for widespread use of forest thinning to reduce fire risk (e.g., Hanson et al. 2009, Heiken 2010, DellaSala et al. 2013).

There is currently limited information with which to evaluate responses of spotted owls to wildfires and post-fire salvage logging. This research suggests that wildfires have variable and complex effects on the species (Table 3.1; reviewed below). This is unsurprising given differences in wildfires, research methods, study areas, and spotted owl subspecies and populations. Nonetheless, patterns are evident in the literature concerning spotted owl responses to wildfires and salvage logging and these can be evaluated in light of the species' habitat and prey relationships. Currently available research suggests that low-to-moderate, mixed-severity, or patchy wildfires have limited effects on spotted owls (Table 3.1). In fact, such fires may benefit NSOs in the southern portion of their range by contributing to landscape-level habitat heterogeneity associated with high fitness (Franklin et al. 2000). In contrast, large-scale severe (stand-replacing) wildfires appear to have strong negative effects on spotted owls (Table 3.1; reviewed below). This likely occurs when fires excessively modify, reduce, or fragment concentrations of suitable nesting, roosting, and foraging habitat needed for survival and reproduction (Franklin et al. 2000, Dugger et al. 2005, Schilling et al. 2013; reviewed below and in Ch. 2). Negative effects of extensive severe wildfires appear to be exacerbated by post-fire salvage logging, which structurally simplifies burned areas and removes important habitat legacies for prey (Clark 2007, Lee et al. 2012, 2013, Clark et al. 2013, Comfort 2013; reviewed below).

Regardless of scientific uncertainty concerning spotted owl responses to wildfire, it is clear that recent large wildfires have caused tremendous loss, degradation, and fragmentation of suitable breeding habitat for NSOs on federal lands (Davis and Dugger 2011, USFWS 2011a; also see Healey et al. 2008, Moeur et al. 2011). This is cause for concern because recovery of the subspecies largely relies on habitat protection on federal lands (USFWS 2011a). Furthermore, much of the climate change research indicates that wildfires will be an increasing source of large-scale habitat change in California and other western states during coming decades (Westerling et al. 2006, Lenihan et al. 2008, Westerling and Bryant 2008, Littell et al. 2009, Moritz et al. 2012, Stavros et al. 2014). These concerns have prompted ecologists and federal agencies to advocate widespread forest thinning and other forms of active management to reduce wildfire risk within the range of the NSO (USFS and BLM 1994, USFWS 2008, 2011a, 2012a, Franklin and Johnson 2012). However, the limited information currently available suggests that spotted owls often respond negatively to forest thinning in the short-term (reviewed in Hansen and Mazurek 2010, USFWS 2011a; see Ch. 2); and possibly in the long-term as well (Matthews et al. 2008, Tempel et al. *in press*). Further research is needed to determine how best to balance

potential tradeoffs in objectives for NSO conservation and fuels reduction at multiple spatial and temporal scales. Currently available information suggests that spotted owls tolerate and possibly benefit from low severity, mixed severity, or patchy fire, suggesting that prescribed fire and allowing wildfires to burn under favorable conditions is compatible with conservation objectives for the species (Bond et al. 2002, 2009, Roberts and van Wagtendonk 2006, Roberts et al. 2011, Keane et al. 2011, 2012, Lee et al. 2012, 2013, Comfort 2013, Eyes 2014).

Wildfire Effects on Spotted Owls

Indirect Evidence

Research of associations between landscape-scale habitat attributes and the demography and presence of NSOs has consistently found that the subspecies benefits from some form of habitat heterogeneity in the southern portion of its range (e.g., ecotones or edges between different vegetation classes) (Franklin et al. 2000, Zabel et al. 2003, Olson et al. 2004, Dugger et al. 2005, Carroll and Johnson 2008, Diller et al. 2010, Schilling et al. 2013; reviewed in Ch. 2, including studies' definitions of spotted owl habitat). Yet, these same studies have also strongly demonstrated the importance of large concentrations of suitable breeding habitat around activity centers (reviewed in Ch. 2). Based on this research, wildfires likely have positive effects on NSOs in California when they contribute to beneficial forms of habitat heterogeneity and negative effects when they substantially reduce or degrade suitable habitat around breeding season activity centers. Extensive stand-replacing wildfires have the potential to remove or fragment core concentrations of suitable breeding habitat across multiple NSO territories. These fires, therefore, have the greatest likelihood of substantially impacting NSO populations. Smaller, less severe, or patchy wildfires may impact fewer NSO territories and have weaker negative effects on populations, burn in a manner that contributes to beneficial forms of habitat heterogeneity, or have variable effects among territories.

Direct Evidence

Several studies have investigated responses of NSOs to wildfires (Table 3.1). These studies provide crucial information for evaluating wildfire as a potential threat to the subspecies. However, their inferences are limited due to small sample sizes and short time frames in all cases, the confounding effects of post-fire salvage logging in one case, and pooling of data from all three spotted owl subspecies in another case (Table 3.1; see below). In order to supplement these studies, research of wildfire effects on California spotted owls (*S. o. occidentalis*; CSOs) and Mexican spotted owls (*S. o. lucida*; MSOs) is also included in the following review (Table 3.1). Because inferences from these studies are likewise limited, and given differences among fires, spotted owl subspecies and populations, and research methods, each project is reviewed as a "case study". Relatively thorough descriptions of these studies allow identification of patterns in the literature, which could provide insights into general effects of wildfires on the species.

Table 3.1: Apparent effects of wildfires on spotted owls. See text for additional descriptions of study methods and findings.

Response Metric	Study†	Subspecies	Location*	Apparent Effect**	Notes/Caveats
Survival	*Bond et al. 2002*	NSO, CSO, MSO	CA, AZ, NM	0	Only one post-fire survey season
	Clark et al. 2011	NSO	OR KLA	-	Likely cumulative effect of timber harvesting, severe fire, and salvage logging
Productivity	Gaines et al. 1997	NSO	E WA CAS	0	Apparently no decline but possibly obscured by low reproduction year across population; Possibly lower total reproduction in burned landscapes due to lower pair occupancy; Only one post-fire season
	Bond et al. 2002	NSO, CSO, MSO	CA, AZ, NM	0	Only one post-fire season
	Clark 2007	NSO	OR KLA	0	Apparently no decline but low statistical power; Possibly lower total reproduction in burned landscapes due to lower pair occupancy
	Roberts and van Wagtendonk 2006	CSO	CA SIERRA	+	Apparent higher productivity by four pairs nesting in low-to-moderate severity burns than by 18 pairs in unburned areas
Site Fidelity	*Bond et al. 2002*	NSO, CSO, MSO	CA, AZ, NM	0	Site fidelity similar to other studies
Occupancy	Elliot 1985	CSO	CA COAST	-	Apparent abandonment by two pairs
	Gaines et al. 1997	NSO	E WA CAS	-	Post-fire occupancy was lowest found during five-year study; Only one post-fire season
	Jenness et al. 2004	MSO	AZ, NM	-	Near-significant negative trend; Pooled all fire types and severities
	Keane et al. 2011, 2012	CSO	CA SIERRA/CAS	-/0	Extensive high severity fire apparently had a strong negative effect; Extensive low severity fire apparently had a neutral or weak negative effect; Possibly confounded by salvage logging
	Roberts et al. 2011	CSO	CA SIERRA	-	Modeled-occupancy lower in burned areas but not statistically analyzed; Pooled all fire types and severities
	Lee et al. 2012	CSO	CA SIERRA	0	Similar occupancy at burned vs. unburned
	Lee et al. 2013	CSO	SO CA	-/0	Similar occupancy at burned vs. unburned; Significant reduction with extensive high severity fire in core area
	Clark et al. 2013	NSO	OR KLA	-	Cumulative effect of timber harvesting, severe fire, and salvage logging
	Tempel et al. In Press	CSO	CA SIERRA	-	Site colonization probability negatively associated with area of wildfire; Relatively large sample size and long time frame
Home Range	Clark 2007	NSO	OR KLA	-	Larger home ranges post-fire
	Bond et al. 2013	CSO	CA SIERRA	0	Similar home range sizes to unburned areas
Roosting	King et al. 1997	NSO	E WA CAS	-	Apparent avoidance of moderate and severe burns
	Bond et al. 2009	NSO	CA SIERRA	-	Significant avoidance of moderate and severe burns during breeding season
Foraging	Clark 2007	NSO	OR KLA	+	Apparent weak selection of moderately burned suitable habitat; Possible weak selection for severely burned suitable habitat; Very low use and availability of both moderately and severely burned suitable habitat
	Bond et al. 2009	NSO	CA SIERRA	+	Significant selection of severe burns
	Eyes 2014	CSO	CA SIERRA	-/+	Preference for edges created by fire (particularly high contrast); Avoidance of severely burned areas
Roosting and Foraging	Comfort 2013	NSO	OR KLA	-/+	Preference for small patches of severely burned/salvage logged and avoidance of larger patches; Weak preference for low contrast edges created by fire

†Peer-reviewed publications shown in italics. * Locations: California Klamath (CA KLA); Eastern Washington Cascades (E WA CAS); Oregon Klamath (OR KLA); California, Arizona and New Mexico (CA, AZ, NM); California Central Coast Range (CA COAST); California at margin of northern Sierra Nevada and southern Cascades (CA SIERRA/CAS); California Sierra Nevada (CA SIERRA); southern California San Bernardino and San Jacinto Mountains (SO CA). **Apparent Effect: negative (-), positive (+), neutral (0), varied with fire severity and/or scale (/)—see Notes column and text for further explanations.

Survival

Wildfires may influence spotted owl survival in both the short- and long-term. For example, spotted owls, like other wildlife, could be injured or killed by smoke during fires (Singer and Schullery 1989, Smith 2000). Due to their poor mobility, young spotted owls with undeveloped flight feathers may be at particular risk of mortality during wildfires (Smith 2000). In addition to potential immediate effects, extensive moderate or severe wildfires might influence spotted owl survival over the longer-term by modifying habitat for roosting, foraging, or prey (see below).

Only two studies are currently available for evaluating effects of wildfires on spotted owl survival rates (Bond et al. 2002, Clark et al. 2011; Table 3.1). Bond et al. (2002) reported that 18 of 21 (86%) marked spotted owls were resighted one year after wildfires occurred in California, Arizona, and New Mexico. This minimum survival rate was similar to survival estimates found by long-term studies of the three spotted owl subspecies in unburned landscapes (Seamans et al. 1999, Franklin et al. 2000, W.S. LaHaye unpubl. data). Of the eight territories for which fire severity was mapped, two experienced severe fire within 50-88% of their areas, two experienced 36-50% severe fire, and the remaining four experienced <36% severe fire. Thus, mixed severity wildfires did not appear to have a substantial effect on spotted owl survival in this study one year post-fire.

Clark et al. (2011) found evidence of a negative effect of wildfires and/or post-fire salvage logging on survival of 23 NSOs in the Oregon Klamath Province. Severe fire and/or post-fire salvage logging occurred in 30% and 41% of suitable NSO habitat in the two study areas (suitability score >25: Davis and Lint 2005 [essentially nesting-roosting-foraging habitat; QMD generally > ca. 12 in]). Estimated mean annual survival rates for NSOs located inside fire perimeters (0.69) and apparently displaced by fires and post-fire salvage logging (0.66) were lower than in areas just outside the fire perimeters (0.85) and in an unburned reference study area in the neighboring southern Cascades (0.85: Anthony et al. 2006). The degree to which post-fire salvage logging in the study areas influenced NSO survival rates is unknown. The study's occupancy analyses indicated that pre-fire timber harvesting, high severity wildfire, and post-fire salvage logging cumulatively impacted NSOs through reductions of suitable breeding habitat (Clark et al. 2013; see below).

The findings of Bond et al. (2002) and Clark et al. (2011) regarding effects of moderate-to-extensive amounts of severe wildfire (>36% of the area in half of the territories: Bond et al. 2002; 30-41% of the study area: Clark et al. 2011) appear to be contradictory. Several factors may explain this apparent inconsistency. The most obvious difference between the studies is that the areas studied by Clark et al. (2011) experienced post-fire salvage logging while those studied by Bond et al. (2002) did not. The limited available information suggests that salvage logging negatively affects spotted owls (reviewed below). Additionally, the populations studied by Clark et al. (2011) may have been particularly sensitive to habitat loss to wildfires due to intensive pre-fire timber harvesting across a checkerboard ownership. It should also be noted that Bond et al. (2002) only examined wildfire effects one year post-fire. Fire injuries and post-fire outbreaks of insects and pathogens can continue to result in tree mortality for up to several years after a wildfire (Ryan and Amman 1996, Gaines et al. 1997, Hood et al. 2007).

Reproduction

The spotted owl is a relatively long-lived species (up to 12-17+ yrs in the wild: Gutiérrez et al. 1995) that exhibits a bet-hedging life history strategy (Noon and Biles 1990, Franklin et al. 2000). This means that individuals often forego breeding during poor environmental conditions in order to maximize their chance of surviving and reproducing in the future. Given the species' life history strategy, spotted owl reproductive rates are likely sensitive to environmental changes, including those brought about by wildfires. However, annual fluctuations in spotted owl reproduction caused by variation in weather, prey populations, or breeding condition could obscure effects of wildfires or other factors on reproduction (e.g., Franklin et al. 2000).

At least four studies have examined potential effects of wildfires on spotted owl reproduction (Gaines et al. 1997, Clark 2007, Bond et al. 2002, Roberts and van Wagtendonk 2006 [also Roberts 2008]; Table 3.1). None of these studies found substantive evidence of a wildfire-induced decline in reproduction by the species and one indicated a potentially positive effect. In the eastern Washington Cascades, Gaines et al. (1997) found little or no difference in productivity (number of young per pair) at burned (0.2; n = 5 or 6/ yr) and unburned sites (0.3; n = 13-17/yr) one year after a predominantly moderate to severe wildfire. However, the post-fire survey season clearly occurred during a poor reproduction year, potentially making it difficult to detect a difference between burned and unburned sites. Clark (2007) found no significant differences in productivity in burned areas in the Oregon Klamath Province (n = 31 territories) and an unburned study area in the neighboring southern Cascades (Anthony et al. 2006). He noted, however, that his study likely lacked the statistical power to detect a difference if one occurred. Bond et al. (2002) found that seven pairs of spotted owls produced an average of 1.0 offspring during a single breeding season following wildfires in California, Arizona, and New Mexico. This was similar to productivity rates found in unburned areas during long-term studies of the three spotted owl subspecies (Seamans et al. 1999, Franklin et al. 2000, W.S. LaHaye unpubl. data). In the Sierra Nevada of California, Roberts and van Wagtendonk (2006) reported that four CSO pairs in areas that experienced extensive low-to-moderate severity fire produced eight fledglings, compared with 17 fledglings produced at 18 nests in unburned areas (i.e., burned = 18% of pairs and 32% of fledglings). The authors did not statistically analyze the apparent positive effect of low-to-moderate severity fire on productivity (note: it is possible that Roberts [2008] statistically analyzed this effect but I was unable to obtain a copy of her dissertation for inclusion in this synthesis).

Currently available studies suggest that wildfires generally have minimal short-term effects on spotted owl reproduction and that primarily low-to-moderate severity fire could positively affect reproduction (Gaines et al. 1997, Bond et al. 2002, Roberts and van Wagtendonk 2006, Clark 2007). As noted above, it might be difficult to capture fire effects on spotted owl reproduction (whether positive or negative) during short-term studies, particularly with only a single year of post-fire data (Franklin et al. 2000). In addition, it is possible that solely comparing productivity (e.g., offspring per pair) in burned and unburned areas could obscure a change in total reproduction in burned areas. Studies in Washington and Oregon reported post-fire declines in occupancy by pairs, suggesting that extensive severe fires can reduce reproductive opportunities for spotted owls (Gaines et al. 1997, Clark 2007; see below).

Occupancy

Potential wildfire effects on NSO population rates are most directly evaluated with measures of survival and reproduction. However, occupancy data are often more logistically and economically feasible to collect than are demographic data and could provide an early indication of population trends (MacKenzie 2005, Olson et al. 2005). Spotted owl occupancy is sensitive to environmental factors (Blakesley et al. 2005, Olson et al. 2005) so it is a potentially valuable measure of wildfire effects on the species. Nonetheless, occupancy data must be interpreted carefully since they can be strongly influenced by survey effort, analytical methods, and the presence of barred owls (*Strix varia*) (Olson et al. 2005).

I evaluated 10 studies of wildfire effects on spotted owl occupancy (Table 3.1). As summarized below and in Table 3.1, eight of these provided evidence of a negative effect of either severe wildfires or wildfires in general.

Two studies indicated potentially negative effects of wildfires on spotted owl occupancy but included few territories (Elliot 1985, Gaines et al. 1997). In Monterey County, California, informal yearly surveys suggested that two pairs of CSOs abandoned their territories for at least four years following a wildfire (Elliot 1985). The author did not describe the fire other than noting that it was extensive and caused substantial damage to understories and oaks in the previously occupied areas. In the eastern Washington Cascades, Gaines et al. (1997) found that two of six NSO sites were occupied one year after a predominantly moderate to severe wildfire. This was the lowest occupancy rate found during the five-year study period.

Two studies found statistically weak evidence of a negative effect of fire on spotted owl occupancy, but their methods may have precluded detection of stronger effects (Jenness et al. 2004, Roberts et al. 2011). Jenness et al. (2004) found a statistically insignificant tendency (p = 0.11) for higher occupancy rank (in ascending order: no owls, singles, pairs, reproductive pairs) in unburned sites than in paired burned sites in Arizona and New Mexico (paired sites were close to each other and had similar habitat and topography). Of the 29 paired-site comparisons, 14 (48%) had a higher occupancy rank in unburned sites, 6 (21%) had a higher rank in burned sites, and 9 (31%) were tied. In the Sierra Nevada of California, Roberts et al. (2011) found lower occupancy rates for CSOs in burned areas than in unburned areas, but the difference was not statistically analyzed (modeled-occupancy = 0.46 in burned and 0.72 in unburned). Modeling by both studies indicated that spotted owl occupancy was more strongly influenced by habitat composition or structure than by whether or not fire had recently occurred in territories. However, both studies may have underestimated the impacts of severe wildfires due to pooling of diverse fire types and severities for analysis (including prescribed fires, wildfires, and wildfires allowed to burn under prescribed conditions).

Another study found stronger evidence of a negative effect of wildfires on occupancy by CSOs. Tempel et al. (*in press*) collected occupancy data at 74 CSO territories during long-term (1993/1997-2012) density and regional studies in the central Sierra Nevada. Twelve (16%) territories experienced wildfire during the studies, including nine (12%) that were affected by a mostly-severe wildfire in 2001. The best performing model explaining site colonization during the studies included area of wildfire within estimated territories (988 ac). In this model, wildfire

had a strong negative effect on the probability of colonization, even though relatively few territories were affected by fire. Only three site colonization events were observed in burned territories during six post-fire years. However, CSOs exhibited variable responses to wildfire. For example, five of the territories affected by a largely severe wildfire in 2001 were occupied every year post-fire.

Two studies found evidence of strong declines in occupancy in areas recently burned by extensive severe wildfire but both may have been confounded by post-fire salvage logging (Keane et al. 2011, 2012, Clark et al. 2013). In southwestern Oregon, Clark et al. (2013) examined how extensive wildfires and subsequent salvage logging affected occupancy dynamics of NSO pairs. In their first analysis, the authors compared pre- and post-fire occupancy dynamics in a burned study area in the Oregon Klamath Province (n = 22) to those in an unburned area in the nearby southern Cascades (Anthony et al. 2006). Combined, high severity fire and salvage logging removed or modified 26% of suitable habitat (suitability score >25: Davis and Lint 2005 [essentially nesting, roosting, and foraging habitat; generally QMD > ca. 12 in DBH in study area] in landscapes surrounding NSO activity centers in this area. The burned and salvage-logged study area experienced a 64% reduction in site occupancy during the post-fire period, compared with a 25% reduction in the unburned study area (difference not statistically analyzed). In the second analysis, the authors examined possible effects of severe wildfire and salvage logging on occupancy dynamics in 40 territories located in three burned study areas in the Oregon Klamath Province. In these areas, 19-26% of suitable habitat was burned at high severity and/or salvage logged. During the study's three-year post-fire period, site extinction probabilities were as high as 72% in two combined study areas and 92% in the third area. Site extinction probabilities in the burned study areas were best explained by a model that included extents of high severity fire, salvage logging, and early seral forest. Models that included these variables separately were not competitive with the model containing all three variables, suggesting that NSO occupancy declined due to cumulative habitat loss from severe fire and pre- and post-fire timber harvesting (see Table 6 in Clark et al. 2013). The relative influence of these factors on occupancy is unknown, but the role of severe wildfire cannot be dismissed. For example, the highest extinction probability (92%) occurred in a study area with little salvage logging (<2%) of previously suitable habitat.

Keane et al. (2011, 2012) estimated occupancy of CSOs in two recently burned study areas near the margin of the Sierra Nevada and southern Cascades of California. One wildfire complex, and an unreported amount of post-fire salvage logging, resulted in an almost complete loss of potentially suitable CSO habitat in the area (forest with mean canopy cover $\geq$40% and mean DBH $\geq$11 comprised 70% of the area pre-fire vs. 6% post-fire). Pre-fire occupancy in this study area was unknown but the Forest Service identified 23 CSO activity centers in the area prior to the fires. Rigorous landscape survey coverage by Keane et al. (2011, 2012) confirmed occupancy in only one territory within the fire perimeter during each of two post-fire years, whereas approximately seven to nine territories were found post-fire in a surrounding one-mile survey buffer (total survey area and buffer survey area sizes not reported). The other area studied by Keane et al. (2011, 2012) primarily burned at low severity (ca. 60% of the area). Pre-fire occupancy was likewise unknown in this area but Forest Service pre-project surveys indicated the presence of about 10 territories. Surveyors confirmed occupancy of six territories in this area during the first and second years post-fire. However, the number of occupied

territories in this study area could have been higher during the second post-fire season as survey effort was hindered by safety concerns associated with extensive illegal marijuana cultivation (see Ch. 5 for further discussion of this topic). While the study's findings are preliminary and may have been influenced by post-fire salvage logging, they suggest that effects of large wildfires on CSOs are dependent on the extent of high severity wildfire.

Another study provided further evidence that effects of wildfires on spotted owl occupancy depend on the extent and location of high severity wildfire. Lee et al. (2013) compared occupancy dynamics of CSOs in 71 recently burned sites and 97 unburned sites in the San Bernardino Mountains and San Jacinto Mountains of southern California. An average of 23% of the forest within burned "core areas" (500 ac around activity centers) experienced high severity fire (this percent is based on an assumption that the amount of pre-fire forest in burned core areas was the same as that reported for burned and unburned core areas combined). Mean annual probability of occupancy was 0.48 in unburned sites and 0.31 in burned sites. This difference was not statistically significant. However, Lee et al. (2013) did detect a statistically significant negative effect on occupancy when high severity fire burned more than 125 acres of forest within estimated core areas.

Two studies found that wildfires had little or no effect on spotted owl occupancy (Bond et al. 2002, Lee et al. 2012). Bond et al. (2002) calculated site fidelity for spotted owls in 11 territories burned by wildfires in California, Arizona, and New Mexico. The fires burned most of the area within each estimated territory (territory size = half the nearest neighbor distance in each study area, based on previous studies). Half of the eight territories for which fire severity was mapped primarily burned at low to moderate severity (<36% high severity) and the other half experienced moderate to extensive amounts of severe fire (36-88%). Of 21 color-banded owls in the study, 18 (86%) were resighted the year after the fires and 16 (89%) of these were located in their pre-fire territory. Site fidelity in this study was comparable to that in long-term studies of the three subspecies in unburned areas (Seamans et al. 1999, Franklin et al. 2000, W.S. LaHaye unpubl. data). In the Sierra Nevada, Lee et al. (2012) compared post-fire occupancy in 41 recently burned and 145 unburned historical CSO territories. An average of 32% of forest in burned territories experienced high severity fire. The authors found no significant association between CSO occupancy and whether or not territories had recently experienced wildfire within a 494-acre circle around activity centers (mean occupancy was 0.76 at unburned sites and 0.80 at burned sites).

The studies reviewed above are not directly comparable due to differences in methods, spotted owl subspecies and populations, fire extents and severities, and the presence or absence of post-fire salvage logging. The preponderance of evidence suggests that spotted owls in dry, fire-prone forests are generally resilient to wildfires (Bond et al. 2002, Jenness et al. 2004, Roberts and van Wagtendonk 2006, Keane et al. 2011, 2012, Roberts et al. 2011, Lee et al. 2012, 2013). However, wildfires that severely burn large areas of potentially suitable habitat can substantially impact spotted owl occupancy, particularly when they occur in breeding-season core areas (Elliot 1985, Gaines et al. 1997, Clark et al. 2013, Keane et al. 2011, 2012, Lee et al. 2013, Tempel et al. *in press*). Post-fire salvage logging appears to increase the negative effects of extensive severe wildfires on spotted owl occupancy, most likely by reducing suitability of burned areas for prey and foraging (Lee et al. 2012, 2013, Clark et al. 2013, Comfort 2013; reviewed below).

Home Range Size and Habitat Use

Changes in the behavior of individual spotted owls may provide insight into the mechanisms by which wildfires affect populations. For example, post-fire changes in home range size may reflect wildfire effects on spotted owl energy budgets through changes in travel distances and prey availability. Changes in energy intake and output could, in turn, influence survival, reproduction, and occupancy of spotted owls. Patterns of habitat use may also be informative. For example, selection or avoidance of burned areas may reflect changes in availability of prey or roosting habitat, which could, in turn, influence occupancy, reproduction, or survival of spotted owls.

To my knowledge, only two studies have evaluated spotted owl home range sizes in relation to wildfires (Clark 2007, Bond et al. 2013; Table 3.1). Clark (2007) found that annual home range sizes of NSOs inside two fire perimeters in the Oregon Klamath Province were larger after wildfires than before them (n = 14 owls pre-fire and 20 post-fire). He attributed this difference to owls expanding their home ranges in response to habitat fragmentation caused by severe wildfire and post-fire salvage logging. This hypothesis is supported by other research in the region, which found that NSOs had larger home ranges in fragmented forests than in areas with larger, more intact patches of habitat (Carey et al. 1992, Schilling et al. 2013). Another study in the region suggested that the energetic cost of increased travel in fragmented forest was greater than the energetic benefit of increased access to prey associated with early-successional habitats (Carey and Peeler 1995).

Bond et al. (2013) compared the breeding season home ranges of seven CSOs (from four territories) during a single post-fire year in the Sierra Nevada of California with those in other studies during the same year in other parts of the subspecies range (D. Call, T. Munton, and G. Zimmerman unpubl. data). An average of 23% of forest burned at moderate severity and 9% at high severity within a 1.2 mile radius of the four nests. Pre-fire home range sizes were unknown but CSOs in the four territories did not appear to have unusually large home ranges following predominantly low to moderate severity wildfire.

At least five studies have described patterns of habitat use by spotted owls in burned areas (King et al. 1997, Clark 2007, Bond et al. 2009, Comfort 2013, Eyes 2014; Table 3.1).

King et al. (1997; also Bevis et al. 1997) described initial effects of wildfires on NSOs in two territories in the eastern Washington Cascades. One territory primarily experienced low to moderate severity fire and the other mostly burned at high severity. Both territories experienced an unreported amount of salvage logging in “unsuitable” or severely burned habitat. Most NSO locations (84% and 89%) in the two territories were daytime roosts. In the territory primarily burned at low to moderate severity, 80% of the pair’s post-fire locations were in unburned habitat, 16% were in low severity burns, and 4% were in moderate severity burns. The pair did not appear to roost in severely burned areas. The second territory studied by King et al. (1997) was occupied by a single male. After the wildfire, the male shifted his activity to an unburned area two to three miles away but continued to occasionally use areas near his former activity center. Of those locations, 74% were in unburned habitat, 17% were in low severity burns, 5% were in moderate severity burns, and 4% were in high severity burns. Maps of burn severity

classes and NSO locations indicate that owls in these two territories strongly selected unburned areas for roosting.

Clark (2007) evaluated habitat selection by 12 NSOs (7 territories) inside a wildfire perimeter in the Oregon Klamath Province. NSO locations were primarily nocturnal and may therefore, have largely represented foraging activity. Individuals in this area used all habitat classes, including moderate and severe burns and areas that had been salvage logged. However, when the data from individuals were pooled for analysis, the owls exhibited a strong preference for nesting-roosting habitat (suitability score >50: Davis and Lint 2005 [QMD generally > ca. 27 in DBH in study area]) that was unburned or burned at low severity (unburned and low severity were combined into a single class for analyses). NSOs in the study also selectively used moderately burned, previously-suitable habitat; although both use and availability of this habitat class were low compared with unburned or lightly burned habitat. Owls' use of burned areas was concentrated closer to activity centers, which was expected, given that spotted owls are central place foragers during the breeding season (see Rosenberg and McKelvey 1999).

In the Sierra Nevada, California, Bond et al. (2009) described the habitat associations of seven CSOs from four territories during a single post-fire season. Of the four nests found during the study, one was approximately 0.3 mile outside the fire perimeter, one was in forest burned at low severity, and two were in forest burned at moderate severity. One of the two nest trees found in moderate severity burns was apparently killed by the fire and one produced the only fledgling detected during the study. It is unclear from the paper whether these events occurred at the same nest or different nests. The four pairs roosted in all burn severity classes but exhibited statistically significant selection of low severity burns and avoidance of moderate and high severity burns. Only one of 60 roost sites was located in a high severity burn. Burned roost sites generally resembled unburned roost sites (>60% canopy cover and large-diameter trees). Bond et al. (2009) also evaluated CSO selection of foraging habitat in the area. Probability of use for foraging was highest when sites were burned and within 0.6 mile of nests or roosts. Probability of use was also positively associated with presence of edge between burn severity classes. Five of the owls foraged in high severity burns within 0.9 mile of nests or roosts more often than in other burn severity classes. Bond et al. (2009) suggested that CSOs in these four territories selectively foraged in high severity burns in order to access abundant prey in those areas. This hypothesis was supported by their finding that high severity burns had the highest herb and shrub cover and highest basal area of snags of any burn severity class, including unburned. These features are key resources for spotted owl prey communities (Carraway and Verts 1991, Carey et al. 1999, Holloway and Smith 2011).

Comfort (2013) evaluated habitat selection (roost and foraging locations combined) by 23 NSOs in a burned area in the Oregon Klamath Province. Her best performing model for explaining habitat selection included habitat suitability, disturbance severity, high contrast edge, and low contrast edge. Habitat selection varied with spatial scale but NSOs exhibited a strong preference for higher habitat suitability and avoidance of patches affected by higher severity disturbance (high severity wildfire and/or salvage logging). NSOs showed a preference for high contrast edge at small spatial scales (2-8 ac) and avoidance at medium and large scales (32-2,049 ac). NSOs also exhibited a weak preference for low contrast edge. Comfort (2013) concluded that patchy, mixed severity fire (small patches of high severity fire within a matrix of unburned and

low-to-moderate severity fire) created conditions favored by NSOs in her study, whereas large patches created by high severity fire and subsequent salvage logging were strongly avoided. Salvage logging apparently contributed to conditions avoided by NSOs by structurally homogenizing burned areas, which increased the sizes of high severity patches and amounts of high contrast edge (Comfort 2013). However, the relative influence of high severity wildfire and post-fire salvage logging on habitat selection by NSOs in this study is unknown.

Eyes (2014) evaluated foraging habitat selection by 13 CSOs (8 territories) during three breeding seasons in a recently burned landscape (1-15 yrs prior) in Yosemite National Park in the Sierra Nevada. On average, 25% of the home range (minimum convex polygon) had recently experienced low severity fire, 16% moderate severity fire, and 4% high severity fire. Three of Eye's (2014) four best performing models explaining habitat selection by foraging CSOs included a fire severity metric (Fire Severity Index). These models indicated that the probability of an area's use by foraging CSOs decreased with increasing fire severity. However, foraging CSOs were more likely to use edge sites than non-edge sites and exhibited a tendency for greater use of high contrast edges created by severe fire than for lower contrast edges created by low/moderate severity fire or other disturbances. Eye's (2014) findings that CSOs avoided the interiors of high severity burns and favored high contrast edges created by severe fire is consistent with Comfort's (2013) findings at smaller spatial scales around NSO locations.

The limited available information concerning spotted owl habitat use following wildfires indicates that the species avoids roosting in moderate and high severity burns (King et al. 1997, Clark 2007, Bond et al. 2009). This finding is concordant with the spotted owl's close association with densely-canopied older forest for roosting (Blakesley 2004). Little is known about the effects of wildfire on selection of nest sites. Bond et al. (2009) found three CSO nests in forest recently burned at low and moderate severity, and young fledged from one nest in a moderate severity burn. Moderate severity fire killed one of the four CSO nest trees in their study. Eyes (2014) found a CSO nest adjacent to a high severity burn but the nest failed during her study. Based on the species' nesting habitat requirements (Blakesley 2004), long-term use of severely burned areas for nesting is likely uncommon. Three studies specifically examined selection of foraging habitat by spotted owls. All three found use of all burn severity classes, but Clark (2007) and Eyes (2014) found a preference for foraging in unburned to moderately burned areas (also see Comfort 2013, which combined foraging and roost locations in analyses) while Bond et al. (2009) found a preference for severe burns. It is unclear if this difference was due to differences in the studies' methods, effects of fire and timber harvesting on vegetation, or the composition of prey communities and spotted owl diets. Findings by Comfort (2013) and Eyes (2014) suggest that foraging spotted owls avoid large patches recently burned by high severity fire but benefit from some amount of high contrast habitat edge created by patchy high severity fire.

Wildfire Effects on Prey

In New Mexico, Ganey et al. (2014) found that species richness, relative abundance, and biomass of small mammals were greater in four MSOs' burned wintering areas than in their nest core areas. Abundances of deer mice, pocket gophers (*Thomomys* spp.), and other "pioneer" or "early-successional" prey often increase following fires (Ream 1981, Zwolak and Foresman

2007, Zwolak 2009, Bond et al. 2013). Dusky-footed woodrats appear to initially respond negatively to severe fires (Schwilk and Keeley 1998, Smith 2000) but not to patchy low severity fire, although loss of nest houses might have a brief negative effect on reproduction (Lee and Tietje 2005). However, it is possible that severe fire benefits dusky-footed woodrats over longer time periods (e.g., ≥5-20 yrs) through creation of brushy habitat. Stand-replacing fires should negatively affect abundances of prey associated with well-canopied forest, such as northern flying squirrels and tree voles. These taxa, along with dusky-footed woodrats, are the primary prey for NSOs in California (reviewed in Ch. 2). Low severity fires could also have negative effects on northern flying squirrels and other prey associated with closed canopy forests by reducing dead woody materials, fire-intolerant understory plants, and truffles (Lehmkuhl et al. 2006, Meyer et al. 2007). Thus, wildfires likely have complex effects on NSO prey communities, depending on local or regional differences in prey community composition; wildfire size, severity, and configuration; and the length of time vegetation has had to regenerate following fire.

Post-Fire Salvage Logging

While salvage logging might be judiciously used to meet certain conservation objectives (e.g., generating downed wood to minimize erosion or create wildlife habitat), it is generally conducted to meet economic goals or remove hazard trees (Peterson et al. 2009). Intensive or poorly planned salvage logging can have a variety of negative effects on ecosystems, such as soil compaction, increased erosion, and impacts on insectivorous and cavity-nesting and -denning animals (reviewed in McIver and Starr 2000, Noss et al. 2006, Peterson et al. 2009).

At least three studies have directly evaluated effects of post-fire salvage logging on spotted owls (Clark 2007 and Clark et al. 2013, Lee et al. 2012, 2013). Clark (2007) conducted a radio-telemetry study in areas recently burned by wildfires in the Oregon Klamath Province. He recorded limited use of salvage logged areas; presumably for foraging since locations were primarily nocturnal. Use of salvage logged areas was slightly lower than expected based on its abundance in territories (not statistically analyzed), indicating weak avoidance of salvage logged areas by NSOs. However, avoidance might have been stronger since some of the study's telemetry locations were potentially recorded prior to the occurrence of salvage logging. Most (60%) NSO locations in salvage logged areas occurred in riparian buffers, thinned areas, and patches of wildlife leave trees, rather than intensively salvaged areas. During the same study, Clark et al. (2013) found that post-wildfire declines in NSO occupancy were best explained by a model that included extents of pre-fire timber harvesting, severe wildfire, and post-fire salvage logging. Models that included these factors separately were not competitive with this model, indicating that severe fire and pre- and post-fire harvesting collectively contributed to declines in NSO occupancy; most likely through cumulative habitat loss or degradation.

In the Sierra Nevada, Lee et al. (2012) recorded occupancy for eight CSO territories that experienced wildfire and post-fire salvage logging. Seven of the territories were occupied during the two-year period between the occurrence of wildfire and post-fire salvage logging, whereas none of the territories were occupied following salvage logging.

Lee et al. (2013) evaluated effects of salvage logging on CSOs in the San Bernardino and San Jacinto Mountains of Southern California. They noted that salvage logging in their study area was modest compared with commercial salvage logging typically employed in the Pacific Northwest and Sierra Nevada (salvage logging in their study area mostly consisted of firewood cutting on private in-holdings and hazard tree removal along Forest Service roads). Lee et al. (2013) did not find a statistically significant effect of post-fire salvage logging on CSO occupancy dynamics. However, site extinction probability was slightly higher, and mean annual probability of occupancy was slightly lower, in salvage logged areas than in other burned areas. Weak negative effects of light salvage logging were apparent during all eight post-fire study years.

The limited available evidence suggests that salvage logging decreases the probability that spotted owls will use burned areas (Comfort 2013) and increases the probability that they will abandon their territories following wildfires (Clark 2007, Lee et al. 2012, 2013, Clark et al. 2013). This could occur because salvage logging reduces suitability of burned areas for foraging spotted owls and their prey. Stands recently burned by moderate or severe fire often contain high biodiversity due to the presence of both early-successional conditions and key biological legacies in the form of snags, logs, and residual live trees (Noss et al. 2006). Due to fire suppression and salvage logging, stands with these conditions are currently rare in many fire-prone forests within the spotted owl's range (Noss et al. 2006). Selective use of burned areas for foraging is likely due to spotted owls exploiting short-term increases in prey associated with both early-successional vegetation (e.g., shrubs) and legacy habitat elements (e.g., large diameter snags, logs, and live trees) (Ream 1981, Zwolak 2009, Bond et al. 2013). Salvage logging removes legacy elements, while associated use of herbicides reduces shrubs and grasses important to many prey species (Bond et al. 2013, Comfort 2013). In the longer-term, spotted owls can continue to benefit from the contributions of legacy habitat elements to regenerating stands. For example, large legacy snags, trees, and logs can provide valuable habitat elements for northern flying squirrels and other prey (Holloway and Smith 2011). Removal of these elements through salvage logging could therefore reduce the value of subsequent regenerating stands as prey habitat. Harvesting of legacy snags and live trees could also directly affect spotted owls by reducing availability of foraging perches in the short-term and suitable nest trees during later successional stages.

Summary of Direct Evidence Concerning Wildfire and Salvage Logging Effects

Inferences from studies of direct effects of wildfires and salvage logging on spotted owls are limited due to inclusion of only a small number of spotted owls or territories. The preponderance of currently available evidence indicates that spotted owls are often resilient to low-, moderate-, or mixed-severity wildfires but can be strongly impacted by extensive severe wildfires. Following wildfire, many spotted owls may remain in their territories, exploit short-term increases in prey in burned areas, and continue to reproduce at reasonably high rates. However, wildfires that result in substantial loss or fragmentation of suitable habitat, particularly within breeding core areas, can cause spotted owls to increase their home range sizes, abandon their territories, and possibly, emigrate from burned landscapes or die of starvation or disease. Negative effects of severe wildfires appear to be greatest when suitable habitat is already limited

(e.g., due to widespread intensive timber harvesting) and when post-fire salvage logging reduces suitability of burned areas for foraging and prey.

Wildfire Effects on Recent Habitat Trends

Past and continuing habitat loss was a primary reason for listing the NSO under the federal Endangered Species Act (USFWS 1990). At the time of listing, the Fish and Wildlife Service estimated that 60-88% of the subspecies' habitat had already been lost (USFWS 1990; also see Ch. 2). They attributed most of this loss to widespread intensive timber harvesting. Since listing of the NSO and subsequent adoption of the Northwest Forest Plan, timber harvesting has declined and wildfire has been identified as the primary source of forest disturbance and habitat loss on federal lands (Courtney et al. 2004, Healey et al. 2008, Davis and Dugger 2011, Moeur et al. 2011, USFWS 2011a, Kennedy et al. 2012). Nonetheless, timber harvesting continues to be the primary source of habitat loss on non-federal lands (Healey et al. 2008, Davis and Dugger 2011, Moeur et al. 2011, Kennedy et al. 2012; see below).

Estimates of recent trends in amounts of NSO habitat, and of older forest in general, have been produced as part of monitoring efforts for the Northwest Forest Plan; and are therefore, largely restricted to the Plan's area and time span (Davis and Lint 2005, Moeur et al. 2005, 2011, Healey et al. 2008, Davis and Dugger 2011). I have focused on estimates by Davis and Dugger (2011) because they replaced those of Davis and Lint (2005) and are more specific to NSO habitat than those of Moeur et al. (2005, 2011) and Healey et al. (2008). I did not review habitat trend estimates based on federal ESA Section 7 consultation records (Bigley and Franklin 2004, USFWS 2012b) due to greater scientific uncertainty and methodological bias associated with those data (see Bigley and Franklin 2004). Trends described by Bigley and Franklin (2004), Moeur et al. (2005, 2011), Healey et al. (2008), and the US Fish and Wildlife Service (2012b) quantitatively differ from those of Davis and Dugger (2011) but similarly indicate that wildfires have been the primary source of recent habitat loss on federal lands.

Davis and Dugger (2011) used remotely sensed vegetation data (satellite imagery) to model changes in habitat suitability across the NSO's range during the first 15 years of the Northwest Forest Plan (1994-2007 in California and 1996-2006 in Oregon and Washington). Habitat suitability was based on characteristics surrounding thousands of NSO pair locations across the Plan area. Suitable breeding habitat was defined as having both a probability of owl presence greater than expected based on random chance and environmental conditions typical of those found around nesting and roosting pairs. Estimated habitat trends included gross loss of both suitable breeding ("nesting/roosting") habitat and interior ("core") suitable breeding habitat (>330 ft from edge). Davis and Dugger (2011) considered habitat loss to have occurred when an area classified as suitable at the beginning of Northwest Forest Plan was later downgraded to a lower suitability rank (unsuitable or marginal) due to vegetation changes caused by forest disturbances. Davis and Dugger (2011) did not estimate recruitment of, or net changes in, breeding habitat because their remotely sensed data was incapable of accurately capturing relatively slow and subtle habitat changes during development of intermediate-aged and older stands. They did, however, estimate net trends in NSO dispersal habitat, which they defined as forest with a mean conifer canopy cover of at least 40% and a mean conifer DBH of at least 11 inches. Recruitment of dispersal habitat was more detectable than that of breeding habitat due to

more rapid and measurable growth in younger forest (some recruitment also occurred due to degradation of suitable breeding habitat by forest disturbances).

Estimated gross losses of suitable breeding habitat on federal and non-federal lands are presented in Tables 3.2 and 3.3, respectively. During the first 15 years of the Northwest Forest Plan, wildfires were responsible for an estimated gross loss of 236,700 acres (2.7%) of suitable breeding habitat on federal lands rangewide and 13,100 acres (0.3%) on non-federal lands (1.9% of federal and non-federal lands combined). Estimated habitat loss on federal lands was similar to that expected at the time of the Northwest Forest Plan's implementation; however, relatively high rates of habitat loss in relatively dry, fire-prone regions have been a source of conservation concern for NSOs in those areas (Davis and Dugger 2011). In California, wildfires removed an estimated 75,500 acres (4.1%) of suitable breeding habitat on federal lands and 5,600 acres (0.4%) on non-federal lands (2.4% combined). Approximately 70% of habitat loss to wildfires on federal lands occurred within the Oregon and California Klamath Provinces (Table 3.2). Most of this habitat loss was caused by the 1999 Megram Fire and 2002 Biscuit Fire (Table 3.4). Fires in the Eastern Cascades Provinces of Washington, Oregon, and California contributed less to total habitat loss than did fires in the Klamath Provinces, but were often more destructive in terms of proportion of suitable habitat lost within individual fire perimeters. In contrast with federal lands, wildfires were responsible for very little habitat loss on non-federal lands; rather, timber harvesting accounted for most losses in these areas (Figure 3.1).

Table 3.2: Estimated gross losses of suitable NSO breeding habitat on federal lands due to wildfires during 1994-2007 in California and 1996-2006 in Oregon and Washington (adapted from Davis and Dugger 2011, USFWS 2011a).

State	Province	Initial Acres	Acres Lost	Percent Lost
California	CA Cascades	213,200	1,800	0.8%
	CA Klamath	1,489,800	71,600	4.8%
	CA Coast	145,400	2,100	1.4%
Oregon	OR Coast Range	611,200	0	0.0%
	Western OR Cascades	2,258,700	28,900	1.3%
	Eastern OR Cascades	402,900	17,800	4.4%
	Willamette Valley	3,400	0	0.0%
	OR Klamath	985,000	93,600	9.5%
Washington	Olympic Peninsula	763,100	200	0.0%
	Eastern WA Cascades	673,600	20,000	3.0%
	Western WA Cascades	1,283,000	700	0.1%
	Western WA Lowlands	24,700	0	0.0%
Rangewide Total		8,854,000	236,700	2.7%

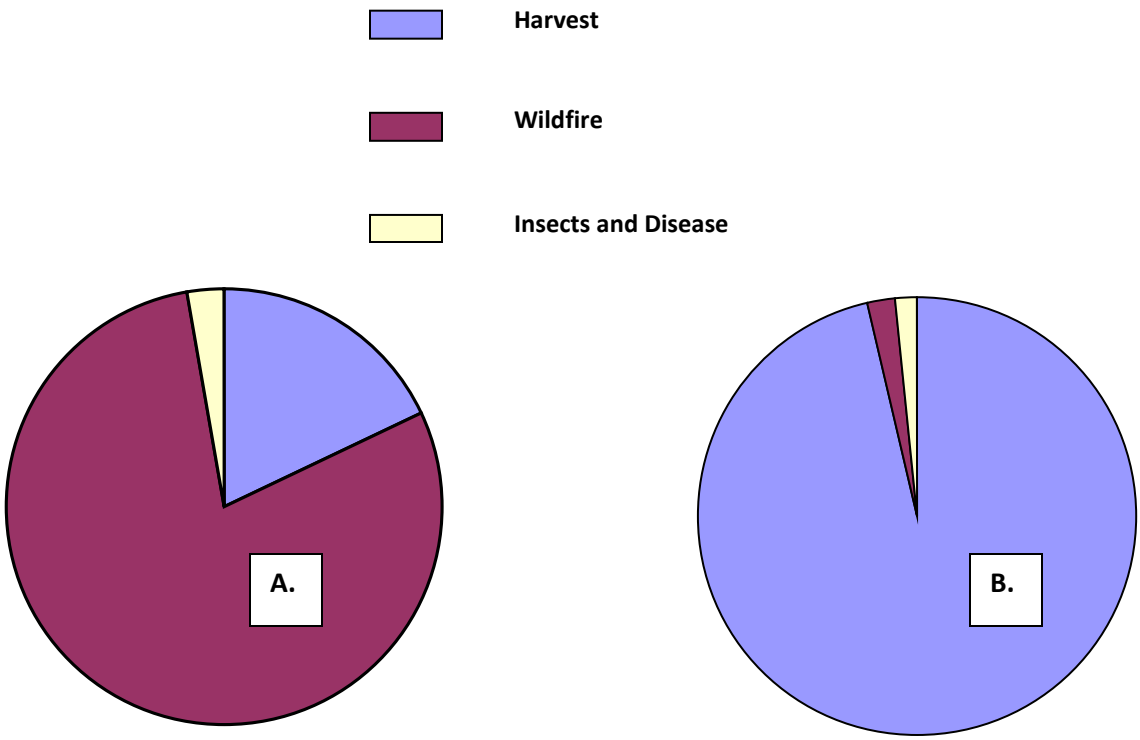
Table 3.3: Estimated gross losses of suitable NSO breeding habitat on non-federal lands due to wildfires during 1994-2007 in California and 1996-2006 in Oregon and Washington (adapted from Davis and Dugger 2011, USFWS 2011a).

State	Initial Acres	Acres Lost	Percent Lost
California	1,556,700	5,600	0.4%
Oregon	1,382,400	5,100	0.4%
Washington	1,258,900	2,400	0.2%
Total	4,198,000	13,100	0.3%

Table 3.4: Estimated gross losses of suitable NSO breeding habitat to individual wildfires during 1994-2007 (note: "habitat degraded" describes areas downgraded from highly suitable to suitable; from Davis and Dugger 2011).

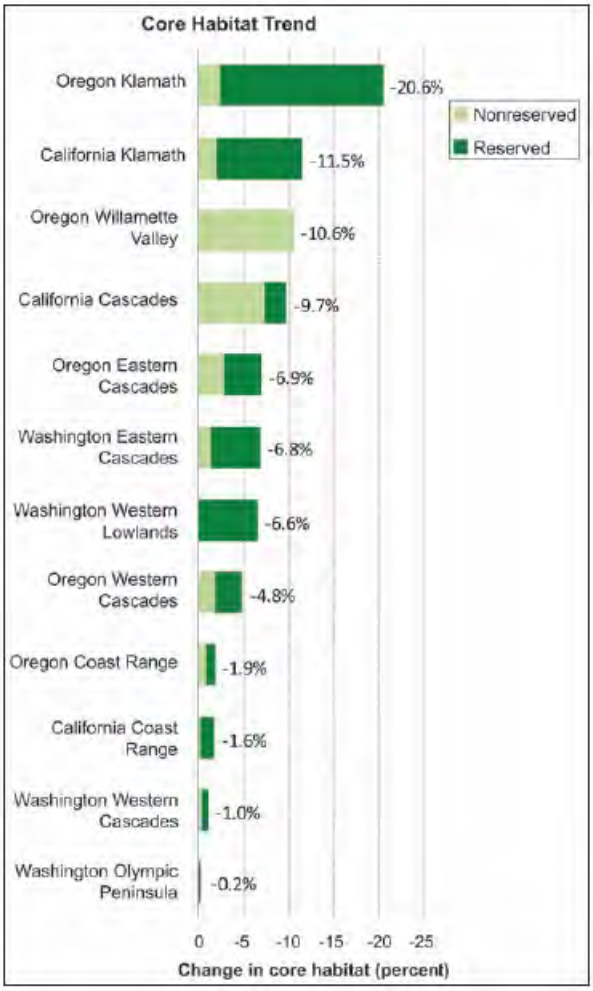
Fire name	Year	Broad physiographic province	Habitat in wildfire perimeter	Habitat lost		Habitat degraded	
			Acres	*Acres*	*%*	*Acres*	*%*
Biscuit Fire	2002	Klamath Mountains	226,230	93,730	41	12,019	5
Megram Fire	1999	Klamath Mountains	76,337	27,520	36	4,589	6
B&B Complex	2003	East Cascades	26,269	16,403	62	907	3
Bake-oven Fire	2006	Klamath Mountains	23,946	8,873	37	581	2
Boulder Fire	2002	West Cascades	34,059	8,460	25	2,074	6
Davis Fire	2003	East Cascades	8,050	6,943	86	5	0
Pigeon Fire	2006	Klamath Mountains	13,896	5,634	41	327	2
Rex Complex	2001	East Cascades	8,548	4,750	56	278	3
Timbered Rock	2002	West Cascades	10,216	4,539	44	569	6
Spring Fire	1996	West Cascades	13,504	3,931	29	858	6
Deep Harbor Fire	2004	East Cascades	5,761	3,930	68	64	1
Hancock Fire	2006	Klamath Mountains	12,712	3,132	25	336	3
Apple Fire 2	2002	West Cascades	12,227	2,810	23	928	8
Fischer Fire	2004	East Cascades	4,479	2,340	52	34	1
Fork Fire	1996	Klamath Mountains	2,962	2,113	71	14	0
Needles Fire	2003	East Cascades	1,946	874	45	1	0
Trough Fire	2001	Klamath Mountains	1,851	798	43	4	0
Hunter Fire	2006	Klamath Mountains	2,236	789	35	40	2
Deer Point Fire	2002	East Cascades	505	380	75	0	0
Tatoosh Complex	2006	East Cascades	666	378	57	0	0

Figure 3.1: Proportions of suitable breeding habitat loss attributed to harvesting, wildfire, and insects and diseases on (A) federal lands and (B) non-federal lands during 1994-2007 (adapted from Davis and Dugger 2011 and USFWS 2011a).



Davis and Dugger (2011) reported substantial losses of interior (>330 ft from edge) breeding habitat on federal lands during the first 15 years of the Northwest Forest Plan (Figure 3.2). These losses primarily occurred in reserved areas. Changes in ratios of interior and edge habitat classes indicated that increased fragmentation of suitable breeding habitat on federal lands was greatest in the Oregon and California Klamath Provinces and California Cascades Province (see Table 3-3 in Davis and Dugger 2011). Increased fragmentation in these regions was primarily due to wildfires.

Figure 3.2: Gross losses of interior suitable breeding habitat on reserved and non-reserved federal lands during 1994-2007 in California and 1996-2006 in Oregon and Washington (from Davis and Dugger 2011).



Davis and Dugger (2011) estimated a 5.2% net gain in NSO dispersal habitat. Much of this gain was due to succession in young forests in non-reserved lands at the margins of federal forests. However, accounting for forest connectivity and NSO dispersal distances, Davis and Dugger (2011) reported a 1% net loss of "dispersal-capable landscape". Much of the loss of dispersal-capable landscape in the Klamath and Eastern Cascades Provinces was due to large wildfires,

whereas timber harvesting on non-federal lands was responsible for much of the loss in other regions.

Loss and fragmentation of breeding habitat to wildfires was likely at least partially offset by recruitment of new habitat through succession of mature and old forest. However, Davis and Dugger (2011) found that detectable recruitment of breeding habitat primarily occurred in the marginal suitability class. This finding was supported by Moeur et al. (2005), who found that about 90% of recruitment of older forest (mature and old-growth combined) during the first 10 years of the Northwest Forest Plan was at the lower end of the class' diameter range (i.e., mean DBH 20-30 in). In their subsequent report, Moeur et al. (2011) noted that given the short length of the monitoring period (10-14 yrs), recruitment was "likely due to incremental stand growth over the 20-in diameter threshold, or from understory disturbances that removed smaller diameter trees and raised the average stand diameter above the threshold, rather than from an increase in forests of much larger and older trees." It is likely that some newly recruited mature forest provides suitable habitat for NSOs but much if it could lack the canopy layering, large diameter snags and logs, and other structural attributes typical of nesting and roosting habitat (Blakesley et al. 2004).

Loss and fragmentation of suitable breeding habitat does not necessarily equate to negative impacts on NSOs (Franklin and Gutiérrez 2002; e.g., Bond et al. 2002, 2009, Lee et al. 2012). Studies in southern Oregon and northern California found that the presence and fitness of NSOs are generally highest in landscapes with a mix of both large amounts of suitable breeding habitat and other habitat classes, such as foraging habitat or "non-habitat" (Franklin et al. 2000, Zabel et al. 2003, Olson et al. 2004, Dugger et al. 2005; reviewed above and in Ch. 2 [see Ch. 2 for studies' habitat definitions]). Fitness is also generally highest when suitable breeding habitat occurs in large or clustered patches with large amounts of ecotone or edge between vegetation classes (Franklin et al. 2000, Dugger et al. 2005). This combination of conditions is important because it provides NSOs with a balance of resources needed for both survival and reproduction (Franklin et al. 2000). Active fire regimes in dry forests within the NSO's range in California (e.g., mixed-conifer and interior mixed-evergreen) historically contributed to these conditions by generally sparing older forest and maintaining some form of habitat heterogeneity at both stand and landscape scales (Skinner and Taylor 2006, Skinner et al. 2006, Stuart and Stephens 2006). Some contemporary wildfires may still burn in this manner and thereby continue to perform an important ecosystem function in these forests. However, large severe wildfires have contributed, along with fire suppression and timber harvesting, to homogenization of some forests in interior northern California (Skinner et al. 2006). Thus, large severe wildfires may impact NSOs in California through loss of habitat heterogeneity, as well as reduced amounts and connectivity of suitable breeding habitat.

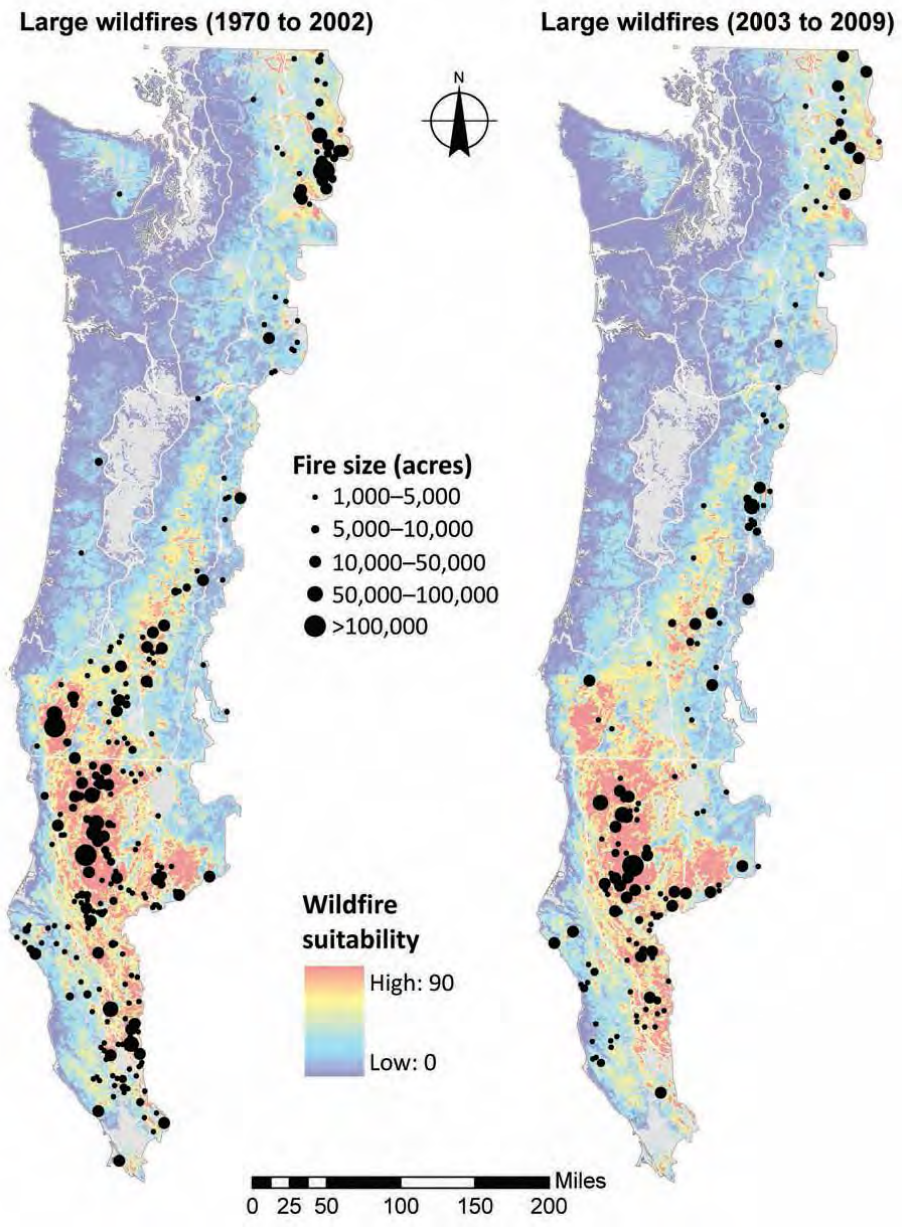
Fire Risk in California

Prior to Euro-American settlement, dry forests in California generally experienced relatively frequent, low-to-moderate or mixed severity fire regimes (Skinner and Taylor 2006, Skinner et al. 2006, Stuart and Stephens 2006, Van de Water and Safford 2011). Mean pre-settlement fire return intervals in California were 11 years in yellow pine forests (e.g., *Pinus ponderosa*, *P. jeffreyi*), 11-16 years in mixed-conifer forests, and 29 years in mixed-evergreen forests (Van de

Water and Safford 2011). Mean fire return intervals in redwood forests south of Del Norte County were also relatively frequent (6-44 yrs: Stuart and Stephens 2006). Frequent fire during the pre-settlement period generally maintained forests with less dense and more clumped tree distributions, higher proportions of fire-resistant trees (i.e., larger size classes and more fire-tolerant species), and lighter and less continuous fuel beds than occur today (Skinner and Taylor 2006, Skinner et al. 2006, Stuart and Stephens 2006). In northern California, this characteristic fine-scale structural heterogeneity was often overlaid with coarser variability created by effects of elevation, terrain, soils, and other physiographic factors on fire and vegetation patterns (Skinner and Taylor 2006, Skinner et al. 2006, Sawyer 2007). For example, in areas of deeply incised terrain in the Klamath Mountains and southern Cascades of California, upper slopes and south and west facing aspects typically experienced more frequent and severe fire than did other areas (Skinner and Taylor 2006, Skinner et al. 2006). Due to fire suppression, early-successional vegetation communities formerly maintained by frequent, small-scale severe wildfire have greatly declined in some areas of California (Skinner 1995, Nagel and Taylor 2005). Overall, research indicates that fire suppression and other human activities have led to decreased forest heterogeneity at both stand and landscape scales and have contributed to substantial changes in fire regimes in California's dry forests (Skinner and Taylor 2006, Skinner et al. 2006, Stuart and Stephens 2006).

Due to fire suppression, fire-free periods have dramatically increased in California's interior forests (Skinner and Taylor 2006, Skinner et al. 2006). For example, fire rotation near Hayfork in the Klamath Mountains increased more than 10-fold (from 19 to 238 yrs) during the post-settlement period (Taylor and Skinner 2003). Abnormally long fire-free periods have facilitated increased accumulation and continuity of fuels in dry, fire-prone forests (Skinner and Taylor 2006, Skinner et al. 2006, Stuart and Stephens 2006). When wildfires do occur there is often an increased risk of them becoming very large and for suppression forces to be overwhelmed by their size and number (e.g., CAL FIRE 2008). As in other dry forests across the western U.S., the mean and maximum sizes of wildfires, and the total annual area burned, significantly increased in California's dry montane forests during the 20th and early 21st Centuries (Miller et al. 2009, 2012). CAL FIRE (2008) noted that more than half of the 26 largest fires recorded in California during 1932-2008 occurred during the last eight years of that period. Based on recent (1970-2002) fire behavior, most of northern California's interior can be classified as highly prone to large (>1,000 ac) wildfires (Davis et al. 2011; Figure 3.3).

Figure 3.3: Relative probability of large (>1,000 ac) wildfires ("wildfire suitability") across the NSO's range (from Davis et al. 2011). Modeling was based on landscape and climatic characteristics of locations at which large wildfires occurred during 1970-2002 (left) and was compared with subsequent (2003-2009) locations (right).



Studies of recent trends in extents of high severity wildfire in California have found conflicting results. For example, Miller et al. (2009) and Miller and Safford (2012) reported a substantial increase in the extent of high severity wildfire in the Sierra Nevada and southern Cascades of California during 1984-2010; while Hanson and Odion (2014) did not find an increase in the Sierra Nevada during the same period. Similarly conflicting results have been found for the California Klamath Province. Hanson et al. (2009) found a significant increase in high severity wildfire in the California and Oregon Klamath Provinces during 1984-2005; whereas Miller et al. (2012) did not find an increase in the California Klamath Province during a similar period (1987-2008). Scientific debate ensued regarding the appropriateness of methods used in various studies to determine trends in high severity fire (e.g., Hanson et al. 2009, 2010 vs. Spies et al. 2010).

Differences in findings regarding trends in high severity wildfire are related to variation in studies' temporal and spatial scales of analysis, as well as in methods for determining fire severity (Courtney et al. 2008, Miller et al. 2012, Hanson and Odion 2014). For example, Miller et al. (2012) noted that both their own study and those of Odion et al. (2004, 2010) may have underestimated trends in high severity wildfire in the California Klamath Province due to inclusion of unusual fire years. Studies by Odion et al. (2004, 2010) were based on fire effects during a single year (1987), which Miller et al. (2012) described as unusual. Large areas burned at below-average severity during 1987 due to abnormally strong inversions, and the fact that some of the wildfires burned well into fall when conditions often favor lower severity fire. Miller et al. (2012) also noted that their own ability to detect a trend in wildfire severity could have been compromised by inclusion of both this year and 2008, which likewise experienced unusually large, low severity wildfires. Differences in the area analyzed could also affect evaluations of trends in high severity wildfire. For example, the Biscuit Fire, which was predominantly located in Oregon, included extensive areas of high severity fire and therefore could have influenced results of trends analyses for the Oregon and California Klamath Provinces combined versus the California Klamath alone (Miller et al. 2012).

Regardless of whether or not the extent of high severity wildfire increased in California during the last two decades, large severe wildfires have recently occurred in these areas, and they were responsible for most loss, degradation, and fragmentation of suitable breeding habitat for NSOs on federal lands (Davis and Dugger 2011, Davis et al. 2011; see above). These data cannot be used to project how fires in the future will affect NSOs since they do not necessarily represent past or future fire conditions or effects. However, it is highly unlikely that wildfires will cease to be a major source of habitat loss for NSOs in the future. Rather, climate change research has generally projected a continued increase in the number and sizes of wildfires and the annual area burned in California and other western states during coming decades (Westerling et al. 2006, Lenihan et al. 2008, Westerling and Bryant 2008, Littell et al. 2009, Moritz et al. 2012, Stavros et al. 2014). There is scientific uncertainty regarding recent and future trends in the extent of high severity wildfire in California. Nonetheless, large severe wildfires will at least occasionally occur in the future and will continue to be a source of habitat loss and modification for NSOs in the state.

Increases in the number and sizes of wildfires, and effects of wildfires on NSO habitat trends, have led to calls for widespread use of thinning and other forms of active management in dry, fire-prone forests within the Northwest Forest Plan area (USFS and BLM 1994, USFWS 2008,

2011, 2012a, Franklin and Johnson 2012). Some researchers and stakeholders, however, have expressed doubts regarding estimates of wildfire risk and effects on NSOs, concerns about potential effects of thinning on NSOs, and distrust of federal agency intentions (Hanson et al. 2009, Heiken 2010, DellaSala et al. 2013, Odion et al. 2014). As discussed in Chapter 2 (also Hansen and Mazurek 2010, USFWS 2011a), there is currently little known about the effects of forest thinning on spotted owls but the preponderance of evidence indicates that commercial thinning can have negative short-term effects on the species (also see Tempel et al. *in press* regarding potential long-term effects). Federal agencies should carefully consider this information, as well as apparent effects of wildfires on NSOs, when formulating land management policies and prescriptions aimed at reducing wildfire risk in landscapes occupied by the subspecies. Land managers should also consider greater use of prescribed fire and allowing wildfires to burn under favorable conditions; particularly at lower elevations in the California Klamath Province, where summertime inversions often minimize fire severity (Miller et al. 2012).

Acknowledgements

I am grateful to Ray Davis and Derek Lee for their helpful comments on earlier drafts of this chapter. I recognize that many of the topics reviewed in this chapter are scientifically or politically contentious. The approach and conclusions in this review are my own and do not necessarily reflect those of the reviewers.

Ch. 4: Barred Owls

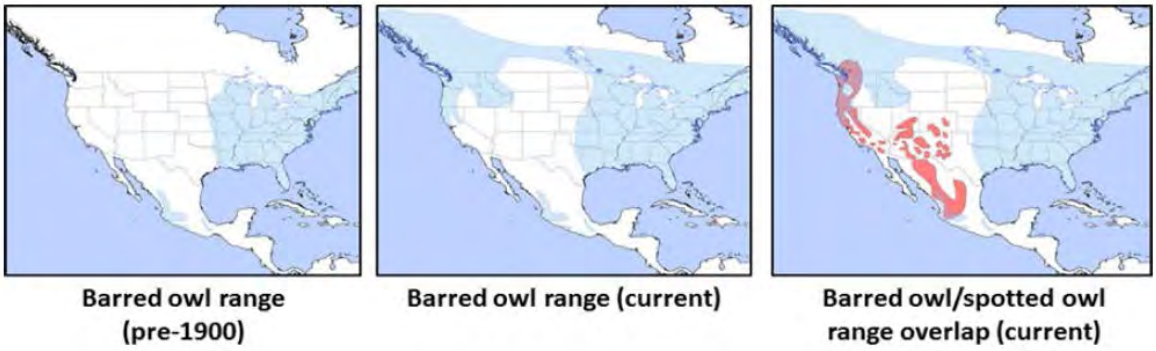
Introduction

At the time of the NSO's federal listing, the barred owl was recognized as a potential threat to the subspecies (USFWS 1990, Thomas et al. 1990). Since then, barred owls have continued to invade the range of the NSO and are apparently increasing in numbers (USFWS 2013). As reviewed herein, a large body of correlational and anecdotal evidence, supplemented by preliminary findings from barred owl removal experiments, indicates that barred owls are negatively impacting NSO populations across their range and that this is due to competition between the two species for space, habitat, and food. Research reviewed below indicates that the barred owl is a superior competitor to the NSO due to its larger size, more aggressive behavior, higher reproductive potential, higher population densities, and broader ecological niche (e.g., USFWS 2013, Wiens et al. 2014). The USFWS (2011a) recently listed the barred owl invasion as one of three main threats currently faced by NSOs (along with timber harvesting and wildfires). The USFWS (2011a) described this threat as "extremely pressing and complex" and "requiring immediate consideration." Information reviewed below suggests that lethal control of barred owls is a viable management option for some areas, although it may be difficult to overcome emotional and ethical resistance to killing one charismatic species to save another (Diller et al. 2013, Higley 2014). Habitat conservation for NSOs appears to be of increasing importance because the negative effects of habitat loss and fragmentation on NSOs can be exacerbated by the presence of barred owls (Dugger et al. 2011).

The Barred Owl's Expansion

Prior to the mid-1900s, the barred owl's range was confined to southeastern Canada, the eastern U.S., and portions of Mexico (Gutiérrez et al. 2004, 2007; Figure 4.1). By the mid-20th century the barred owl's range began expanding westward across North America and currently includes the southern boreal forest zone and British Columbia in Canada and the northern Rocky Mountains, Pacific Northwest, and northern California in the U.S. (Livezey 2009, USFWS 2013; Figure 4.1). The barred owl's range now completely overlaps that of the NSO and partially overlaps that of the California spotted owl (*S. o. occidentalis*) (Figure 4.1). It is unclear whether the barred owl's westward range expansion occurred via the Great Plains or Canada's boreal forests (USFWS 2013). It is also uncertain whether this range expansion was facilitated by natural factors, human activities, or a combination of the two. Hypotheses concerning the cause of the barred owl's range expansion include increased adaptation by the species to coniferous forests; natural climate change; environmental changes associated with widespread intensive timber harvesting; and conversion of open areas to forest due to fire suppression, planting parks and woodlands, removal of keystone species, or other human activities (Gutiérrez et al. 2004, USFWS 2013).

Figure 4.1: Historical and current range of the barred owl and comparison of the current ranges of the barred owl and spotted owl (from USFWS 2013).



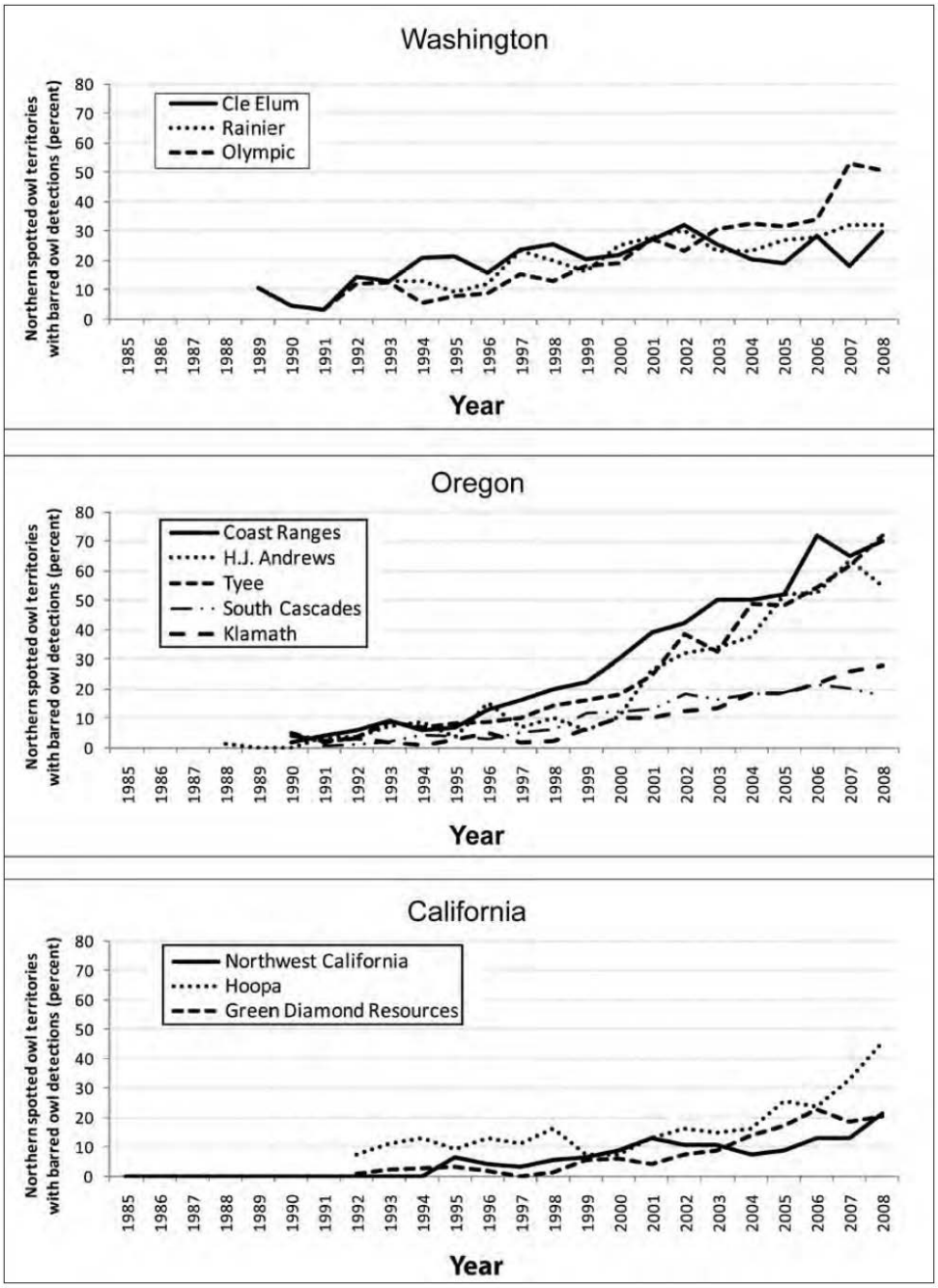
Reliable data concerning current barred owl densities and population trends are unavailable. Most information about barred owl trends in the Pacific Northwest and California is based on incidental detections during surveys for spotted owls (USFWS 2013). Researchers have estimated that only 1/2 to 2/3 of barred owls present are detected during NSO surveys (Gutiérrez et al. 2004, Bailey et al. 2009, Wiens et al. 2011). Researchers have only recently begun to systematically survey for barred owls within the range of the NSO and only in limited areas. In California, the Northwest California, Green Diamond, and Hoopa NSO demographic studies initiated systematic surveys for barred owls in 2009 (Franklin et al. 2014, Green Diamond Resource Company 2014).

Some early studies of barred owls within the NSO's range likely overestimated barred owl numbers by focusing on cumulative and nighttime detections (Gutiérrez et al. 2004). However, barred owl trends are now more frequently evaluated in terms of the number of spotted owl territories in which barred owls have been detected (USFWS 2013; e.g., Forsman et al. 2011, Calforests 2014). Reports of the number of spotted owl territories with barred owl detections probably underestimate barred owl densities and population trends (USFWS 2013). Barred owls often have substantially smaller home ranges than spotted owls so it is possible for a single spotted owl home range to encompass multiple barred owl home ranges (Singleton et al. 2010, Wiens 2012; see below). Without color-banding or follow-up surveys to determine the identity and occupancy status of barred owls, it is often unclear if multiple detections within spotted owl territories represent one or multiple barred owls. Furthermore, a lack of barred owl-specific surveys in many areas has likely led to underestimates of barred owl presence. For example, in 2013, NSO-specific surveys on the Hoopa reservation in northwestern California indicated that barred owls were present in 43% of NSO territories on the reservation, whereas barred owl-specific surveys revealed that barred owls were present in 75% of NSO territories (Higley and Mendia 2013).

Despite uncertainty regarding barred owl densities and population trends, incidental detections clearly indicate that the species rapidly expanded its range into that of the NSO (USFWS 2013). For example, barred owls expanded their range from western Washington to northern California in less than 10 years (Gutiérrez et al. 2004). Incidental detections also suggest that barred owl densities are continuing to increase within the range of the NSO. From 1985-2008, the

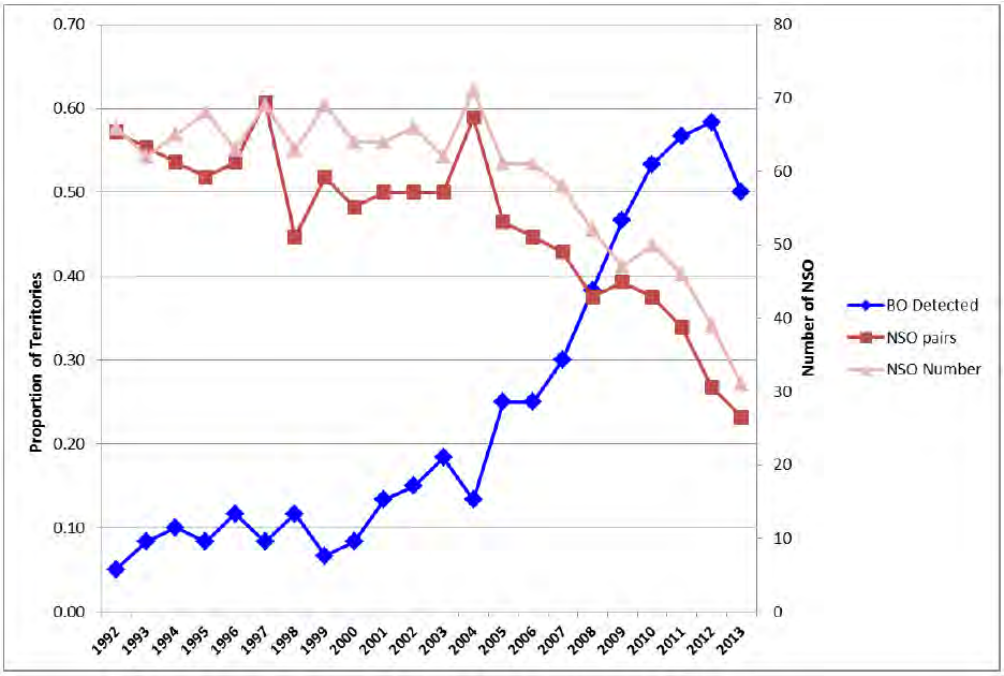
proportion of NSO territories with known barred owl presence increased in demographic study areas throughout the NSO's range, suggesting increasing barred owl populations (Forsman et al. 2011; Figure 4.2). Until the mid-2000s, barred owl increases in Washington and Oregon were steeper than those in California (Forsman et al. 2011; Figure 4.2), which is consistent with the species' later colonization of California (USFWS 2013). However, barred owls are currently increasing at an accelerated pace in at least some portions of northwestern California (see below).

Figure 4.2: Annual proportion of northern spotted owl territories with barred owl detections (≤0.62 mi from spotted owl activity center) on demographic study areas in Washington, Oregon, and California (from Dugger and Davis 2011, adapted from Forsman et al. 2011).



Recent reports from California's demographic studies indicate that barred owls continued to increase in numbers and to invade additional NSO territories during 2009-2013 (Higley and Mendia 2013, Franklin et al. 2014, Green Diamond 2014). As noted above, California's demographic studies initiated barred owl-specific surveys in 2009. The Green Diamond Resource Company also began a barred owl removal experiment in a portion of their demographic study area during the same year (see below). Detection and occupancy data reported here for 2009-2013 are not directly comparable to previously collected data, except for from the Hoopa demographic study, which separately reported data from NSO- and barred owl-specific surveys. In the Northwest California demographic study area and nearby Regional Study Area, the number of NSO territories with barred owl detections increased by 76% (from 21 to 37) during 2009-2013 and the estimated number of barred owl sites increased by 170% (10 to 27) (Franklin et al. 2014). On Green Diamond Resource Company lands, the total estimated number of barred owl sites increased by 57% (numbers not reported) during 2011-2013 (Green Diamond 2014). In the Hoopa demographic study area, NSO-specific surveys indicated that the percent of NSO territories with barred owl presence increased from 47% to 58% during 2009-2012 and dropped to 50% in 2013 for unreported reasons (Higley and Mendia 2013; Figure 4.3).

Figure 4.3: Total number of northern spotted owls detected (NSO Number), percentage of territories occupied by spotted owl pairs (NSO Pairs) and percent of historical spotted owl territories with at least one barred owl detection (BO Detected) received during spotted owl surveys, annually within the Hoopa Valley Indian Reservation demographic study area during 1992-2013 (from Higley and Mendia 2013).



Cumulative detections in the California Natural Diversity Database (CNDDB) from 1978 through 1990, 1998, 2006, and 2013 provide a crude picture of the barred owl's expansion in California (Figure 4.4). These detection data suggest that the species expanded its range into the state along the northern coast and southern Cascades and more rapidly increased in wetter regions (Figures 4.4 and 4.5). Earlier and more rapid colonization of relatively mesic forests by barred owls is consistent with observations from studies in Washington (Gutiérrez et al. 2007). While cumulative detections cannot be used to evaluate the abundance or densities of barred owls, they suggest that the species is relatively abundant along the coast and in the adjacent Six Rivers National Forest and vicinity (including the Northwest California and Hoopa demographic study areas), whereas they appear to still be in the process of colonizing the Mendocino, Klamath, and Shasta-Trinity National Forests and other interior areas of northern California. However, it is possible that this pattern is biased by the fact that most barred owl detections occur during surveys for spotted owls, which may be more densely concentrated or better surveyed in northwestern California. Concentrations of barred owl detections in northwestern California may be partly associated with intensive survey effort for spotted owls in the region's three demographic study areas. Furthermore, the Six Rivers National Forest conducted forest-wide surveys for NSOs in 2010 and subsequently continued to survey large areas associated with forest projects. Barred owls have a broader ecological range than do spotted owls, so they may be more widely distributed than is shown in Figure 4.4 (USFWS 2013).

Figure 4.4: Cumulative northern California barred owl detections in the California Natural Diversity Database from 1978 through A) 1990, B) 1998, C) 2006, and D) 2013 (note: dark red symbols denote higher concentrations of detections).

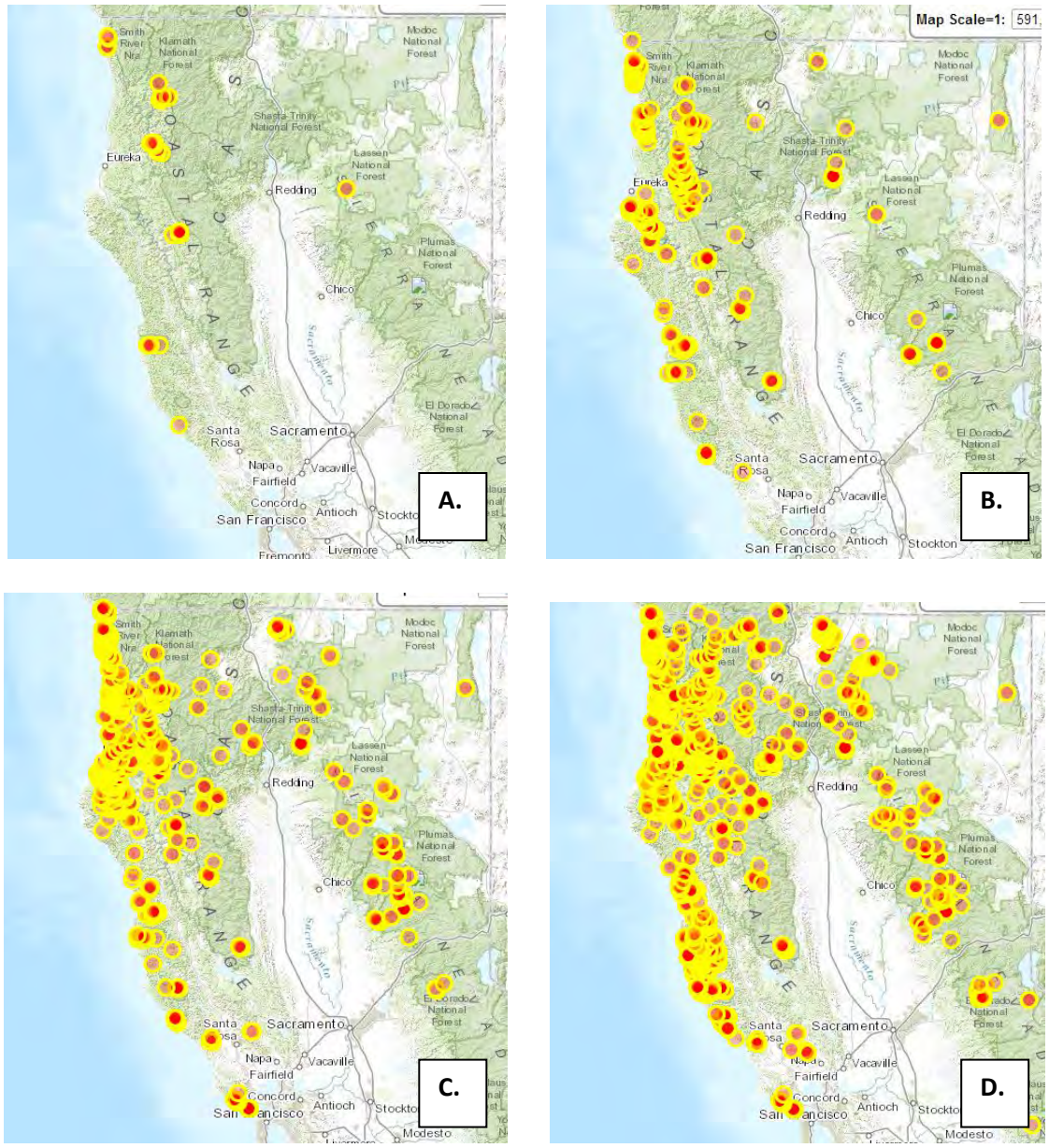
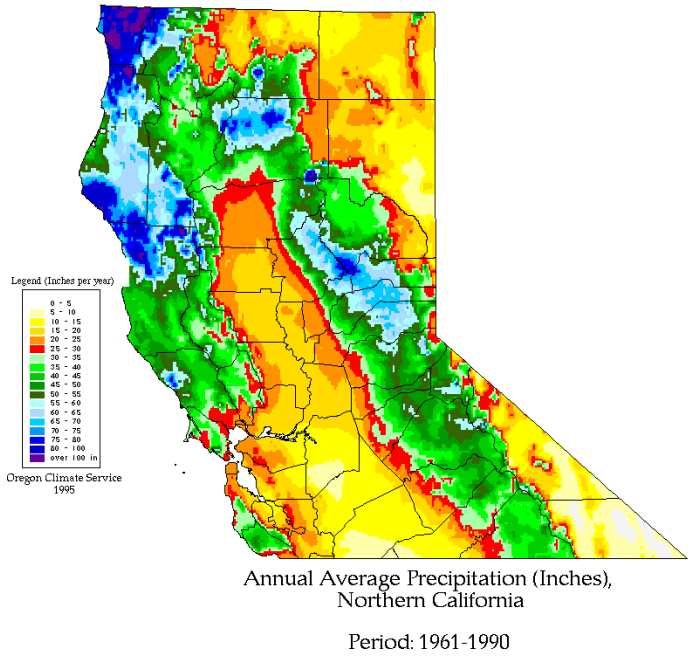


Figure 4.5: PRISM precipitation map for northern California (1961-1990) (Western Regional Climate Center).



Barred owls have increased dramatically in California's Redwood National and State Parks (Gutiérrez et al. 2004). In 2012 alone, NSO surveyors detected at least 17 barred owls at 10 different sites (Schmidt 2013). In contrast, NSOs were detected at only four historical territories in 2012. It is possible that more NSO territories were active during that year as relatively little of the landscape was surveyed. However, Schmidt (2013) noted that the Redwood National and State Parks have discontinued surveying many areas due to what appears to be almost complete displacement of NSOs by barred owls. Based on clusters of barred owl detections ($\leq$1 mi apart) during 1993-2012, Schmidt (2013) estimated that the Redwood National and State Parks contain a total of 58 barred owl territories. Barred owls have only recently invaded National Park lands in Marin County, California and have been slow to increase in numbers thus far (Ellis et al. 2013). Barred owls were first detected in Marin County in 2002 and were detected at only four (13%) NSO monitoring sites in the area in 2012 (Ellis et al. 2013). Ellis et al. (2013) hypothesized that the barred owl's expansion into Marin County has been limited due to extensive agricultural and urban lands surrounding the area. They also stated however, that barred owl numbers would likely continue to increase in the area over time and could eventually pose a substantial conservation problem for this small and relatively isolated population.

Most information about barred owls on private timberlands in California is from ownerships in the Redwood Province. Data provided by the Green Diamond Resource Company are described above, along with those from other NSO demographic studies in California. Reports from both the Humboldt Redwood Company (Humboldt County) and Mendocino Redwood Company (Mendocino and Sonoma Counties) suggest that barred owls are currently rapidly increasing on those lands. Despite a marked decline in annual numbers of nighttime NSO surveys, Humboldt

Redwood Company (2013) found an overall increase in barred owl detections within 0.5 mile of NSO activity centers during 2003-2013 (Figure 4.6). However, some of the increase in barred owl detections between 2010 and 2011 could have been due to greater survey effort associated with adoption of the USFWS (2012c) revised survey protocol for NSOs. Mendocino Redwood Company (2014) data suggest that barred owls increased substantially on their lands during 2005-2013 (Figure 4.7). Barred owls were detected within one mile of 47 (45%) NSO activity centers on these lands in 2013. The number of NSO territories with barred owl detections increased by 113% during 2010-2013. Mendocino Redwood Company (2014) noted that barred owls have been detected within one mile of 71 NSO activity centers on their lands since 2005. The Conservation Fund (in Calforests 2014), which manages lands in Mendocino and Sonoma Counties, stated that barred owls have been detected "across their ownership" since 2009. They currently have four sites at which barred owls are "regularly detected" and another area in which they are "occasionally detected".

Figure 4.6: Number of barred owl detections within 0.5 mile of northern spotted owl activity centers on Humboldt Redwood Company lands during 2003-2013 (from Humboldt Redwood Company 2013).

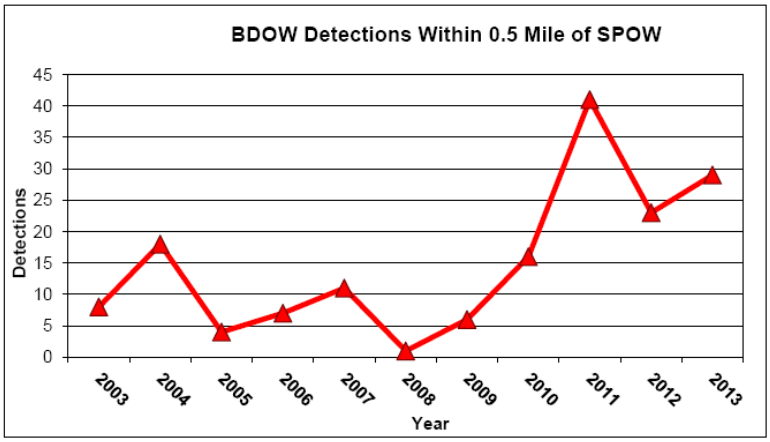
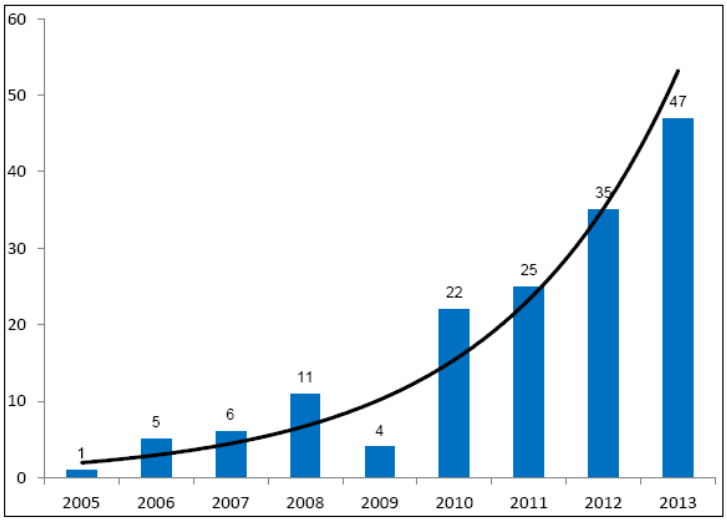


Figure 4.7: Percent (y-axis) and number of northern spotted owl territories (1 mi radius around activity centers) on Mendocino Redwood Company lands with barred owl detections during 2005-2013 (note: the apparent decline in NSO territories with barred owl detections in 2009 coincided with a substantial dip in NSO survey effort) (from Mendocino Redwood Company 2014).



There is relatively little information concerning barred owl numbers on private timberlands in California's Eastern Klamath and Southern Cascade regions. In 2013, Sierra Pacific Industries confirmed barred owl occupancy at 14 of 28 known/historical barred owl sites within their Redding and Weaverville Districts (eastern Klamath and Southern Cascades regions) and located two additional sites (SPI 2014). I was unable to locate any reports of barred owl presence or trends within NSO territories on Sierra Pacific lands. Fruit Growers Supply Company (in Calforests 2014) reported barred owl detections within or "nearby" (distance not reported) five NSO activity centers in Siskiyou County. It was unclear whether these numbers were cumulative or from 2013 alone. Michigan-California Timber Company (in Calforests 2014) reported that barred owls were detected at one site on their lands in Siskiyou County in 2010 and 2012 and two sites in 2009 and 2013. Crane Mills (in Calforests 2014) has detected only one barred owl on their lands in Shasta County. Roseburg Resource Company (in Calforests 2014) has never detected a barred owl during their NSO surveys on lands in Siskiyou and Shasta Counties. The low numbers of barred owl detections on some private timberlands in California's Eastern Klamath and Southern Cascades regions is surprising given the numbers of detections on the Shasta-Trinity and Klamath National Forests and on Sierra Pacific Industries lands in those regions (Figure 4.4), as well as in the Klamath and Southern Cascades demographic study areas in southern Oregon (Davis et al. 2013, Dugger et al. 2014). It is unclear if this is due to differences in survey effort, ecological conditions, management histories, or other factors.

In summary, the barred owl's range now completely overlaps the NSO's range and partially overlaps the California spotted owl's range. Barred owls rapidly expanded their range southward from British Columbia, through Washington and Oregon, and into northern California. The species' range expansion into California appears to have occurred first and most rapidly in northern coastal forests and near the margin of the southern Cascades and northern Sierra

Nevada. The available information suggests that there is currently a high potential for interactions between NSOs and barred owls throughout much of NSO's range in California. The barred owl invasion does not appear to have peaked in the state. Rather, the information reviewed above suggests that the species is continuing to expand into drier, interior portions of California and that their presence in NSO territories is increasing at accelerating rates in the Western Klamath and Redwood regions.

Effects on NSOs

Scientific Uncertainty

There is currently little reliable information concerning trends in barred owl densities or population numbers. Most of what is known about the potential for barred owl interactions with NSOs is based on incidental detections of barred owls during NSO surveys (USFWS 2013). Reliance on NSO surveys limits many studies' inferences concerning barred owl numbers. Gutiérrez et al. (2004) noted that some studies found large numbers of historical NSO territories apparently vacant of both NSOs and barred owls. It is unclear if these vacancies were primarily due to inadequate survey effort for one or both species or if they were caused by some other factor (Gutiérrez et al. 2004). Some of this uncertainty has been reduced due to increased survey effort required by revised survey protocols for NSOs (e.g., USFWS 2012c) and implementation of barred owl-specific surveys in some areas. Inferences from studies of barred owl effects on NSOs are further limited by the observational and retrospective nature of most research of this topic (Livezey and Fleming 2007, USFWS 2013). Most studies of barred owl effects on NSOs have examined correlations between changes in NSO occupancy or demography and barred owl presence near NSO activity centers (see below). These studies do not definitively prove that barred owl presence causes changes in NSO occupancy or demography. However, preliminary results of barred owl removal experiments more directly support conclusions that barred owl presence negatively affects NSOs in a variety of ways (see below).

Hybridization

At the time of the NSO's listing there was concern among some researchers that hybridization between spotted owls and barred owls would lead to the loss of the spotted owl as a distinct species (Gutiérrez et al. 2004). Despite genetic, morphological, ecological, and behavioral differences between spotted owls and barred owls, there appear to be few strong isolating mechanisms to prevent them from interbreeding (Gutiérrez et al. 2007). Yet, hybridization between the two species appears to be relatively rare. For example, an extensive review of NSO survey and banding records from 1970-1999 in Oregon and Washington found reports of only 47 NSO-barred owl hybrids (Kelly and Forsman 2004). Hybridization therefore appears to pose little threat to NSOs compared with the effects of competition (Kelly and Forsman 2004; see below). However, hybridization could become a more serious issue in the future as NSOs continue to decline and become less able to locate conspecific mates (Gutiérrez et al. 2007).

Demography

Forsman et al. (2011) evaluated demographic trends for NSOs in 11 demographic study areas during 1985-2008. They found that NSO reproduction (fecundity) was negatively associated with the presence of barred owls (≤0.62 mi from NSO activity centers) in four study areas, including Green Diamond's in California. Inclusion of the barred owl covariate in one of the best performing models in the meta-analysis of reproduction across all study areas provided weak support for an effect of barred owl presence on reproduction throughout the NSO's range (Forsman et al. 2011). The negative association between reproduction and barred owl presence was likely underestimated since researchers often cannot relocate NSOs displaced by barred owls, and many displaced NSOs may be unable to find new territories and reproduce (Forsman et al. 2011). Apparent survival of NSOs was negatively associated with the presence of barred owls in six of the study areas, including Northwest California and Green Diamond (95% confidence intervals did not overlap zero or only slightly overlapped zero). The meta-analysis for all study areas showed a negative association between barred owl presence and apparent survival and recruitment, although the evidence for an effect on recruitment was statistically weak. Populations in seven study areas, including Northwest California and Green Diamond, declined during the latter portion of the study period (95% confidence intervals did not overlap zero or only slightly overlapped zero for these areas). Model selection results for the meta-analysis of population change indicated support for models that included the barred owl covariate. Forsman et al. (2011) noted that, of the various factors evaluated for potential effects on NSO vital rates, negative associations with the presence of barred owls were the strongest and most consistent among study areas. Forsman et al. (2011) also noted that they likely underestimated these negative associations by applying the barred owl covariate at the population scale rather than the territory scale. Studies of associations between NSO occupancy rates and barred owl presence suggest that the territory is a more appropriate spatial scale for detecting effects of barred owls on NSOs (see below).

Annual reports from NSO demographic studies in the southern portion of the subspecies' range indicate that negative effects of barred owls on NSO demographic and occupancy rates continued to increase following the study period covered by Forsman et al. (2011) (Davis et al. 2013b, Higley and Mendia 2013, Dugger et al. 2014, Franklin et al. 2014, Green Diamond Resource Company 2014; see Ch. 1). The Northwest California and Hoopa study areas experienced dramatic declines in demographic rates subsequent to the end of the 2011 meta-analysis study period and the declines appeared to be largely driven by increasing competition from barred owls (Higley and Mendia 2013, Franklin et al. 2014). Strong negative effects of barred owls on NSO demography will likely be evident for most or all demographic study areas in the forthcoming meta-analysis, which is due for release in 2015.

Occupancy

Numerous studies distributed across the NSO's range have found evidence of a negative effect of barred owl presence on occupancy by the subspecies (Kelly 2001, Kelly et al. 2003, Pearson and Livezey 2003, Gremel 2005, Olson et al. 2005, Kroll et al. 2010, Dugger et al. 2011, Higley and Mendia 2013, Franklin et al. 2014, Green Diamond Resource Company 2014). These findings

suggest that barred owls are causing large-scale displacement of NSOs and that negative effects of barred owls are largely due to interference competition between the two species (see below).

Gremel (2005) found that occupancy by pairs of NSOs in the Olympic National Park in Washington declined significantly at sites with barred owl presence, whereas pair occupancy remained stable at sites without barred owl detections. During 1992-2003 in this study area, the number of barred owl detections in NSO sites per number of survey days increased by 15% per year. During the same period, mean occupancy by NSOs declined from 61% to 42% in sites with barred owl detections.

In the southwestern Washington Cascades, Pearson and Livezey (2003) found a 9% annual increase in the number of barred owl detections relative to the number of NSO detections during 1982-2003. Unoccupied historical NSO core areas (500 ac) had significantly more barred owl activity centers at three spatial scales (0.5, 1.0, 1.8 mi) than did occupied core areas.

Kelly et al. (2003) evaluated potential effects of barred owl presence on NSO occupancy in five demographic study areas in Washington and Oregon. Their analyses indicated that barred owls had a stronger negative effect on NSO occupancy when located closer to activity centers than when farther away. Occupancy by NSOs exhibited a highly significant decline when barred owls were detected within 0.5 mile of activity centers ($P = 0.001$), compared with a lower tendency to decline when barred owls were detected farther away ($P = 0.06$).

Olson et al. (2005) examined associations between NSO occupancy dynamics and the presence of barred owls near activity centers (distance not reported) in three study areas in western Oregon. Barred owl presence was low (detected near <10% of NSO sites each year) in all three study areas during the first eight years of the study (1990-1997), increased substantially in one of the study areas thereafter (maximum of 28% of sites in 2001), and more gradually in the other two (ca. 10% of sites in 2001). Despite relatively low barred owl presence (e.g., compared with Forsman et al. 2011, Figure 4.2), site occupancy probabilities for NSO pairs decreased by 5-15% with increasing barred owl presence.

In one of the western Oregon demographic study areas evaluated by Olson et al. (2005) (Tyee), Bailey et al. (2009) found no evidence of an effect of barred owl presence on NSO occupancy during 2002-2003. They cautioned however, that their study's inferences were weak since barred owl presence was relatively low at the time of the study (detections in <12% of NSO territories based on Olson et al. 2005). Just five years after their study period ended, barred owls were detected in 70% of NSO territories (0.62 mi around activity centers) in the study area (Forsman et al. 2011; Figure 4.2).

In the eastern Cascades of Washington, Kroll et al. (2010) found that the mean probability of occupancy by NSOs was significantly lower for sites with barred owl presence (0.50) than without it (0.76) (presence not spatially defined in the paper). Although the percent of NSO sites with barred owl detections was moderate compared with some areas (max. ca. 33% [estimated from graph] vs. Figure 4.2), site occupancy probabilities for NSOs declined by about 50% during 1990-2003.

In the southwestern Cascades of Oregon, Dugger et al. (2011) found significant differences in mean annual occupancy for NSO pairs with nearby barred owl detections (presence not spatially defined) than in those without. During the latter 13 years of the study, mean annual site occupancy was approximately 10-15% at sites with barred owl presence compared with about 58-78% at sites without barred owl presence (estimated from graph).

Both the Northwest California and Hoopa demographic studies reported dramatic recent declines in NSO occupancy coincident with rapid increases in the percent of NSO territories with barred owl presence (Higley and Mendia 2013, Franklin et al. 2014; e.g., Figure 4.3). Both studies reported sharp declines in NSO numbers and occupancy in the mid-2000s subsequent to a longer period of gradual decline (e.g., Figure 4.3). These observations suggest that the barred owl expansion and its effects on NSOs in the Western Klamath rapidly changed after a post-colonization lag period elapsed or when a crucial threshold in barred owl density was reached.

Green Diamond Resource Company is currently conducting an experiment to evaluate the effects of lethally removing barred owls from NSO territories in California's Redwood Province. Preliminary results from this study suggest that removal of barred owls results in rapid recolonization of sites by NSOs. Green Diamond Resource Company (2014) reported a 43% increase in the number of sites occupied by NSOs in their treatment (barred owl removal) area during the first year (2008 to 2009) and an additional 9% increase the following year (2009 to 2010). In contrast, the number of sites occupied by NSOs in an adjacent control portion of the study area (no barred owl removal) was virtually unchanged from 2008 to 2009 and declined by 23% from 2009 to 2010. However, the degree to which barred owl removal positively affected NSO occupancy in this study is difficult to evaluate. The beginning of Green Diamond's removal study roughly coincided with implementation of a new survey protocol which likely resulted in greater detections of both NSOs and barred owls. Future analyses from this study should provide clearer insight into the effects of barred owl presence and removal on NSO occupancy.

Habitat Use

Dugger and Davis (2011) stated that "the relationship between spotted owl fitness and habitat characteristics may have become disconnected through interspecific competition with barred owls." They based this hypothesis on their finding that mean habitat suitability at NSO pair locations within the Northwest Forest Plan area decreased by approximately 9% between 1994/1996 and 2006/2007 (Davis and Dugger 2011). This decline in mean habitat suitability at NSO pair locations did not appear to be solely due to a loss of suitable breeding habitat, which declined by about 3% in this area during the study period. This hypothesis is also supported by findings that NSOs in the northern portion of their range are often displaced by barred owls into steeper and higher elevation areas (Pearson and Livezey 2003, Gremel 2005, Hamer et al. 2007). Hamer et al. (2007) suggested that displacement of NSOs to higher elevation forests could result in reduced survival or reproduction during years with severe winters. Wiens et al. (2014) found a high degree of overlap in the habitat associations of NSOs and barred owls in western Oregon (e.g., strong selection of old conifer forest). Their best model of habitat use indicated that NSOs were less likely to use locations within or in close proximity to the core-use area of a barred owl.

This finding provides further evidence that barred owls displace NSOs from their preferred habitat.

Territorial Behavior

Barred owl presence and calling is associated with reduced responsiveness of spotted owls to conspecific calls, including survey broadcasts (Olson et al. 2005, Crozier et al. 2006, Bailey et al. 2009, Kroll et al. 2010). This is partially of interest to researchers and land managers because it influences the field and analytical methods required for measuring occupancy by NSOs (Olson et al. 2005, USFWS 2012c). Reduced vocalizing by NSOs in the presence of barred owls is also of concern because NSOs rely on vocalizations to defend their territories, locate vacant territories and potential mates, form pair bonds, and announce prey deliveries (Gutiérrez et al. 1995). Widespread disruption of these activities could impact NSO demographic rates.

Interspecific Competition

Gutiérrez et al. (2004) described the ecological and morphological separation that exists among sympatric owls worldwide. Their review found that species within the same genus are generally segregated by geographic range or habitat associations. It also showed that sympatric congeneric owls are usually strongly divergent in size, which varies with diet and possibly, hunting mode. Spotted owls and barred owls are both members of the genus *Strix*. Gutiérrez et al. (2004) noted that the two species only differ in body mass by 18%, which is likely too little to allow coexistence. A building body of evidence indicates that barred owls indeed negatively affect spotted owls (reviewed above), and that this occurs through both direct (interference) and indirect (exploitative) competition (Gutiérrez et al. 2004, 2007, USFWS 2013; see below). Wiens (2012) stated that "when viewed collectively, the behavioral and life history traits exhibited by barred owls may give them a significant advantage over spotted owls when competing for critical resources such as space, habitat, and food."

Surveyors have observed barred owls attacking spotted owls and have themselves been attacked while imitating spotted owl calls (Gutiérrez et al. 2004). There is also limited evidence of barred owl predation of NSOs. Leskiw and Gutiérrez (1998) provided strong circumstantial evidence that a barred owl killed and partially consumed an NSO in Redwood National Park, California. Johnston (2002 cited in Gutiérrez et al. 2004) found circumstantial evidence of barred owl predation of a juvenile NSO in the southern Oregon Cascades. However, most cases of barred owl aggression toward NSOs appear to be a related to territorial defense, rather than predation (USFWS 2013).

Studies in Washington found that barred owl home ranges are relatively small and tend to have little overlap, which is consistent with aggressive territorial behavior (Hamer et al. 2007, Singleton et al. 2010). In contrast, neighboring NSO home ranges often broadly overlap, particularly during winter (Hamer et al. 2007). There is limited anecdotal evidence of spotted owls aggressively interacting with barred owls (Gutiérrez et al. 2004), and spotted owls appear to reduce detection probabilities for barred owls (Bailey et al. 2009). Nonetheless, barred owls generally exhibit higher levels of vocal and physical aggression than do NSOs and are typically dominant during interactions between the two species (Van Lanen et al. 2011). Significantly

reduced detection probabilities for NSOs in the presence of barred owls provides further evidence of the larger, more aggressive barred owl's behavioral dominance over NSOs (see above).

Barred owls are dietary generalists compared with NSOs (USFWS 2013, Wiens et al. 2014). As dietary generalists, barred owls may be better able to colonize a wider variety of habitats than NSOs and may be more resilient to fluctuations in prey populations (USFWS 2013). The barred owl's generalist diet is likely a primary reason for the species' relatively small home ranges and associated ability to occur at high densities (see below). Furthermore, because barred owl diets overlap with those of NSOs, it is possible that they negatively affect NSOs by depressing populations of key prey, such as northern flying squirrels and woodrats (Gutiérrez et al. 2007, USFWS 2013).

The barred owl's habitat associations in the Pacific Northwest and California are poorly understood. As discussed earlier, most barred owl detections are incidental to spotted owl surveys so relatively little is known about the ecology of barred owls outside of areas occupied by spotted owls. Early studies of the barred owl's habitat associations in the Pacific Northwest suggested that the species is more associated with younger forest types than are NSOs (Gutiérrez et al. 2007). However, subsequent research has found that barred owls use a variety of habitats and, like NSOs, often show a preference for old forest (Gutiérrez et al. 2007, USFWS 2011a, Wiens et al. 2014). Thus, barred owls appear to be capable of occupying a broader variety of habitat types than NSOs but the two species likely compete for access to mature and old forest. The two species may also compete for nest sites since they both rely on the same kinds of pre-existing nest structures (Gutiérrez et al. 2007). Together, overlapping habitat associations with NSOs, use of a broader range of habitat types, and the ability to occur at relatively high densities allows barred owls to form large source populations in close proximity to NSOs (USFWS 2013).

Perhaps due to their generalist diet, barred owls often have substantially smaller home ranges than do NSOs (Gutiérrez et al. 2007, USFWS 2013). Estimates of barred owl home ranges in Washington were three to nine times smaller than those of NSOs in the state (Hamer et al. 2007, Singleton et al. 2010). Barred owl home ranges in the Oregon Coast Ranges were two to four times smaller than those of NSOs (Wiens et al. 2014). There does not appear to be any existing research comparing the home range sizes of barred owls and NSOs in California (Gutiérrez et al. 2007). Annual home range sizes for NSOs (100% minimum convex polygon) in the California and Oregon Klamath Provinces varied among studies and with forest types and contiguity but were similar to or somewhat larger (0-60% larger) than those for barred owls in the Oregon Coast Ranges (Sisco 1990, Carey et al. 1992, Zabel et al. 1993, Irwin et al. 2006). The NSO's smaller home ranges in California suggest that they may have lower encounter rates with barred owls than occurs in Oregon and Washington. However, it is possible that barred owls also have smaller home ranges in California. Estimates of barred owl home range sizes in California are needed.

Wiens et al. (2014) found that barred owls in the Oregon Coast Ranges had a slightly higher annual survival probability than sympatric NSOs (0.92 vs. 0.81; not statistically significant) and that pairs produced an average of 4.4 times as many young. Barred owls have a wider range of clutch sizes than NSOs (1-5 vs. 1-3), are capable of laying additional clutches within a season if

the first is lost, and appear to exhibit lower annual fluctuations in reproduction (USFWS 2013). The USFWS (2013) noted that "the ability of barred owls to forage on a wider diversity of prey species and in a wider diversity of habitats may explain their reproductive success in comparison with spotted owls." There is a need for further research of the barred owl's natural history and ecology within the range of the NSO (Gutiérrez et al. 2007, Livezey and Fleming 2007). However, the currently available information indicates that the demographic performance of barred owls is superior to that of NSOs.

Overall, barred owls appear to primarily impact NSOs through interference competition for space, habitat, and food, although they may also indirectly affect NSOs by depressing prey populations (Gutiérrez et al. 2007, Hamer et al. 2007, Van Lanen et al. 2011, USFWS 2013, Wiens et al. 2014). Barred owls are generally superior competitors to NSOs in terms of size, aggression, demographic performance, and ability to exploit a wider array of habitats and prey (Gutiérrez et al. 2007, USFWS 2013, Wiens et al. 2014).

Barred Owl Management

The information reviewed above indicates that barred owls pose a serious and increasing threat to NSOs throughout their range, including in California. Barred owl presence in NSO territories has continued to increase across the NSO's range and appears to have strongly contributed to declining NSO demographic and occupancy rates. Barred owl presence can also reduce the ability of biologists and land managers to effectively locate and conserve NSOs. Given the negative effects of barred owls on NSOs, it is clear that policymakers and land managers must address the barred owl threat if successful recovery of the NSO is to remain a conservation priority. Current proposals for addressing the barred owl threat include barred owl removal and habitat conservation.

Some researchers have expressed concern that barred owl removal experiments would be costly, ineffective, and distracting (Livezey 2010, Rosenberg et al. 2012). However, preliminary results from barred owl removal experiments indicate that lethal removal of barred owls is effective, relatively inexpensive, and conforms to animal welfare standards (Diller 2013, Diller et al. 2013, Higley 2014). Other objections to barred owl removal are primarily ethical or emotional (Gutiérrez et al. 2007, Diller 2013). There is substantial emotional resistance to lethal removal of barred owls, even among scientists and land managers involved with barred owl removal experiments (e.g., Diller 2013). Relocation of barred owls to zoos or their native forests in the eastern U.S. is logistically and politically unfeasible, so killing barred owls appears to be the only viable removal option (USFWS 2013). Primary ethical concerns regarding barred owl removal include whether or not it is appropriate to remove or control a native species or to intervene in its potentially natural range expansion (USFWS 2013). The USFWS (2013) reviewed scientific literature regarding the barred owl's status as a native or nonnative species and whether its range expansion was natural or human caused. It found that the literature was inconclusive regarding both issues. However, it concluded that humans are responsible for intervening in the barred owl's expansion because the NSO's vulnerability to barred owl competition and other stressors is due to timber harvesting and other past and continuing human activities. Regardless, the currently available evidence suggests that NSOs will continue to

decline, and could ultimately become extinct, without widespread or strategic barred owl control measures.

The barred owl's increasing impact on NSOs in Late Successional Reserves, National Parks, and other reserved lands demonstrates that habitat protection alone is insufficient for addressing the barred owl threat (Gutiérrez et al. 2004). Nonetheless, habitat conservation remains crucial to the NSO's conservation (USFWS 2011a). The importance of retaining suitable breeding habitat for NSOs has been well demonstrated at individual, territory, and population scales (e.g., Solis and Gutiérrez 1990, Franklin et al. 2000, Forsman et al. 2011; see Ch. 2). Habitat conservation might also be important for minimizing barred owl impacts on NSOs (USFWS 2011a). Habitat loss and fragmentation due to timber harvesting or other disturbances could intensify competition between NSOs and barred owls by bringing them into closer proximity (Gutiérrez et al. 2007, USFWS 2011a). Dugger et al. (2011) found some support for this hypothesis in their study of NSO occupancy in southern Oregon. Their results indicated that barred owl presence and landscape-level habitat characteristics have additive effects on NSO occupancy rates. Specifically, the presence of barred owls appeared to exacerbate the negative effects of habitat loss and fragmentation on NSO occupancy. The USFWS (2011a) suggested that retaining and restoring habitat may provide displaced or recruited NSOs with refugia from negative interactions with barred owls (USFWS 2011a). Dugger et al. (2011) did not find direct support for this hypothesis. In their study, higher amounts and lower fragmentation of older forest did not reduce the negative effects of barred owls on NSO occupancy. However, they noted that some NSOs in their study continued to survive and successfully reproduce in areas with barred owl presence, possibly indicating that there are ecological conditions under which the two species can coexist. Additional and more direct research of the potential value of habitat refugia for NSOs is needed.

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Ch. 5: Outdoor Marijuana Cultivation

Introduction

Although marijuana is perhaps the largest cash crop in California (Gettman 2006), little is known about environmental effects associated with its cultivation. Recent research has indicated that outdoor marijuana cultivation is currently having widespread and profound environmental impacts in California (Gabriel et al. 2012, 2013, Thompson et al. 2014, Bauer et al. 2015). Negative impacts of outdoor marijuana cultivation include wildlife deaths caused by pesticide exposure and poaching; habitat degradation caused by logging, road construction, pollution, and water diversion; and heightened safety concerns for research and resource personnel (Gabriel et al. 2012, 2013, Thompson et al. 2014, Bauer et al. 2015). The specific effects of outdoor marijuana cultivation on NSOs are unknown. Recent findings of widespread pesticide exposure among fishers (*Pekania pennanti*) and barred owls in northwestern California suggest that NSOs within the state are likewise exposed and could be experiencing the same effects seen in fishers (Gabriel et al. 2012, 2014). NSOs could also be directly affected by environmental degradation from outdoor marijuana cultivation via habitat modification (e.g., clearing or logging) or suppression of rodent populations (poisoning), or indirectly affected through ecological changes caused by reduced streamflows or pollution (e.g., impacts on vegetation or prey from reduced water availability). Safety concerns associated with illegal marijuana cultivation may also be impacting NSOs and other wildlife through reduced research and survey efficiency and effort (Gabriel et al. 2013).

Pesticides

Pesticide application is usually intended to suppress populations of rodents, insects, mollusks, and other agricultural and urban pests, but can have inadvertent negative impacts on humans, pets, and other non-target animals (Erickson and Urban 2004, Albert et al. 2010, Mnif et al. 2011, Gabriel et al. 2012). Widespread secondary exposure to pesticides has been reported for raptors, carnivores, and other wildlife that consume poisoned rodents around farms and human dwellings (Albert et al. 2010, Murray 2013). Researchers have generally assumed that pesticides pose little threat to wildlife outside of agricultural and urban areas (Gabriel et al. 2013). However, a recent publication reported that 79% of fishers tested in two study areas on federal and tribal forest lands in California had been exposed to anticoagulant rodenticides (ARs), including four that died from lethal toxicosis (Gabriel et al. 2012; note: at least two more fishers in California died from AR poisoning following publication of this study: Gabriel et al. 2013). Most fishers in the study had been exposed to multiple AR compounds (range = 1-4, mean = 1.6). These findings not only raised concern for the West Coast fisher population, which the U.S. Fish and Wildlife Service recently proposed to list as threatened under the federal Endangered Species Act, but for the NSO, which overlaps the fisher in terms of distribution, habitat associations, and diet (Gabriel et al. 2013, Calforests 2014, USFWS 2014). Subsequently, ARs have been detected in a dead NSO recovered in Mendocino County (Calforests 2014) and 34 of 84 (40%) barred owls tested for exposure in Humboldt County (Gabriel et al. 2014). Although barred owls were tested as a proxy for NSOs, NSOs may be more widely exposed to ARs given their greater dietary specialization on rodents (see USFWS 2013). Strong circumstantial evidence implicates pervasive illegal outdoor marijuana cultivation

as the primary source of pesticide exposure for forest predators in California (Gabriel et al. 2012, 2013, Thompson et al. 2014).

ARs detected in fishers in northwestern California include brodifacoum, bromadiolone, chlorophacinone, diphacinone, and warfarin (Gabriel et al. 2012). Brodifacoum and bromadiolone are classified as second-generation anticoagulant rodenticides (SGARs). SGARs were introduced in the 1970s due to widespread development of resistance among rodents to first-generation anticoagulant rodenticides (FGARs), such as warfarin, chlorophacinone, and diphacinone (Buckle et al. 1994). SGARs are more acutely toxic than FGARs and generally require only a single dose to kill rodents (Erickson and Urban 2004). However, rodents usually survive 5-10 days after consuming a lethal dose, during which time they may continue to consume additional rodenticide and remain available to predators (Cox and Smith 1992, Erickson and Urban 2004). SGARs are more persistent in animal tissues than FGARs and insecticides, which are more rapidly metabolized and excreted (Erickson and Urban 2004). Thus, exposure to FGARs and other non-SGAR pesticides is more difficult to detect than for SGARs and exposure to them could be underestimated (Albert et al. 2010, Thompson et al. 2014). Rodents, such as dusky-footed woodrats (*Neotoma fuscipes*) and deer mice (*Peromyscus* spp.), may be the primary source of AR exposure for NSOs because they are targeted by AR application and because they generally comprise most of the biomass in NSO diets (Forsman et al. 2004). Insects may be an additional source of AR exposure for NSOs and other wildlife. In terms of frequency of consumption, insects can substantially contribute to NSO diets regionally, locally, or seasonally (e.g., 1-14% of prey items in various regions of Oregon: Forsman et al. 2004). Insects are not killed by ARs and may therefore continue to accumulate them in their tissues, essentially becoming small “packets” of AR (Gabriel et al. 2014).

Large quantities of ARs, particularly SGARs, are often spread across large areas in and around illegal outdoor marijuana grow sites (Gabriel et al. 2012, Thompson et al. 2014; Figure 5.1). Gabriel et al. (2012) noted that thousands of pounds of pesticides were found at illegal outdoor marijuana grow sites in California in 2008 and that 150 pounds of pesticide were found during a single three-week eradication operation on the Mendocino National Forest in 2011. Three sites raided in Humboldt County in 2013 contained a total of at least 17 pounds of SGAR bait, which researchers estimated was sufficient to kill 2,753 woodrats, 14 fishers, or five spotted owls (Humboldt County Sheriff’s Office press release). Other pesticides, such as organochlorine, organophosphate, and carbamate insecticides, some of which are banned in the U.S., are also frequently found at illegal outdoor marijuana grow sites (HSVTC 2012, Thompson et al. 2014). Pesticides are often applied along with large quantities of fertilizer at the base of marijuana plants grown outdoors (Thompson et al. 2014; Figure 5.1), suggesting that marijuana and surrounding plants may be taking up pesticidal compounds from the soil. If this occurs, then rodents and insects may accumulate pesticides through consumption of plants as well as pesticidal bait. Investigation of pathways of pesticide exposure for NSOs, as well as levels of exposure and potential physiological, behavioral, and population impacts, is needed.

Figure 5.1: (A) Rodenticide and other pesticides found at a trespass outdoor marijuana grow site in Humboldt County (photo: Humboldt County Sheriff's Office) and (B) rodenticide bait and dry fertilizer strewn together below approximately 2,000 marijuana plants at a trespass outdoor grow site in Humboldt County (from Gabriel et al. 2012).

ARs are vitamin K antagonists, which cause impairment of the blood's ability to clot (Murray 2013). A lethal dose of AR causes animals to die from hemorrhage (Erickson and Urban 2004). Animals may also exhibit weakness prior to death or with a sublethal dose (Erickson and Urban 2004). Rodents exposed to ARs show altered behavior, such as spending more time in the open, freezing rather than bolting when threatened, and staggering (Cox and Smith 1992). These behaviors may increase predation risk for affected rodents and the opportunity for secondary exposure of predators to ARs (Cox and Smith 1992). Owls and other raptors with sublethal secondary exposure to ARs may often have reduced blood-clotting activity and can die from minor wounds such as those commonly inflicted by prey (Erickson and Urban 2004, Murray 2013, Thompson et al. 2014). Non-AR pesticides have a variety of physiological effects, such as disrupting endocrine function or damaging the central nervous system (Grue et al. 1997, Mnif et al. 2011). Chronic or sublethal exposure to carbamate or organophosphate pesticides has been shown to reduce immune response, cause neurological disorders, reduce thermoregulatory control, and impair anti-predator behavior in wildlife (Grue et al. 1997; reviewed in Thompson et al. 2014). Pesticides can also have additive or synergistic effects on animals (Larsen et al. 2003 cited in Mnif et al. 2011, Relyea 2009). This is a source of additional concern for NSOs and

other forest predators active near outdoor marijuana cultivation sites, where multiple types of pesticide are often present (HSVTC 2012, Thompson et al. 2014). Mortalities associated with exposure to pesticides are likely underestimated because carcasses are often predated or scavenged before biological samples can be obtained and because sublethal exposure can predispose wildlife to death from other causes (Albert et al. 2010).

There is no information available concerning population-level impacts of secondary pesticide exposure for NSOs in California. As reviewed above, secondary exposure to pesticides can kill raptors and other wildlife both through lethal toxicosis and by increasing the risk of mortality due to other factors such as predation, hypothermia, disease, parasites, or injury. NSO population rates are particularly sensitive to changes in adult survival (Noon and Biles 1990) so it is possible that direct and indirect mortalities associated with pesticide exposure could contribute to population declines (Sibly et al. 2000, Thompson et al. 2014). Pesticide exposure could also negatively impact NSO reproduction. Gabriel et al. (2012) noted that fisher mortalities caused by AR poisoning occurred between mid-April and mid-May. The timing of these deaths coincided with the planting phase of outdoor marijuana cultivation, when seedlings are most vulnerable to rodent pests and AR use is likely highest (Gabriel et al. 2012). This time of year is also when NSOs incubate and brood young (Gutiérrez et al. 1995). Reduced parental care during this phase, for example due to compromised behavior or death of one or both parents, could result in death of offspring due to exposure, undernourishment, or predation (Grue et al. 1997). NSO populations could also be negatively impacted by pesticide suppression of prey populations or changes in community ecology caused by reductions of insects, small mammals, carnivores, raptors, amphibians, and aquatic animals. For example, pesticide impacts on plants, herbivores, or predators could cause wider ecological effects through trophic cascades (Relyea and Diecks 2008).

Other Environmental Effects

Activities related to outdoor marijuana cultivation can have a variety of environmental impacts beyond exposure of wildlife to pesticides, including negative effects of illegal and poorly planned water diversion, logging, and road construction; pollution of water and soils; poaching of wildlife; and ignition of wildfires (reviewed below). Negative impacts occur on both public and private lands (Gabriel et al. 2013, Bauer et al. 2015). However, the potential environmental impacts of marijuana cultivation could vary considerably, depending on the operation's location, scale, and practices. For example, some marijuana industry organizations and growers advocate growing practices aimed at minimizing environmental damage from outdoor cultivation (e.g., http://emeraldgrowers.org/). There does not appear to be any information available at this time regarding effects of ecological degradation from marijuana cultivation on NSOs. Negative effects on NSOs are possible given the subspecies' sensitivity to habitat modification (see Ch. 2 and 3) and close association with riparian areas (e.g., Hamer et al. 2007, Irwin et al. 2012), where the impacts of marijuana cultivation are often concentrated. Furthermore, safety concerns associated with marijuana cultivation can substantially impact the ability of land managers to effectively survey and manage spotted owls and other sensitive wildlife (Keane et al. 2011, Gabriel et al. 2013, D. Hansen pers. obs.; see below).

Personnel with the California Department of Fish and Wildlife recently estimated hydrologic impacts of marijuana cultivation in northwestern California using high-resolution aerial imagery in Google Earth (Bauer et al. 2015; e.g., Figure 5.2) and marijuana industry estimates of marijuana plant water requirements. Using these methods, they estimated that more than 112,000 marijuana plants were cultivated in 2011/2012 in just four watersheds in Humboldt and Mendocino Counties (Table 5.1). Based on estimated numbers of marijuana plants and assumed water usage of 6 gallons per day per plant, they calculated that marijuana cultivation uses between 2% and 173% of the water that flows in the Redwood Creek and Salmon Creek watersheds per day during periods of minimum streamflow (Table 5.2). Although based on several assumptions (marijuana cultivation water sources and usage, complete visibility of cultivation sites in aerial imagery, complete usage of greenhouses), these estimates have raised considerable concern about potential negative impacts of marijuana cultivation on watershed health and aquatic animals. NSOs often exhibit a preference for nesting, roosting, and foraging in and near riparian areas (e.g., Hamer et al. 2007, Irwin et al. 2007). Thus, it is plausible that ecological changes caused by widespread water diversion for marijuana cultivation have negative indirect effects on NSOs.

Figure 5.2: Outdoor (A) and greenhouse (B) marijuana cultivation sites identified with Google Earth (from S. Bauer, unpubl.).

Table 5.1: Estimated numbers of outdoor marijuana plants, marijuana greenhouses, marijuana plants in greenhouses, total number of marijuana plants, and water use per day for marijuana cultivation in four watersheds in Humboldt and Mendocino Counties (from Bauer et al. 2015).

Watershed	Outdoor Plants	Green-houses (counted)	Total area, m^2 (Green-houses)	Estimated Plants in Green-houses	Estimated Total Plants in Watershed	Estimated Water Use per Day (Liters)
Upper Redwood Creek	4,434	220	20749.4	18,612	23,046	523,144
Salmon Creek	11,697	302	20557.5	18,440	30,137	684,110
Redwood Creek South	10,475	324	18703.9	16,777	27,252	618,620
Outlet Creek	15,165	266	18651.1	16,730	31,895	724,016

Table 5.2: Estimated percent of low stream flow used for marijuana cultivation in four watersheds in Humboldt and Mendocino Counties (from Bauer et al. 2015).

Watershed	Area (km^2)	Plants per km^2	Demand as percent of seven-day low flow	
			Percent of low flow maximum	Percent of low flow minimum
Upper Redwood Creek	175.3	131.6	2%	23%
Salmon Creek	95.1	316.9	36%	173%
Redwood Creek South	64.7	421.2	34%	165%
Outlet Creek	419.1	76.1	17%	>100%*

* The seven-day low flow minimum was measured as 0.0 CMS at the gage.

Marijuana growers on both public and private lands often illegally clearcut vegetation in order to create growing space for marijuana plants and room for artificial ponds and other structures (Gabriel et al. 2013, Bauer et al. 2015; Figure 5.3). Illegal cutting, along with creation of roads to access grow sites, can increase sedimentation in streams and creeks and thereby degrade habitat quality for aquatic and amphibious animals (Bauer et al. 2015). The effect of illegal vegetation clearing on NSOs is unknown. Given the close association of both marijuana cultivation and NSOs with riparian areas and surrounding uplands (e.g., Hamer et al. 2007, Irwin et al. 2007), it is plausible that widespread marijuana cultivation results in habitat loss or fragmentation for NSOs.

Figure 5.3: Areas cleared for outdoor marijuana cultivation on private and public lands, respectively.

Unidentified source.

C. Thompson.

Widespread outdoor marijuana cultivation can further damage watershed health by polluting water and soils. In addition to pesticides, tremendous quantities of fertilizer are often applied at marijuana grow sites (HSVTC 2012, Thompson et al. 2014). Fertilizers, along with low flows caused by drought conditions and water diversion, might contribute to algae blooms and reduced oxygen levels in creeks and rivers. Other pollution, including human waste, trash, and spilled diesel fuel from generators, is also frequently observed in and around streams at raided outdoor marijuana grow sites (HSVTC 2012, C. Thompson, pers. comm.). Like water diversion and increased stream sedimentation, pollution from outdoor marijuana cultivation is primarily a source of concern for aquatic and amphibious animals but could have indirect ecological effects on NSOs and other wildlife.

Multiple recent wildfires in California have been attributed to marijuana growers. For example, in 2014, a marijuana grower was indicted on charges of starting the Nicolls Fire that burned

nearly 1,700 acres in the Sequoia National Forest (SacBee 2014b). This grower allegedly set multiple fires in an attempt to avoid capture by other growers that he claimed were trying to kill him. Another marijuana grower was recently arrested for igniting the 2014 Bully Fire that burned nearly 13,000 acres in Shasta County (SacBee 2014a). This fire was apparently started when the grower's rental truck ignited dry grass when driven off-road in order to deliver soil amendments to a grow site. In 2009, a marijuana grower's camp stove ignited the 90,000-acre La Brea Fire in the Los Padres National Forest in southern California (inciweb). Large wildfires (e.g., thousands of acres) can burn through multiple NSO territories and can negatively affect NSOs in a variety of ways, particularly when they burn large areas at moderate to high severity (see Ch. 3).

Illegal marijuana growers are often heavily armed in order to protect their crops and for poaching wildlife for food or to prevent wildlife damage to plants, equipment, or food caches (Gabriel et al. 2013, Boehm 2014; Figure 5.4). Many biologists and other field personnel working in California's forests have been interrogated, pursued, or shot at by marijuana growers (Gabriel et al. 2013, D. Hansen pers. obs.). Safety concerns associated with widespread illegal marijuana cultivation can substantially curtail the ability of researchers and land managers to effectively locate, study, and manage spotted owls and other wildlife. For example, Six Rivers National Forest biologists were repeatedly excluded from entire pre-project NSO survey units in 2013 due to evidence of trespass outdoor marijuana cultivation (D. Hansen pers. obs.). Similarly, Keane et al. (2011) stated that their California spotted owl (*S. o. occidentalis*) survey crew was excluded from large portions of a study area in the Sierra Nevada in 2010 due to extensive illegal marijuana cultivation operations. Gabriel et al. (2013; M. Gabriel unpubl. data) estimated that safety concerns due to trespass outdoor marijuana cultivation resulted in exclusion of researchers from 15-25% of one fisher study area in California and a projected additional cost of $500,000-750,000 for the life of the combined budgets of two of California's fisher research projects. Wildlife surveyors who were able to work alone in the past must now frequently work in pairs for safety reasons, reducing survey efficiency and increasing project costs (Gabriel et al. 2013, D. Hansen pers. obs.). Exclusion from study areas can also compromise the ability of researchers to properly design and complete research investigating important conservation issues, such as effects of pesticides on fishers (Gabriel et al. 2013) and wildfires on spotted owls (Keane et al. 2011).

Figure 5.4: Armed marijuana growers posing in front of a poached deer (from Gabriel et al. 2013).

Magnitude and Location of Threat

Estimates of marijuana production and value are generally based on either federal marijuana seizure data (e.g., assuming that seizures represent 10 or 15% of the total amount produced) or marijuana consumption surveys and estimates of plant yields and market value (Gettman 2006) (reviewed in PBS 2014). Estimates from both of these methods indicate that California is, by far, the primary marijuana-producing state in the U.S. and that most of this production is from outdoor cultivation (NDIC 2011, Gettman 2006). Gettman (2006) estimated that, in 2006 alone, California produced an estimated 8.6 million pounds of marijuana with a value of more than 13.8 billion dollars. An estimated 89% of this product and value was from outdoor cultivation. If correct, marijuana is the largest cash crop in California (Gettman 2006), which is remarkable given that California is the most productive agricultural state in the U.S. (USDA 2014).

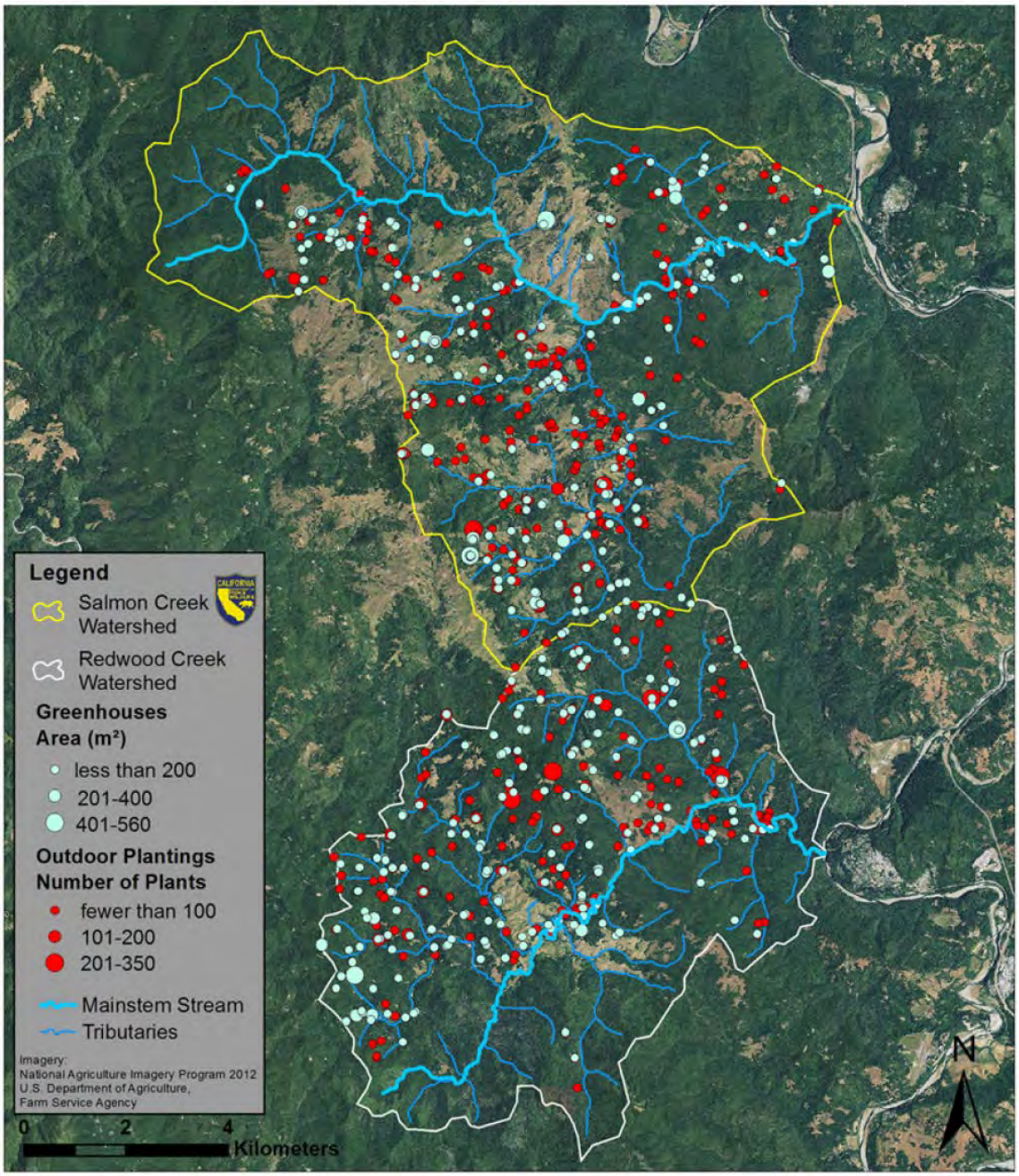
Outdoor marijuana cultivation in California has increased dramatically in recent years, including on both public and private lands (NDIC 2011, S. Bauer, unpubl. data). This rapid growth was due to increased demand for domestically grown marijuana; possibly driven by state legalization of marijuana for medical use, changes in public perception of health or legal risk associated with marijuana use, or reduced imports from other countries due to tighter border control measures implemented after 9/11 (NDIC 2007, 2011, SacBee 2012). However, rapid growth of marijuana production in California apparently outstripped consumer demand in the last few years, particularly following federal crackdowns on medical marijuana dispensaries in the state (SacBee 2012). Desire among growers to maintain high profits in the face of increasing supply and decreasing prices could be a factor driving recent increases in the size and intensity (e.g., use of pesticides, fertilizer, and water) of many outdoor marijuana cultivation operations.

The number of outdoor marijuana plants eradicated in the U.S. increased by 250% between 2005 and 2010 (NDIC 2011). Federal eradication data suggest that trespass outdoor marijuana cultivation is increasing particularly rapidly on National Forests in California (NDIC 2011).

Between 2005 and 2013, over 16 million marijuana plants were eradicated at approximately 3,356 sites on National Forests in California (Boehm 2014). Federal agencies have largely attributed increased numbers of trespass outdoor marijuana cultivation sites to expansion of operations by international drug trafficking organizations (e.g., Mexican drug cartels) into remote mountainous areas (particularly in northern California) in order to avoid detection by law enforcement personnel (NDIC 2007, Boehm 2014). However, the degree to which increases in amounts of eradicated or seized marijuana reflect increased production versus increased drug enforcement effort is unclear, as is the scale of international drug trafficking organizations' role in outdoor marijuana cultivation in California (NDIC 2010).

Outdoor marijuana production in California is also growing rapidly on private lands (NDIC 2007, S. Bauer, unpubl. data). Personnel with the California Department of Fish and Wildlife (S. Bauer, unpubl. data) used aerial imagery in Google Earth to estimate changes in the number and sizes of marijuana cultivation operations in four watersheds in Humboldt and Mendocino Counties during 2009-2012. In 2011 and 2012 they identified nearly 1,300 outdoor grow sites and more than 1,100 greenhouses likely used for marijuana cultivation in these watersheds (Table 5.1, S. Bauer, unpubl. data; e.g., Figure 5.5). The number and size of marijuana cultivation operations identified increased in all four watersheds by 68-104% between 2009 and 2012 (S. Bauer, unpubl. data). The total number of greenhouses and the number of greenhouses greater than 1,000 ft^2 increased by 69% and 87%, respectively. Continued use of aerial imagery and flyovers will shed greater light on the number, size, and location of outdoor marijuana operations on both public and private lands. For example, the California Department of Fish and Wildlife (2012) noted that law enforcement officers spotted more than 200 new marijuana grow operations in the Mattole Watershed in Humboldt County during a single flyover.

Figure 5.5: Locations and sizes of marijuana cultivation operations identified in the Salmon Creek and Redwood Creek South Watersheds using aerial imagery in Google Earth (from Bauer et al. 2015).



Summary and Management Implications

There is currently little direct information regarding potential impacts of illegal outdoor marijuana cultivation on NSOs. However, widespread application of ARs and other toxicants at outdoor grow sites are negatively impacting fishers, which have overlapping home ranges and

diets with NSOs in northwestern California (Gabriel et al. 2012, 2013, Thompson et al. 2014). There is also evidence of widespread exposure to toxicants among barred owls in Humboldt County, and an NSO from Mendocino County recently tested positive for ARs (Calforests 2014, Gabriel et al. 2014). Thus, it is likely that NSOs in California are widely exposed to toxicants applied at illegal outdoor marijuana grow sites. ARs and other pesticides can directly kill owls and other raptors or increase their vulnerability to other sources of mortality such as predation, disease, parasites, hypothermia, or injury (reviewed above). Furthermore, illegal outdoor marijuana cultivation is apparently causing widespread environmental degradation through toxicant exposure in other animals, reduced streamflows, pollution, poorly planned logging and road construction, and wildlife poaching (Gabriel et al. 2013, Bauer et al. 2015). Safety concerns associated with the widespread presence of heavily armed marijuana growers may also be impacting conservation of spotted owls and other wildlife by reducing the efficiency and effectiveness of research and survey efforts (Keane et al. 2011, Gabriel et al. 2013, D. Hansen pers. obs.).

Increased funding and effort are needed for evaluation of effects of outdoor marijuana cultivation on NSOs, other wildlife, and ecosystems. Greater funding and coordination are also needed for interdiction, clean-up, and restoration at illegal outdoor grow sites. These efforts require a substantial, multi-agency law enforcement presence, experts capable of identifying and properly disposing of toxicants, personnel and equipment for removing large amounts of trash and other material, and natural resource specialists for rehabilitating or restoring sites (Gabriel et al. 2013, Boehm 2014). Even if marijuana is legalized in California, tremendous resources, effort, and coordination may still be needed to regulate the industry and to continue to locate, clean up, and restore abandoned or interdicted illegal grow sites. Only a small portion of interdicted outdoor grow sites in California have been cleaned up thus far and even less have been restored. Many of these sites may continue to pose an environmental threat long after they are abandoned by growers (Gabriel et al. 2013). For example, water-resistant packaging can keep ARs and other toxicants viable for years, which bears can eventually find and open, allowing further poisoning and exposure of wildlife even after growing operations have ceased at the site (HSVTC 2012, M. Gabriel, pers. comm.).

The Environmental Protection Agency (EPA) and California Department of Pesticide Regulation (CDPR) have recently taken steps to reduce threats from SGARs to wildlife, children, and pets. Since 2011, EPA regulations have prohibited the sale of SGARs to the general consumer. Under EPA regulations, SGARs may only be purchased at agricultural stores, in bait station form rather than as loose pellets, and in relatively small quantities (Bradbury 2008). Most AR manufacturers quickly complied with these regulations and brought replacement products to market containing FGARs or neurotoxins, rather than SGARs (CDPR 2013, Murray 2013). However, the EPA only recently reached an agreement with Reckitt Benckiser to end distribution of their popular d-Con® products containing SGARs and sold without a protective bait station by March 31, 2015 (EPA 2014). On July 1, 2014, the CDPR further limited access to SGAR products in California by classifying them as restricted materials (California Department of Consumer Affairs 2014). In California, products containing SGARs can only be purchased from CDPR-licensed pest control dealers by certified applicators (California Department of Consumer Affairs 2014). Increased restrictions on public access to products containing SGARs should help to reduce exposure of wildlife to these compounds. However, considering that banned pesticides are

commonly found at trespass outdoor marijuana cultivation sites (HSVTC 2012, Gabriel et al. 2013, Thompson et al. 2014) growers will likely continue to widely apply SGARs in forests occupied by NSOs, fishers, and other sensitive wildlife. Furthermore, reduced availability of SGARs could simply contribute to greater application of other pesticides, including newly emerging toxicants or large amounts of legal FGARs.

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Management Recommendations

Below I provide a brief list of management recommendations and research needs. This list is solely based on information reviewed in this report. Additional management and research needs may exist for northern spotted owls (*Strix occidentalis caurina*; NSOs). Furthermore, land managers, land agencies, and policymakers may need to consider other management information and objectives alongside those for NSOs. These recommendations are mine alone and do not necessarily reflect the positions of the Environmental Protection Information Center (EPIC) or any of the document's reviewers.

1. The NSO is rapidly declining across its range. The subspecies' rate of decline has recently accelerated in California. The NSO faces an array of threats to its persistence in California and elsewhere within its range. Therefore, I recommend that:
    a. The California Fish and Game Commission list the NSO as threatened or endangered under the California Endangered Species Act.
    b. The U.S. Fish and Wildlife Service uplist the NSO from threatened to endangered under the federal Endangered Species Act.

2. Habitat retention guidelines for NSOs in the California Forest Practice Rules (CAL FIRE 2014) should be revised. The U.S. Fish and Wildlife Service's (2009) recommended guidelines for portions of California outside the redwood zone should be adopted as soon as possible. The U.S. Fish and Wildlife Service's (2011b) recommendations for the redwood zone are based on less extensive and rigorous scientific information but also appear to reflect a more accurate and current understanding of the NSO's ecology than do the California Forest Practice Rules. Recommendations for the redwood zone could potentially be revised based on modeling of Habitat Fitness Potential (Diller et al. 2010), as were those for the state's northern interior (USFWS 2009).

3. The California Department of Fish and Wildlife should continue to hire biologists with expertise in NSO-habitat relationships to assist with reviews of Timber Harvest Plans. I am under the impression that few CAL FIRE biologists have specialized knowledge of raptor ecology and conservation. Qualified wildlife biologists with the U.S. Fish and Wildlife Service formerly consulted on Timber Harvest Plans but the agency has not been regularly involved in the review process since 2008.

4. Industrial timber companies required to monitor NSOs (e.g., as part of Habitat Conservation Plans) should, whenever possible, provide modeled occupancy rates that account for detectability of NSOs and other factors that can obscure occupancy trends (e.g., see Ch. 1, Figure 1.5). Unmodeled occupancy rates are frequently cited as evidence of stable NSO populations on industrial timberlands in California (Calforests 2014). Claims of population stability or increase on industrial timberlands conflict with evidence from more rigorous research projects that have found declines in occupancy and population vital rates on federal, tribal, and private lands in northwestern California (Forsman et al. 2011, Franklin et al. 2013, 2014, Higley and Mendia 2013, Green Diamond Resource Company 2014); interior northern California (Farber and Kroll 2012);

and the Oregon Klamath and southern Cascades (Forsman et al. 2011, Davis et al. 2013, 2014, Dugger et al. 2014).

5. Barred owl removal experiments should be continued and more widespread removal programs should be planned for both public and private lands. Without barred owl removal programs, the NSO is likely to continue to spiral toward extinction, regardless of habitat protection measures.

6. Rigorous studies of effects of forest thinning and partial harvesting on NSOs and their key prey (especially dusky-footed woodrats) are needed (e.g., using a before-after-control-impact study design and an adequate sampling framework). Ideally, the silvicultural prescriptions would resemble those proposed for widespread use on federal lands. Meanwhile, land managers should assume that commercial thinning and partial harvesting negatively affect NSOs and their primary prey in California; as the currently available information generally supports this assumption. If land managers or agencies deem that thinning is necessary to address wildfire risk or meet other objectives, it should be focused outside of core patches of mature and old forest (i.e., those surrounding NSO activity centers). Thinning and other fuels reduction activities could potentially be focused in portions of the landscape that are least likely to receive use by NSOs and that are most likely to experience fire (e.g., upper and southwesterly slopes).

7. Additional research is needed to evaluate effects of severe wildfires on NSOs. This issue is scientifically and politically contentious; although there is fairly broad consensus that extensive severe fires pose a threat to NSOs in dry, fire-prone forests, such as those that occur within much of northern California outside the redwood zone (USFWS 2011a). Land agencies could better support research of wildfire effects on spotted owls by avoiding or postponing post-fire salvage logging in burned study areas. The confounding effects of salvage logging are often cited as reason to ignore research indicating that extensive severe wildfires negatively affect spotted owls. Both territory and population/landscape level and multi-year studies of severe fire effects would be useful.

8. Additional research is needed to investigate effects of post-fire salvage logging on NSOs. However, the limited available evidence suggests that salvage logging negatively affects both spotted owls and their prey. Salvage logging does not appear to be generally concordant with conservation of NSOs, as it removes important biological legacies and structurally simplifies burned areas.

9. Prescribed fire appears to have neutral or positive effects on spotted owls and therefore, appears to be consistent with the species' conservation. Allowing wildfires to burn under favorable conditions could also hold promise for reducing understory densities and reducing risk of severe fire, fostering growth of fire-adapted vegetation favored by NSO prey communities, and maintaining or restoring habitat heterogeneity in landscapes homogenized by fire suppression and timber harvesting. Favorable conditions could often exist early or late in the season or in areas where deeply incised topography creates inversions that trap smoke and minimize risk of severe fire.

10. Studies evaluating effects of marijuana cultivation on NSOs are needed. Potential research topics include investigating exposure to anti-coagulant rodenticides and other toxicants, determining effects of rodenticides on prey populations around grow sites, and examining whether or not marijuana growing on private lands potentially affects NSOs (e.g., proximity to activity centers, potential negative effects of illegal water diversion and logging on riparian areas and watersheds used by NSOs).

11. Increased financial and logistical support is likely needed for interdiction, clean-up, and restoration at trespass marijuana grow sites on public lands. Increased law enforcement could also potentially alleviate financial strains and safety concerns for NSO research and monitoring projects.

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Tom Wheeler <tom@wildcalifornia.org>

NSO in CA Reviews

Dan Hansen <danhansen03@gmail.com> Fri, Jul 3, 2015 at 4:14 PM
To: Tom Wheeler <tom@wildcalifornia.org>

Tom,

I'm also pasting email contents in some emails as they also contain comments from the reviewers.

Dan

Hi Dan,

I did not have much to comment on this one. Again, you did a very thorough review of the information out there, and your summary of the work I've been involved with (on both timber and fire) was good. I added a few minor clarifications here and there. I suggested one more paper by Wilson and Forsman, this link:

http://www.fs.fed.us/pnw/pubs/pnw_gtr880/pnw_gtr880_009.pdf

On both papers, I recommend you be careful in the use of the general term "habitat" as it can mean many different things, and tends to confuse the issue if used without providing good definitions.

Good luck on this and best regards,

Ray

Raymond J. Davis

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Hi Dan,

Attached is my review and comments of your wildfire writeup. I'm still reviewing the timber writeup and will aim to get that to you by this afternoon.

Overall, a very thorough review, but there are a few more articles that I would add. In particular a paper by Tempel et al (in press). Effects of forest management on California Spotted Owls:

implications for reducing wildfire risk in fire-prone forests. Ecological Applications. Other papers that might provide good info:

1. Dennison, P. E., S. C. Brewer, J. D. Arnold, and M. A. Moritz (2014), Large wildfire trends in the western United States, 1984–2011, Geophys. Res. Lett., 41, 2928–2933

2. Moritz, M. A., M.-A. Parisien, E. Batllori, M. A. Krawchuk, J. Van Dorn, D. J. Ganz, and K. Hayhoe. 2012. Climate change and disruptions to global fire activity. Ecosphere 3(6):49.

3. Stavros et al. 2014. Regional projections of the likelihood of very large wildland fires under a changing climate in the contiguous Western United States. Climatic Change

4. Mallek, C., H. Safford, J. Viers, and J. Miller. 2013. Modern departures in fire severity and area vary by forest type, Sierra Nevada and southern Cascades, California, USA. Ecosphere 4(12):15

5. Ganey et al. 2014. Relative abundance of small mammals in nest core areas and burned wintering areas of Mexican spotted owls in the Sacramento Mountains, New Mexico. The Wilson Journal of Ornithology 126(1):47–52

6. Willey and Ripper. 2014. Home range characteristics of Mexican spotted owls in the Rincon Mountains, Arizona. The Wilson Journal of Ornithology 126(1):53–59

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NSO in CA Reviews

Dan Hansen <danhansen03@gmail.com> Fri, Jul 3, 2015 at 4:19 PM
To: Tom Wheeler <tom@wildcalifornia.org>

Diller emails pasted below....

Hi Dan,

I completed the review of the barred owl chapter and I hope to complete the timber section by Saturday. Overall, I thought you did a great job with a thorough and comprehensive review of the barred owl issues in the NW. I have some specific comments on the attached copy, but they mostly related to the emphasis on certain publications. In particular, Dave Wiens study in the Oregon coast range is the best data available on habitat use, competitive interactions, food habits and reproduction. It is superior to any other study to date, because he had radio transmitters on both species simultaneously using the same landscape meaning we know they had equal opportunity to select habitat, prey and etc. When you wrote this, you only had it available in the more cumbersome dissertation, but you could now use the recently published monograph.

Good luck with this.

Lowell

I agree that the old meta-analysis (Forsman et al. 2011) is very dated at this point. I would rely on the annual reports from all the various study areas to provide the best current status.

Lowell

Hi Lowell,

I have a quick question about the site density estimates in Green Diamond's 2014 report. Would you call them empirical or mark-recapture estimates? Although most of the owls were likely banded, I didn't see any mention of mark-recapture methods for estimating density as was done in Diller and Thome 1999.

Thanks!

Hi Dan,

Yes, they were empirical counts based on marked birds. So the marking prevents double counting birds, which could happen frequently for non-nesting birds that move around a lot, but the empirical counts don't account for missed birds due to less than perfect detection probabilities. So these empirical counts of marked owls is equivalent to what used to be called "minimum number alive." However, spotted owls have such high detection probabilities that the estimate from using mark-recapture techniques would only provide a minor inflation of the empirical counts. The trends from spotted owls on Green Diamond will be available soon from the most recent 2015 meta-analysis.

Lowell

Hi Dan,

I reviewed the status and trends chapter, and like the barred owl chapter, I thought it was very thorough and well written. I inserted some comments for you to consider, but I didn't have any major concerns. Probably my most substantial comment is that I think modeling exercises are primarily useful for developing testable hypotheses, and although I haven't actually reviewed it in detail, I don't put a lot of credence in the source-sink model you cited. Obviously, you could really benefit from the new meta-analysis, but you pretty much guessed what it is going to say.

Lowell

Tom Wheeler <tom@wildcalifornia.org>

NSO in CA Reviews

Dan Hansen <danhansen03@gmail.com> Fri, Jul 3, 2015 at 4:33 PM
To: Tom Wheeler <tom@wildcalifornia.org>

Hi Rob,

I've marked this doc up in track changes and with comments. I assume you're trying to say fire is a real threat as part of your listing petition, but you should reconsider that position.

I read most of the section you sent me, but was irritated by the overall bias and anti-fire tone throughout, and gave up with my careful review about 1/3 of the way through. It didn't read like an objective review of existing owl and fire data. It seemed the author assumed fire could only be bad for owls. It also failed to properly weigh studies according to sample size and whether or not they were peer-review publications. There were too many instances where stats in a paper said something (or said there was no effect there), then the author used an anecdote to refute the stats and advance a 'fire is bad' position. Also, author speculation in discussion sections shouldn't be reported as results.

I feel it also mischaracterized the risk of severe fire as a forgone conclusion with some minor uncertainty, while completely ignoring the threats posed by logging in the name of fire risk reduction. If the threat from logging is expounded upon in other sections, it should also reverberate in the wildfire and salvage section. Furthermore, the author fails to establish whether fuels thinning projects have any effect on fire severity during the extreme fire weather that accompanies the vast majority of big fires (typically they don't).

I think continuing in the current anti-fire tone might alienate potential allies of your petition in the environmental and scientific communities. I suggest a focus on logging as the main threat of the past, and the continued threat of the present even though it is now sold as 'fuels thinning'.

Best,
-Derek Lee

Tom Wheeler <tom@wildcalifornia.org>

NSO in CA Reviews

Dan Hansen <danhansen03@gmail.com> Fri, Jul 3, 2015 at 4:34 PM
To: Tom Wheeler <tom@wildcalifornia.org>

Dan,

Attached is the draft that you sent a while back. With a few edits. Not many, I think you did a pretty good job of outlining the potential risks given the lack of information available. I couldn't really comment much on the environmental degradation issues, only pesticide exposure. I tried to fill in a number of your citations and made a few changes to the text. I do have a number of photos as well, if you want to highlight anything.

Craig

Craig Thompson

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Barred Owls

Introduction

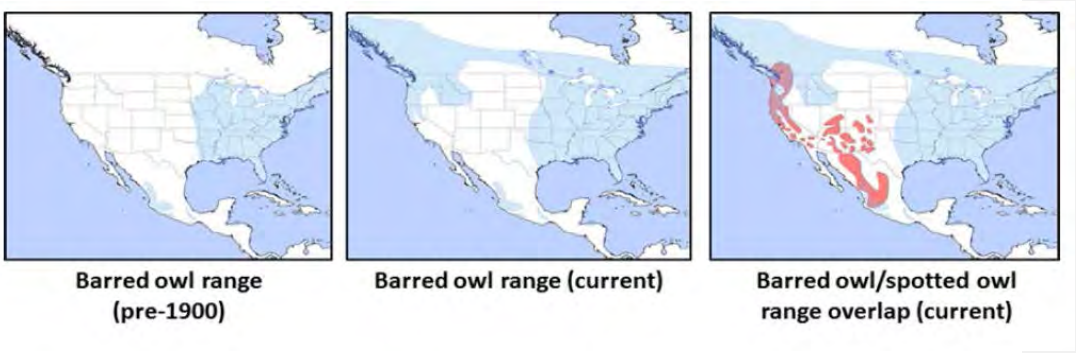
At the time of the northern spotted owl's (*Strix occidentalis caurina*; NSO) federal listing, the barred owl was recognized as a potential threat to the subspecies (USFWS 1990, Thomas et al. 1990). Since then, barred owls have continued to invade the range of the NSO and are apparently increasing in numbers (USFWS 2013). As reviewed herein, a large body of correlational and anecdotal evidence, supplemented by preliminary findings from barred owl removal experiments, indicates that barred owls are negatively impacting NSO populations across their range and that this is due to competition between the two species for space, habitat, and food. Research reviewed below indicates that that the barred owl is a superior competitor to the NSO due to its larger size, more aggressive behavior, higher reproductive potential, and broader ecological niche. The USFWS (2011) recently listed the barred owl invasion as one of three main threats currently faced by NSOs (along with timber harvesting and wildfire). The USFWS (2011) described this threat as "extremely pressing and complex" and "requiring immediate consideration." Information reviewed below suggests that lethal control of barred owls is a viable management option for some areas, although it may be difficult to overcome emotional and ethical resistance to killing one charismatic species to save another. Habitat conservation for NSOs appears to be of increasing importance because the negative effects of habitat loss and fragmentation on NSOs can be exacerbated by the presence of barred owls (Dugger et al. 2011).

Comment [LVD1]: It may not have been available when you were writing this, but the Wiens et al. 2014 monograph would be a good citation here.

The Barred Owl's Expansion

Prior to the mid-1900s, the barred owl's range was confined to southeastern Canada, the eastern U.S., and portions of Mexico (Gutiérrez et al. 2004, 2007; Figure 1). By the mid-20th century the barred owl's range began expanding westward across North America and currently includes the southern boreal forest zone and British Columbia in Canada and the northern Rocky Mountains, Pacific Northwest, and northern California in the U.S. (Livezey 2009, USFWS 2013; Figure 1). The barred owl's range now completely overlaps that of the NSO and partially overlaps that of the California spotted owl (*S. o. occidentalis*) (Figure 1). It is unclear whether the barred owl's westward range expansion occurred via the Great Plains or Canada's boreal forests (USFWS 2013). It is also uncertain whether this range expansion was facilitated by natural factors, human activities, or a combination of the two. Hypotheses concerning the cause of the barred owl's range expansion include increased adaptation by the species to coniferous forests; natural climate change; environmental changes associated with widespread intensive timber harvesting; and conversion of open areas to forest due to fire suppression, planting parks and woodlands, removal of keystone species, or other human activities (Gutiérrez et al. 2004, USFWS 2013).

Figure 1: Historical and current range of the barred owl and comparison of the current ranges of the barred owl and spotted owl (from USFWS 2013).



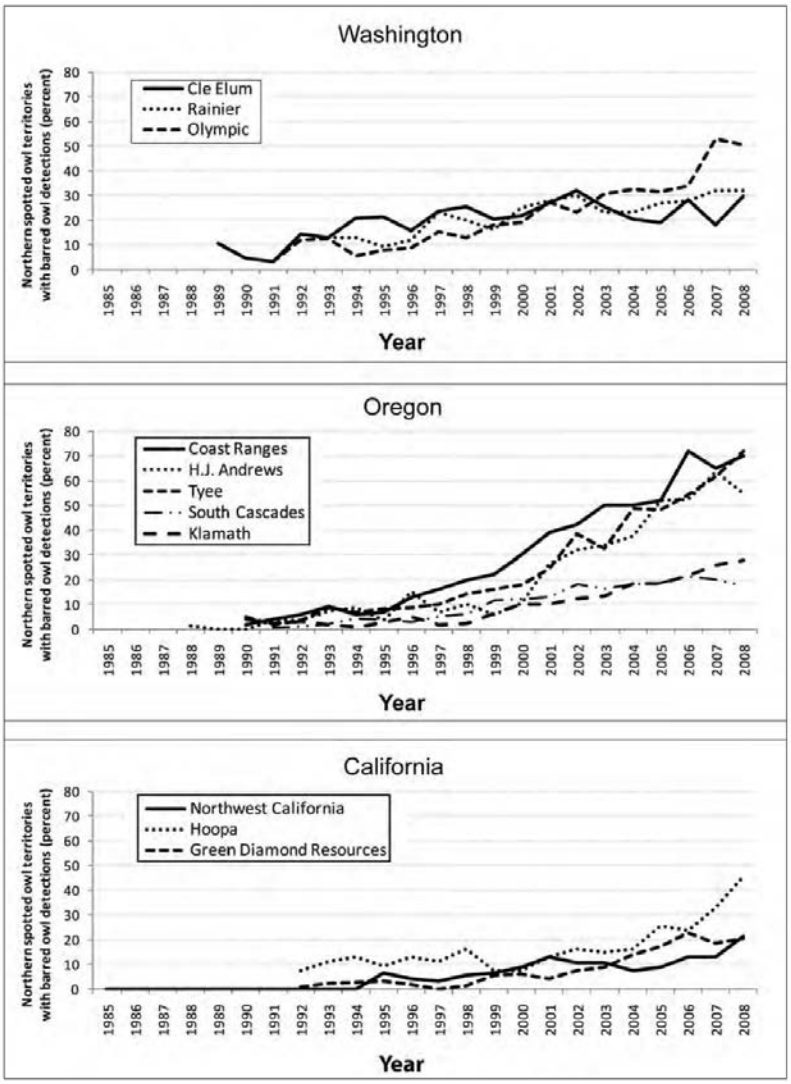
Reliable data concerning current barred owl densities and population trends are unavailable. Most information about barred owl trends in the Pacific Northwest and California is based on incidental detections during surveys for spotted owls (USFWS 2013). Researchers have estimated that only 1/2 to 2/3 of barred owls present are detected during NSO surveys (Gutiérrez et al. 2004, Bailey et al. 2009, Wiens et al. 2011). Researchers have only recently begun to systematically survey for barred owls within the range of the NSO and only in limited areas. In California, the Northwest California, Green Diamond, and Hoopa NSO density studies initiated systematic surveys for barred owls in 2009 (Franklin et al. 2014, Green Diamond Resource Company 2014, *Hoopa citation*).

Some early studies of barred owls within the NSO's range likely overestimated the species' numbers by focusing on cumulative and nighttime detections (Gutiérrez et al. 2004). However, barred owl trends are now more frequently evaluated in terms of the number of spotted owl territories in which barred owls have been detected (USFWS 2013; e.g., Forsman et al. 2011, Calforests 2014). Reports of the number of spotted owl territories with barred owl detections

probably underestimate barred owl densities and population trends (USFWS 2013). Barred owls often have substantially smaller home ranges than spotted owls so it is possible for a single spotted owl home range to encompass multiple barred owl home ranges (Singleton et al. 2010, Wiens 2012; see below). Without color-banding or follow-up surveys to determine the identity and occupancy status of barred owls, it is often unclear if multiple detections within spotted owl territories represent one or multiple barred owls.

Despite uncertainty regarding barred owl densities and population trends, incidental detections clearly indicate that the species rapidly expanded its range into that of the NSO (USFWS 2013). For example, barred owls expanded their range from western Washington to northern California in less than 10 years (Gutiérrez et al. 2004). Incidental detections also suggest that barred owl densities are continuing to increase within the range of the NSO. From 1985-2008, the proportion of NSO territories with known barred owl presence increased in density study areas throughout the NSO's range, suggesting increasing barred owl populations (Forsman et al. 2011; Figure 2). Barred owl increases in Washington and Oregon have been steeper than those in California (Forsman et al. 2011; Figure 2), which is consistent with the species' later colonization of California (USFWS 2013). More recent information suggests that barred owl increases are also currently accelerating in northwestern California (see below).

Figure 2: Annual proportion of northern spotted owl territories with barred owl detections (≤0.62 mi from spotted owl activity center) on density study areas in Washington, Oregon, and California (from Dugger and Davis 2011, adapted from Forsman et al. 2011).



Recent reports from California's density studies suggest that barred owls continued to increase in numbers and to invade additional NSO territories during 2009-2013 (Franklin et al. 2014, Green Diamond 2014, *Hoopa citation*). As noted above, California's density studies initiated barred owl-specific surveys in 2009. The Green Diamond Resource Company *(and Hoopa?)* also began a barred owl removal experiment in a portion of their density study area during the same year (see below). Thus, detection and occupancy data from 2009-2013 are not directly comparable to previously collected data. In the Northwest California density study area and nearby Regional Study Area, the number of NSO territories with barred owl detections increased by 76% (from 21 to 37) during 2009-2013 and the estimated number of barred owl sites increased by 170% (10 to 27) (Franklin et al. 2014). On Green Diamond Resource Company lands, the total estimated number of barred owl sites increased by 57% (numbers not reported) during 2011-2013 (Green Diamond 2014). *Hoopa 2009-2013 information…* The degree to which estimated increases in barred owl sites and NSO territories with barred owl detections reflect growing barred owl populations as opposed to increased and cumulative survey effort is unclear. However, the available data indicate that barred owls are continuing to invade NSO territories in California's density study areas and that this is occurring at an increasing rate.

Comment [LVD2]: Hoopa's study was initiated in September 2013 following signing of the ROD for the barred owl removal experiment. Their study is one of four planned for the FWS removal experiments, but lack of funding has delayed the implementation of the other study areas until this year (2015).

Comment [LVD3]: There are still comparable surveys that are being done using the original protocol and those data are kept separate from new barred owl-specific surveys.

Cumulative detections in the California Natural Diversity Database (CNDDB) from 1978 through 1990, 1998, 2006, and 2013 provide a crude picture of the species' expansion in California (Figure 3). These detection data suggest that barred owls expanded their range into the state along the northern coast and southern Cascades and more rapidly increased in wetter regions (Figures 3 and 4). Earlier and more rapid colonization of relatively mesic forests by barred owls is consistent with observations from studies in Washington (Gutiérrez et al. 2007).

While cumulative detections cannot be used to evaluate the barred owl's densities or population trends, they suggest that barred owls are relatively abundant along the coast and in the adjacent Six Rivers National Forest, whereas they appear to still be in the process of colonizing the Mendocino, Klamath, and Shasta-Trinity National Forests and other interior areas of northern California. However, it is possible that this pattern is ~~due to~~biased by the fact that most barred owl detections occur during surveys for spotted owls, which may be more densely concentrated or better surveyed in northwestern California. Concentrations of barred owl detections in northwestern California may be partly associated with intensive survey effort for spotted owls in the Green Diamond, Northwest California, and Hoopa density study areas. Furthermore, the Six Rivers National Forest conducted forest-wide surveys for NSOs in 2010 and 2011 and subsequently continued to survey large areas associated with forest projects (cite). Barred owls have a broader ecological range than do spotted owls, so they may be more widely distributed than is shown in Figure 3 (USFWS 2013).

Comment [LVD4]: The detections can be used to establish general trends, but they don't allow for estimates of population density or abundance.

Comment [LVD5]: THP surveys throughout the region are also reporting barred owl detections.

Figure 3: Cumulative northern California barred owl detections in the California Natural Diversity Database from 1978 through A) 1990, B) 1998, C) 2006, and D) 2013 (note: dark red symbols denote higher concentrations of detections).

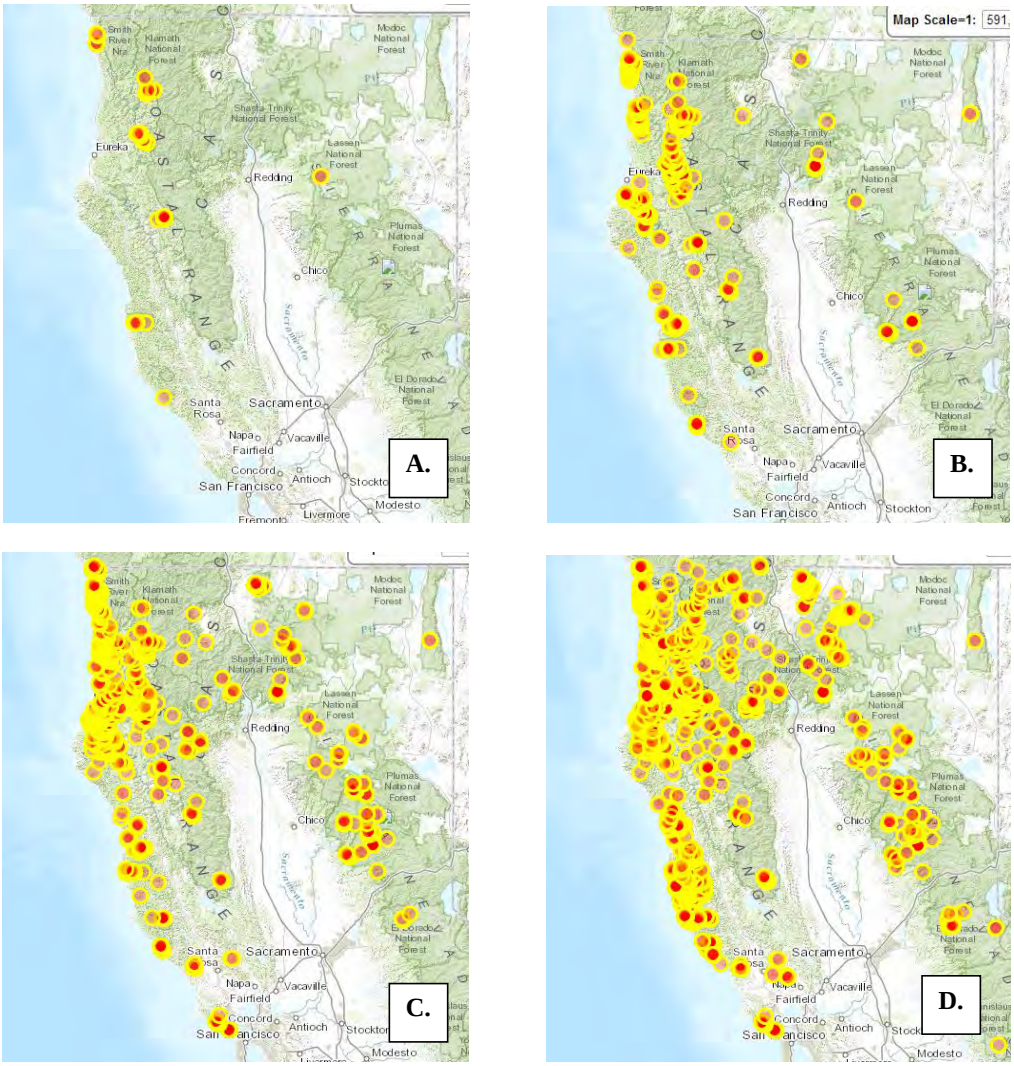
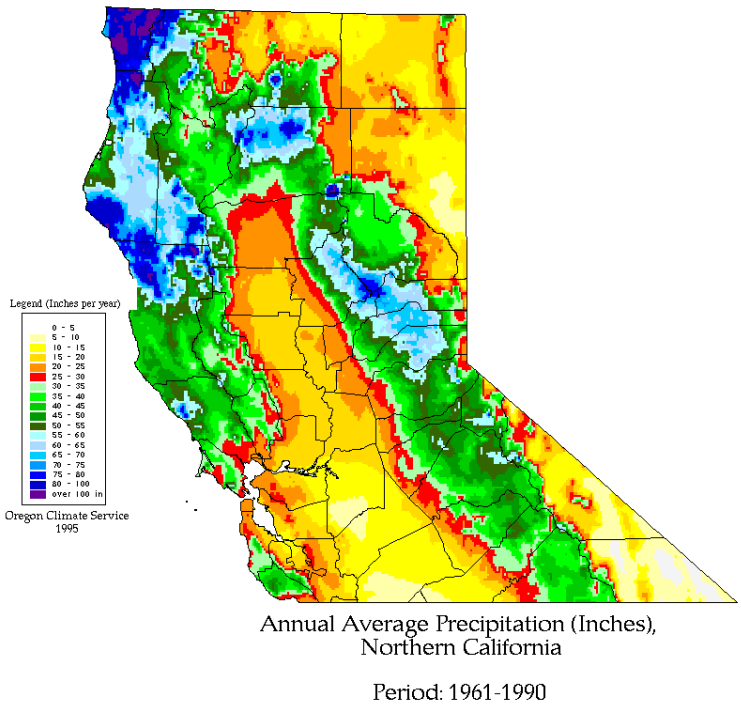


Figure 4: PRISM precipitation map for northern California (1961-1990) (Western Regional Climate Center).



Barred owls have increased dramatically in California's Redwood National and State Parks (Gutiérrez et al. 2004). In 2012 alone, NSO surveyors detected at least 17 barred owls at 10 different sites (Schmidt 2013). In contrast, NSOs were detected at only four historical territories in 2012. It is possible that more NSO territories were active during that year as relatively little of the landscape was surveyed. However, Schmidt (2013) noted that the Redwood National and State Parks have discontinued surveying many areas due to what appears to be almost complete displacement of NSOs by barred owls. Based on clusters of barred owl detections ($\leq$1 mi apart) during 1993-2012, Schmidt (2013) estimated that the Redwood National and State Parks contain a total of 58 barred owl territories. Barred owls have only recently invaded National Park lands in Marin County, California and have been slow to increase in numbers thus far (Ellis et al. 2013). Barred owls were first detected in Marin County in 2002 and were detected at only four (13%) NSO monitoring sites in the area in 2012 (Ellis et al. 2013). Ellis et al. (2013) hypothesized that the barred owl's expansion into Marin County has been limited due to extensive agricultural and urban lands surrounding the area. They also stated however, that barred owl numbers would likely continue to increase in the area over time and could eventually pose a substantial conservation problem for this small and relatively isolated population.

Most information about barred owls on private timberlands in California is from ownerships in the Redwood Province. Data provided by the Green Diamond Resource Company are described above, along with those from other NSO density studies in California. Reports from both the Humboldt Redwood Company (Humboldt County) and Mendocino Redwood Company (Mendocino and Sonoma Counties) suggest that barred owls are currently rapidly increasing on those lands. Despite a marked decline in annual numbers of nighttime surveys, Humboldt

Redwood Company (2013) found an overall increase in barred owl detections within 0.5 mile of NSO activity centers during 2003-2013 (Figure 5). However, some of the increase in barred owl detections between 2010 and 2011 was likely due to greater survey effort associated with adoption of the USFWS (2012) revised survey protocol for NSOs. Mendocino Redwood Company (2014) data suggest that barred owls increased dramatically on their lands during 2005-2013 (Figure 6). Barred owls were detected within one mile of 47 (45%) NSO activity centers on these lands in 2013. The number of NSO territories with barred owl detections increased by 113% during 2010-2013. Mendocino Redwood Company (2014) noted that barred owls have been detected within one mile of 71 NSO activity centers on their lands since 2005. The Conservation Fund (in Calforests 2014), which manages lands in Mendocino and Sonoma Counties, stated that barred owls have been detected "across their ownership" since 2009. They currently have four sites at which barred owls are "regularly detected" and another area in which they are "occasionally detected".

Figure 5: Number of barred owl detections within 0.5 mile of northern spotted owl activity centers on Humboldt Redwood Company lands during 2003-2013 (from Humboldt Redwood Company 2013).

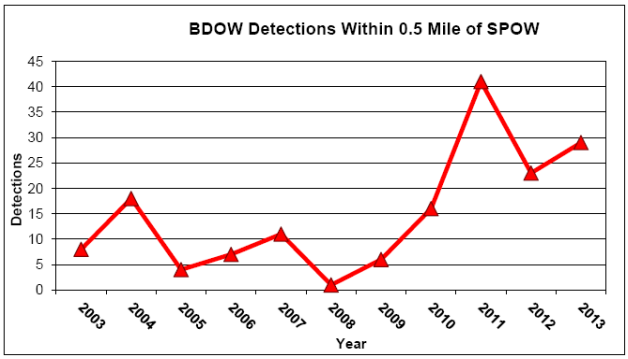
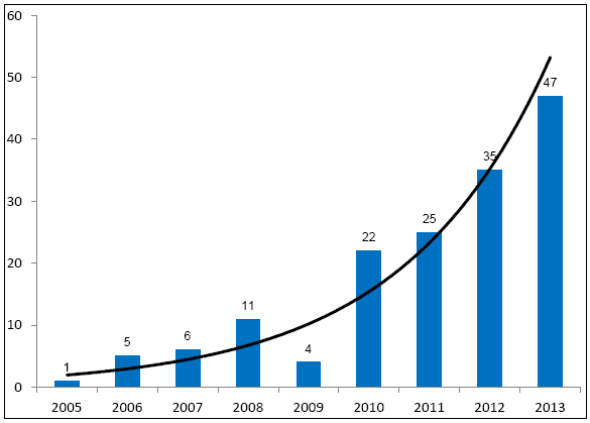


Figure 6: Percent (y-axis) and number of northern spotted owl territories (1 mi radius around activity centers) on Mendocino Redwood Company lands with barred owl detections during 2005-2013 (note: the apparent decline in NSO territories with barred owl detections in 2009 coincided with a substantial dip in NSO survey effort) (from Mendocino Redwood Company 2014).



There is relatively little information concerning barred owl numbers on private timberlands in California's eastern Klamath and Southern Cascade regions. In 2013, Sierra Pacific Industries confirmed barred owl occupancy at 14 of 28 known/historical barred owl sites within their Redding and Weaverville Districts (eastern Klamath and Southern Cascades regions) and located two additional sites (SPI 2014). We are unaware of any reports of barred owl trends or presence in NSO territories on Sierra Pacific lands. Fruit Growers Supply Company (in Calforests 2014) reported barred owl detections within or "nearby" (distance not reported) five NSO activity centers in Siskiyou County. It was unclear whether these numbers were cumulative or were from 2013 alone. Michigan-California Timber Company (in Calforests 2014) reported that barred owls were detected at one site on their lands in Siskiyou County in 2010 and 2012 and two sites in 2009 and 2013. Crane Mills (in Calforests 2014) has detected only one barred owl on their lands in Shasta County. Roseburg Resource Company (in Calforests 2014) has never detected a

barred owl during their NSO surveys on lands in Siskiyou and Shasta Counties. The low numbers of barred owl detections on some private timberlands in California's eastern Klamath and Southern Cascades regions is somewhat surprising given the numbers of detections on the Shasta-Trinity and Klamath National Forests and on Sierra Pacific Industries lands (Figure 3). It is unclear if this is due to a difference in survey effort, ecological conditions, management history, or some other factor.

In summary, the barred owl's range now completely overlaps the NSO's range and partially overlaps the California spotted owl's range. Barred owls rapidly expanded their range southward from British Columbia, through Washington and Oregon, and into northern California. The species' range expansion into California appears to have occurred first and most rapidly in northern coastal forests and near the margin of the southern Cascades and northern Sierra Nevada. However, it is unclear if these patterns actually reflect the species' expansion or are merely an artifact of higher survey effort for spotted owls in these areas. Regardless, the available information suggests that there is currently a high potential for interactions between NSOs and barred owls throughout much of NSO's range in California. The barred owl invasion does not appear to have peaked in the state. Rather, the information reviewed above suggests that the species is continuing to expand into drier, interior portions of the Klamath and Southern Cascades Provinces and that their presence in NSO territories is increasing at accelerating rates in the Redwood Province and western Klamath.

Comment [LVD6]: I don't think there is any doubt that it is a reflection of the species' expansion, because it mimics what happened in WA and OR as well. That said, I agree that the magnitude of the expansion is likely somewhat biased by the greater survey effort on the coast.

Effects on NSOs

Scientific Uncertainty

As discussed above, there is currently little reliable information concerning trends in barred owl densities or population numbers. Most of what is known about the potential for barred owl interactions with NSOs is based on incidental detections of barred owls during NSO surveys (Gutiérrez et al. 2004). Reliance on NSO surveys limits many studies' inferences concerning barred owl numbers. Gutiérrez et al. (2004) noted that some studies have found large numbers of historical NSO territories apparently vacant of both NSOs and barred owls. It is unclear if these vacancies were primarily a reflection of inadequate survey effort for one or both species or if they are caused by some other factor (Gutiérrez et al. 2004). Some of this uncertainty has been reduced due to increased survey effort required by revised survey protocols for NSOs (e.g., USFWS 2012) and implementation of barred owl-specific surveys in some areas. Inferences from studies of barred owl effects on NSOs are further limited by the observational and retrospective nature of most research of this topic (Livezey and Fleming 2007). Most studies of barred owl effects on NSOs have examined correlations between changes in NSO occupancy or demography and barred owl presence near NSO activity centers (see below). These studies do not definitively prove that barred owl presence causes changes in NSO occupancy or demography. However, preliminary results of barred owl removal experiments more directly support conclusions that barred owl presence negatively affects NSOs in a variety of ways (see below).

Comment [LVD7]: That assessment is over 10 years out of date, and as rapidly as the barred owl science is advancing, I would not consider it appropriate to cite for scientific uncertainty. You should be using the barred owl EIS, Wiens et al. 2014 and other more recent studies.

Comment [LVD8]: This is way out of date and irrelevant at this point.

Comment [LVD9]: But the Wiens study does – you could cite his dissertation or the 2014 monograph.

Hybridization

At the time of the NSO's listing there was concern among some researchers that hybridization between spotted owls and barred owls would lead to the loss of the spotted owl as a distinct species (Gutiérrez et al. 2004). Despite genetic, morphological, ecological, and behavioral differences between spotted owls and barred owls, there appear to be few strong isolating mechanisms to prevent them from interbreeding (Gutiérrez et al. 2007). Yet, hybridization between the two species appears to be relatively rare. For example, an extensive review of NSO survey and banding records from 1970-1999 in Oregon and Washington found reports of only 47 NSO-barred owl hybrids (Kelly and Forsman 2004). Hybridization therefore appears to pose little threat to NSOs compared with the effects of competition (Kelly and Forsman 2004; see below). However, hybridization could become a more serious issue in the future as NSOs continue to decline and become less able to locate conspecific mates (Gutiérrez et al. 2007).

Demography

Forsman et al. (2011) evaluated demographic trends for NSOs in 11 density study areas during 1985-2008. They found that NSO reproduction (fecundity) was negatively associated with the presence of barred owls ($\leq$0.62 mi from NSO activity centers) in four study areas, including Green Diamond's in California. Inclusion of the barred owl covariate in one of the best performing models in the meta-analysis of reproduction across all study areas provided weak support for an effect of barred owl presence on reproduction throughout the NSO's range (Forsman et al. 2011). The negative association between reproduction and barred owl presence

was likely underestimated since researchers often cannot relocate NSOs displaced by barred owls, and many displaced NSOs may be unable to find new territories and reproduce (Forsman et al. 2011). Apparent survival of NSOs was negatively associated with the presence of barred owls in six of the study areas, including Northwest California and Green Diamond (95% confidence intervals did not overlap zero or only slightly overlapped zero). The meta-analysis for all study areas showed a negative association between barred owl presence and apparent survival and recruitment, although the evidence for an effect on recruitment was statistically weak. Populations in seven study areas, including Northwest California and Green Diamond, declined during the latter portion of the study period (95% confidence intervals did not overlap zero or only slightly overlapped zero for these areas). Model selection results for the meta-analysis of population change indicated support for models that included the barred owl covariate. Forsman et al. (2011) noted that, of the various factors evaluated for potential effects on NSO vital rates, negative associations with the presence of barred owls were the strongest and most consistent among study areas. Forsman et al. (2011) also noted that they likely underestimated these negative associations by applying the barred owl covariate at the population scale rather than the territory scale. Studies of associations between NSO occupancy rates and barred owl presence suggest that the territory is a more appropriate spatial scale for detecting effects of barred owls on NSOs (see below).

Occupancy

Several studies distributed across the NSO's range have found evidence of a negative effect of barred owl presence on occupancy by the subspecies (Kelly 2001, Kelly et al. 2003, Pearson and

Livezey 2003, Gremel 2005, Olson et al. 2005, Kroll et al. 2010, Dugger et al. 2011, Green Diamond Resource Company 2014, *Hoopa citation*). These findings suggest that barred owls are causing large-scale displacement of NSOs and that negative effects of barred owls are largely due to interference competition between the two species (see below).

Gremel (2005) found that occupancy by pairs of NSOs in the Olympic National Park in Washington declined significantly at sites with barred owl presence, whereas pair occupancy remained stable at sites without barred owl detections. During 1992-2003 in this study area, the number of barred owl detections in NSO sites per number of survey days increased by 15% per year. During the same period, mean occupancy by NSOs declined from 61% to 42% in sites with barred owl detections.

In the southwestern Washington Cascades, Pearson and Livezey (2003) found a 9% annual increase in the number of barred owl detections relative to the number of NSO detections during 1982-2003. Unoccupied historical NSO core areas (500 ac) had significantly more barred owl activity centers at three spatial scales (0.5, 1.0, 1.8 mi) than did occupied core areas.

Kelly et al. (2003) evaluated potential effects of barred owl presence on NSO occupancy in five density study areas in Washington and Oregon. Their analyses indicated that barred owls had a stronger negative effect on NSO occupancy when located closer to activity centers than when farther away. Occupancy by NSOs exhibited a highly significant decline when barred owls were detected within 0.5 mile of activity centers ($P = 0.001$), compared with a lower tendency to decline when barred owls were detected farther away ($P = 0.06$).

Olson et al. (2005) examined associations between NSO occupancy dynamics and the presence of barred owls near activity centers (distance not reported) in three study areas in western Oregon. Barred owl presence was low (detected near <10% of NSO sites each year) in all three study areas during the first eight years of the study (1990-1997), increased substantially in one of the study areas thereafter (maximum of 28% of sites in 2001), and more gradually in the other two (ca. 10% of sites in 2001). Despite relatively low barred owl presence (e.g., compared with Forsman et al. 2011, Figure 2), site occupancy probabilities for NSO pairs decreased by 5-15% with increasing barred owl presence.

In one of the western Oregon density study areas evaluated by Olson et al. (2005) (Tyee), Bailey et al. (2009) found no evidence of an effect of barred owl presence on NSO occupancy during 2002-2003. They cautioned however, that their study's inferences were weak since barred owl presence was relatively low at the time of the study (detections in <12% of NSO territories based on Olson et al. 2005). Just five years after their study period ended, barred owls were detected in 70% of NSO territories (0.62 mi around activity centers) (Forsman et al. 2011; Figure 2).

In the eastern Cascades of Washington, Kroll et al. (2010) found that the mean probability of occupancy by NSOs was significantly lower for sites with barred owl presence (0.50) than without it (0.76) (presence not spatially defined). Although the percent of NSO sites with barred owl detections was moderate compared with some areas (max. ca. 33% [estimated from graph] vs. Figure 2), site occupancy probabilities for NSOs declined by about 50% during 1990-2003.

In the southwestern Cascades of Oregon, Dugger et al. (2011) found significant differences in mean annual occupancy for NSO pairs with nearby barred owl detections (presence not spatially defined) than in those without. During the latter 13 years of the study, mean annual site occupancy was approximately 10-15% at sites with barred owl presence compared with about 58-78% at sites without barred owl presence (estimated from graph).

Green Diamond Resource Company (2014) is currently conducting an experiment to evaluate the effects of lethally removing barred owls from NSO territories in California's Redwood Province. Preliminary results from this study suggest that removal of barred owls results in rapid recolonization of sites by NSOs. Green Diamond reported a 43% increase in the number of sites occupied by NSOs in their treatment (barred owl removal) area during the first year (2008 to 2009) and an additional 9% increase the following year (2009 to 2010). In contrast, the number of sites occupied by NSOs in an adjacent control portion of the study area (no barred owl removal) was virtually unchanged from 2008 to 2009 and declined by 23% from 2009 to 2010. However, the degree to which barred owl removal positively affected NSO occupancy in this study is difficult to evaluate. The beginning of Green Diamond's removal study roughly coincided with implementation of a new survey protocol which likely resulted in greater detections of both NSOs and barred owls. Future analyses from this study should provide clearer insight into the effects of barred owl presence and removal on NSO occupancy.

Add Hoopa barred owl removal preliminary results if obtainable…

Habitat Use

Comment [LVD10]: You should include Wiens dissertation or the recent monograph in the section on habitat use.

Dugger and Davis (2011) stated that "the relationship between spotted owl fitness and habitat characteristics may have become disconnected through interspecific competition with barred owls." They based this hypothesis on their finding that mean habitat suitability at NSO pair locations within the Northwest Forest Plan area decreased by approximately 9% between 1994/1996 and 2006/2007 (Davis and Dugger 2011). This decline in mean habitat suitability at NSO pair locations did not appear to be solely due to a loss of suitable breeding habitat, which declined by about 3% in this area during the study period. This hypothesis is also supported by findings that NSOs in the northern portion of their range are often displaced by barred owls into steeper and higher elevation areas (Pearson and Livezey 2003, Gremel 2005, Hamer et al. 2007). Hamer et al. (2007) suggested that displacement of NSOs to higher elevation forests could result in reduced survival or reproduction during years with severe winters.

Territorial Behavior

Barred owl presence and calling is associated with reduced responsiveness of spotted owls to conspecific calls, including survey broadcasts (Olson et al. 2005, Crozier et al. 2006, Bailey et al. 2009, Kroll et al. 2010). This is partially of interest to researchers and land managers because it influences the field and analytical methods required for measuring occupancy by NSOs (Olson et al. 2005, MacKenzie et al. 2006, USFWS 2012). Accurate assessments of occupancy are needed for evaluating effects of barred owls and other potential stressors on NSOs, and for avoiding inappropriate management activities, such as timber harvesting near nests in occupied territories.

Comment [LVD11]: This is true, but reduced detection probabilities don't necessarily mean reduced ability to detect NSO. The number of surveys required have been increased so that overall detection probabilities are >95%.

Reduced vocalizing by NSOs in the presence of barred owls is also of concern because NSOs rely on vocalizations to defend their territories, locate vacant territories and potential mates, form pair bonds, and announce prey deliveries (Gutiérrez et al. 1995). Widespread disruption of these activities could impact NSO demographic rates.

Interspecific Competition

Gutiérrez et al. (2004) described the ecological and morphological separation that exists among sympatric owls worldwide. Their review found that species within the same genus are generally segregated by geographic range or habitat associations. It also showed that sympatric congeneric owls are usually strongly divergent in size, which varies with diet and possibly, hunting mode. Spotted owls and barred owls are both members of the genus *Strix*. Gutiérrez et al. (2004) noted that the two species only differ in body mass by 18%, which is likely too little to allow coexistence. A building body of evidence indicates that barred owls indeed negatively affect spotted owls (reviewed above), and that this occurs through both direct (interference) and indirect (exploitative) competition (Gutiérrez et al. 2004, 2007, USFWS 2013; see below). Wiens (2012) stated that "when viewed collectively, the behavioral and life history traits exhibited by barred owls may give them a significant advantage over spotted owls when competing for critical resources such as space, habitat, and food."

Surveyors have observed barred owls attacking spotted owls and have themselves been attacked while imitating spotted owl calls (Gutiérrez et al. 2004). There is also limited evidence of barred owl predation of NSOs. Leskiw and Gutiérrez (1998) provided strong circumstantial evidence

that a barred owl killed and partially consumed an NSO in Redwood National Park, California. Johnston (2002 cited in Gutiérrez et al. 2004) found circumstantial evidence of barred owl predation of a juvenile NSO in the southern Oregon Cascades. However, most cases of barred owl aggression toward NSOs appear to be a related to territorial defense, rather than predation (USFWS 2013).

Studies in Washington found that barred owl home ranges are relatively small and tend to have little overlap, which is consistent with aggressive territorial behavior (Hamer et al. 2007, Singleton et al. 2010). In contrast, neighboring NSO home ranges often broadly overlap, particularly during winter (Hamer et al. 2007). There is limited anecdotal evidence of spotted owls aggressively interacting with barred owls (Gutiérrez et al. 2004), and spotted owls appear to reduce detection probabilities for barred owls (Bailey et al. 2009). Nonetheless, barred owls generally exhibit higher levels of vocal and physical aggression than do NSOs and are typically dominant during interactions between the two species (Van Lanen et al. 2011). Significantly reduced detection probabilities for NSOs in the presence of barred owls provides further evidence of the larger, more aggressive barred owl's behavioral dominance over NSOs (see above).

Barred owls are dietary generalists compared with NSOs (USFWS 2013). As dietary generalists, barred owls may be better able to colonize a wider variety of habitats than NSOs and may be more resilient to fluctuations in prey populations (USFWS 2013). The barred owl's generalist diet is likely a primary reason for the species' relatively small home ranges and associated ability to occur at high densities (see below). Furthermore, because barred owl diets overlap with those

of NSOs, it is possible that they negatively affect NSOs by depressing populations of key prey, such as northern flying squirrels and woodrats (Gutiérrez et al. 2007, USFWS 2013).

The barred owl's habitat associations in the Pacific Northwest and California are poorly understood. As discussed earlier, most barred owl detections are incidental to spotted owl surveys so relatively little is known about the ecology of barred owls outside of areas occupied by spotted owls. Early studies of the barred owl's habitat associations in the Pacific Northwest suggested that the species is more associated with younger forest types than are NSOs (Gutiérrez et al. 2007). However, subsequent research has found that barred owls use a variety of habitats and that some individuals prefer densely canopied mature and old forest (Gutiérrez et al. 2007, USFWS 2011). That is, barred owls appear to be capable of occupying a broader variety of habitat types than NSOs but the two species likely compete for access to mature and old forest. The two species may also compete for nest sites since they both rely on the same kinds of pre-existing nest structures (Gutiérrez et al. 2007). Together, overlapping habitat associations with NSOs, use of a broader range of habitat types, and the ability to occur at relatively high densities allows barred owls to form large source populations in close proximity to NSOs (USFWS 2013).

Comment [LVD12]: The only real definitive data on habitat use of NSO and BO is the Wiens study, because he was radio tracking both species simultaneously on the same landscape. This study showed that the two species have almost identical selection for different aged stands with the only difference being that BO tend to use riparian areas more than NSO.

Perhaps due to their generalist diet, barred owls often have substantially smaller home ranges than do NSOs (Gutiérrez et al. 2007, USFWS 2013). Estimates of barred owl home ranges in Washington were three to nine times smaller than those of NSOs in the state (Hamer et al. 2007, Singleton et al. 2010). Barred owl home ranges in the Oregon Coast Ranges were two to four times smaller than those of NSOs (Wiens 2012). There does not appear to be any existing research comparing the home range sizes of barred owls and NSOs in California (Gutiérrez et al.

2007). Annual home range sizes for NSOs (100% minimum convex polygon) in the California and Oregon Klamath Provinces varied among studies and with forest types and contiguity but were similar to or somewhat larger (0-60% larger) than those for barred owls in the Oregon Coast Ranges (Sisco 1990, Carey et al. 1992, Zabel et al. 1993, Irwin et al. 2006). The NSO's smaller home ranges in California suggest that they may have lower encounter rates with barred owls than occurs in Oregon and Washington. However, it is possible that barred owls also have smaller home ranges in California. Estimates of barred owl home range sizes in California are needed.

Wiens (2012) found that barred owls in the Oregon Coast Ranges had a higher annual survival probability (0.92 vs. 0.81) and produced over six times as many young as sympatric NSOs. Barred owls have a wider range of clutch sizes than NSOs (1-5 vs. 1-3), are capable of laying additional clutches within a season if the first is lost, and appear to exhibit lower annual fluctuations in reproduction (USFWS 2013; but see Mazur and James 2000). The USFWS (2013) noted that "the ability of barred owls to forage on a wider diversity of prey species and in a wider diversity of habitats may explain their reproductive success in comparison with spotted owls." There is a need for further research of the barred owl's natural history and ecology within the range of the NSO (Gutiérrez et al. 2007, Livezey and Fleming 2007). However, the currently available information indicates that the demographic performance of barred owls is superior to that of NSOs.

Overall, barred owls appear to primarily impact NSOs through interference competition for space, habitat, and food, although they may also indirectly affect NSOs by depressing prey

populations (Gutiérrez et al. 2007, Hamer et al. 2007, Van Lanen et al. 2011, Wiens 2012, USFWS 2013). Barred owls are generally superior competitors to NSOs in terms of size, aggression, demographic performance, and ability to exploit a wider array of habitats and prey (Gutiérrez et al. 2007, USFWS 2013).

Barred Owl Management

The information reviewed above indicates that barred owls pose a serious and increasing threat to NSOs throughout their range, including in California. Barred owl presence in NSO territories has continued to increase across the NSO's range and appears to be partially responsible for declining NSO demographic and occupancy rates. Barred owl presence can also reduce the ability of biologists and land managers to effectively locate and conserve NSOs. Given the negative effects of barred owls on NSOs, it is clear that policymakers and land managers must address the barred owl threat if successful recovery of the NSO is to remain a conservation priority. Current proposals for addressing the barred owl threat include barred owl removal and habitat conservation.

Some researchers have expressed concern that barred owl removal experiments would be costly, ineffective, and distracting (Livezey 2010, Rosenberg et al. 2012). However, preliminary results from barred owl removal experiments indicate that lethal removal of barred owls is effective, relatively inexpensive, and conforms to animal welfare standards (Diller 2013, Diller et al. 2013, *Hoopa/other experiment area citations*). Other objections to barred owl removal are primarily ethical or emotional (Gutiérrez et al. 2007, Diller 2013). There is substantial emotional

resistance to lethal removal of barred owls, even among scientists and land managers involved with barred owl removal experiments (e.g., Diller 2013). Relocation of barred owls to zoos or their native forests in the eastern U.S. is logistically and politically unfeasible, so killing barred owls appears to be the only viable removal option (USFWS 2013). Primary ethical concerns regarding barred owl removal include whether or not it is appropriate to remove or control a native species or to intervene in its potentially natural range expansion (USFWS 2013). The USFWS (2013) reviewed scientific literature regarding the barred owl's status as a native or nonnative species and whether its range expansion was natural or human caused. It found that the literature was inconclusive regarding both issues. However, it concluded that humans are responsible for intervening in the barred owl's expansion because the NSO's vulnerability to barred owl competition and other stressors is due to timber harvesting and other past and continuing human activities. Regardless, the currently available evidence suggests that NSOs will continue to decline, and could ultimately become extinct, without widespread or strategic barred owl control measures.

The barred owl's increasing impact on NSOs in Late Successional Reserves, National Parks, and other reserved lands demonstrates that habitat protection alone is insufficient for addressing the barred owl threat (Gutiérrez et al. 2004). Nonetheless, habitat conservation remains crucial to the NSO's conservation (USFWS 2011). The importance of retaining suitable breeding habitat for NSOs has been well demonstrated at individual, territory, and population scales (e.g., Solis and Gutiérrez 1990, Franklin et al. 2000, Forsman et al. 2011; see *Threats: Timber Harvesting*). Habitat conservation might also be important for minimizing barred owl impacts on NSOs (USFWS 2011). Habitat loss and fragmentation due to timber harvesting or other disturbances

could intensify competition between NSOs and barred owls by bringing them into closer proximity (Gutiérrez et al. 2007, USFWS 2011). Dugger et al. (2011) found some support for this hypothesis in their study of NSO occupancy in southern Oregon. Their results indicated that barred owl presence and landscape-level habitat characteristics have additive effects on NSO occupancy rates. Specifically, the presence of barred owls appeared to exacerbate the negative effects of habitat loss and fragmentation on NSO occupancy. The USFWS (2011) suggested that retaining and restoring habitat may provide displaced or recruited NSOs with refugia from negative interactions with barred owls (USFWS 2011). Dugger et al. (2011) did not find direct support for this hypothesis. In their study, higher amounts and lower fragmentation of older forest did not reduce the negative effects of barred owls on NSO occupancy. However, they noted that some NSOs in their study continued to survive and successfully reproduce in areas with barred owl presence, possibly indicating that there are ecological conditions under which the two species can coexist. Additional and more direct research of the potential value of habitat refugia for NSOs is needed.

Acknowledgements

Xxxx

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Outdoor Marijuana Cultivation

Introduction

Although marijuana is perhaps the largest cash crop in California (Gettman 2006), its cultivation is largely unregulated and little is known about ~~its~~ environmental effects associated with its cultivation ~~environmental effects~~. Recent research has indicated that outdoor marijuana cultivation is currently having widespread and profound environmental impacts in California (Bauer cite, Gabriel et al. 2012, 2013, Thompson et al. 2014). Negative impacts of outdoor marijuana cultivation include wildlife deaths caused by pesticide exposure and poaching; habitat degradation caused by logging, road construction, pollution, and water diversion; and heightened safety concerns for research and resource personnel (Bauer cite, Gabriel et al. 2012, 2013, Thompson et al. 2014). The specific effects of outdoor marijuana cultivation on northern spotted owls (*Strix occidentalis caurina*; NSOs) are unknown. Recent findings of widespread pesticide exposure among fishers (~~*Martes*~~ *Pekania pennanti*) and barred owls (*Strix varia*) in northwestern California suggest that NSOs ~~in~~ within the state are likewise exposed and could be ~~negatively affected at both territory and population levels~~experiencing the same effects seen in fishers (~~Gabriel cite, Gabriel et al. 2012; reviewed below~~). NSOs could also be directly affected by environmental degradation from outdoor marijuana cultivation, ~~such as through~~via habitat modification ~~or suppression of rodent prey populations~~, or indirectly affected through ecological changes caused by reduced streamflows or pollution. Safety concerns associated with illegal marijuana cultivation may also be impacting NSOs and other wildlife through reduced research and survey efficiency and effort (Gabriel et al. 2013).

Comment [MWG1]: The plant itself is not hazardous, it's the activities associated with its cultivation.

Comment [MWG2]: New genus for the species.

Comment [MWG3]: Anticoagulant Rodenticide Exposure in Barred Owls, a Proxy for the Northern Spotted Owl in California Managed Forests: Implications of Food Web Contamination

Gabriel, M.W.1*, L. Diller2, J. Dumbacher3, J.M. Higley4, G.M. Wengert1, S. Mendia4, D. Lamphear2, D. Early2,K. Hamm2, and R. Poppenga5.
1*

The exposure of wildlife to anticoagulant rodenticides (AR) has been well documented in non-forest settings. Until recently with the discovery of rampant use of ARs within trespass marijuana sites, exposure to ARs in remote forest wildlife was unknown and unexpected. We investigated the landscape-wide AR contamination in 84 Barred Owls, a proxy species for the Northern Spotted Owl (NSO), within NSO suitable habitat on northwestern California managed timberlands. Additionally, we investigated whether owl prey sampled in owl habitat were exposed to ARs. A total of 40% of all tested owls were exposed to ARs while 37 rodents sampled within NSO habitat were negative. However, all invertebrate samples (100%) from trespass grows were positive for ARs. Due to the inherent and swift lethality of ARs, negative rodent data was anticipated; however this is the first report of AR exposure to field collected invertebrates. These results demonstrate that AR contamination within NSO populations in NW California is likely and that food web contamination for these owls and numerous forest wildlife species is concerning.

The Wildlife Society Presentation: Humboldt State University 2014

Comment [MWG4]: Will still need to cite it as unpublished presented data.

Comment [MWG5]: Mentioned above

Comment [MWG6]: How would NSO be affected by reduced wateflows? They do not use inverts >10% of their diet. Barred owls, possible, but NSO impact's due to streamflow's would need to have some substantial premise to make this point.

Pesticides

Pesticide application is usually intended to suppress populations of rodents, insects, mollusks, and other agricultural and urban pests, but can have inadvertent negative impacts on humans, pets, and other non-target animals (Erickson and Urban 2004, Albert et al. 2010, Mnif et al. 2011, Gabriel et al. 2012). Widespread secondary exposure to pesticides has been reported for raptors, carnivores, and other wildlife that consume poisoned rodents around farms and human dwellings (Albert et al. 2010, Murray 2013, ~~Thompson et al. 2014).~~ Researchers have generally assumed that pesticides pose little threat to wildlife outside of agricultural and urban areas (Gabriel et al. 2013). However, a recent publication reported that 79% of fishers tested in two study areas on federal and tribal forest lands in California had been exposed to anticoagulant rodenticides (ARs), including four that ~~apparently~~ died from lethal toxicosis (Gabriel et al. 2012; note: at least two more fishers in California died from AR poisoning following publication of this study: Gabriel et al. 2013). Most fishers in the study had been exposed to multiple AR compounds (range = 1-4, mean = 1.6). These findings not only raised concern for the West Coast fisher population, which the U.S. Fish and Wildlife Service recently proposed to list as threatened under the federal Endangered Species Act, but for the NSO, which has an overlapping distribution and diet with the fisher (Gabriel et al. 2013, Calforests 2014, USFWS 2014). Subsequently, ARs have been detected in a dead NSO recovered in Mendocino County (Calforests 2014) and xx of xx (xx%) barred owls tested for exposure in Humboldt County (Gabriel cite). Although barred owls are being tested as a proxy for NSOs (Gabriel cite), NSOs may be more widely exposed to ARs given their greater dietary specialization on rodents (see

Comment [MWG7]: Cite primary literature, Gabriel and Thompson are primary for fisher but not for other species.

Comment [MWG8]: More of habitat characteristics and some diet overlap.

Comment [MWG9]: See above presentation

USFWS 2013). Strong circumstantial evidence implicates pervasive illegal outdoor marijuana cultivation as the primary source of pesticide exposure for forest predators in California (Gabriel et al. 2012, 2013, Thompson et al. 2014).

ARs detected in forest predators in northern California include brodifacoum, bromadiolone, difethialone, chlorophacinone, diphacinone, warfarin, and coumachlor (Gabriel cite, Gabriel et al. 2012). Brodifacoum, bromadiolone, difethialone are classified as second-generation anticoagulant rodenticides (SGARs). SGARs were introduced in the 1970s due to widespread development of resistance among rodents to first-generation anticoagulant rodenticides (FGARs), such as warfarin, chlorophacinone, and diphacinone (Buckle et al. 1994). SGARs are more acutely toxic than FGARs and generally require only a single dose to kill rodents (Erickson and Urban 2004). However, rodents usually survive 5-10 days after consuming a lethal dose, during which time they may continue to consume additional rodenticide and remain available to predators (Cox and Smith 1992, Erickson and Urban 2004). SGARs are more persistent in animal tissues than FGARs and insecticides, which are more rapidly metabolized and excreted (Erickson and Urban 2004). Thus, exposure to FGARs and other non-SGAR pesticides is more difficult to detect than for SGARs and exposure to them could be underestimated (Albert et al. 2010, Thompson et al. 2014). Rodents such as dusky-footed woodrats (*Neotoma fuscipes*) and deer mice (*Peromyscus* spp.) are likely the primary source of AR exposure for NSOs because they are targeted by AR application and because they generally comprise most of the biomass in NSO diets (Forsman et al. 2004). Insects may be an additional source of AR exposure for NSOs and other wildlife. In terms of frequency of consumption, insects can substantially contribute to NSO diets regionally, locally, or seasonally (Forsman et al. 2004). Insects are not killed by ARs

Comment [MWG10]: Not all were detected, see 2012 Plos paper

Comment [MWG11]: Are they? I would rewrite with a general blanket statement that rodents are the primary source, however the main rodents most likely affected are…

Comment [MWG12]: Please see John Weins 2012 dissertation and publication https://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/28475/WiensJohnD2012.pdf?sequence=2

Comment [MWG13]: See weins study of minimal insect use by NSO

and may therefore continue to accumulate them in their tissues, essentially becoming small "packets" of AR (~~C. Thompson, pers. comm~~This would be primary data from Gabriel un published.).

Large quantities of ARs, particularly SGARs, are often spread across large areas in and around illegal outdoor marijuana grow sites (Gabriel et al. 2012, Thompson et al. 2014; Figure 1). Gabriel et al. (2012) noted that thousands of pounds of pesticides were found at illegal outdoor marijuana grow sites in California in 2008 and that 150 pounds of pesticide were found during a single three-week eradication operation on the Mendocino National Forest in 2011. Three sites raided in Humboldt County in 2013 contained a total of at least 17 pounds of SGAR bait, which researchers estimated was sufficient to kill 2,753 woodrats, 14 fishers, or five spotted owls (Humboldt Sentinel August 2, 2013). Other pesticides, such as organochlorine, organophosphate, and carbamate insecticides, some of which are banned in the U.S., are also frequently found at illegal outdoor marijuana grow sites (HSVTC 2012, Thompson et al. 2014). Pesticides are often applied along with large quantities of fertilizer at the base of marijuana plants grown outdoors (Thompson et al. 2014; Figure 1), suggesting that marijuana and surrounding plants may be taking up pesticidal compounds from the soil. If this occurs, then rodents and insects may accumulate pesticides through consumption of plants as well as pesticidal bait. Investigation of pathways of pesticide exposure for NSOs, as well as levels of exposure and potential physiological, behavioral, and population impacts, is needed.

Comment [MWG14]: Primary source was Humboldt county sheriffs office which we provided them the data for the press release. Cite HCSO

Figure 1: (A) Rodenticide and other pesticides found at a trespass outdoor marijuana grow site in Humboldt County (photo: Humboldt County Sheriff's Office) and (B) rodenticide bait and dry fertilizer strewn together below approximately 2,000 marijuana plants at a trespass outdoor grow site in Humboldt County (from Gabriel et al. 2012).

ARs are vitamin K antagonists, which cause impairment of the blood's ability to clot (Murray 2013). A lethal dose of AR causes animals to die from hemorrhage (Erickson and Urban 2004). Animals may also exhibit weakness prior to death or with a sublethal dose (Erickson and Urban 2004). Rodents exposed to ARs show altered behavior, such as spending more time in the open, freezing rather than bolting when threatened, and staggering (Cox and Smith 1992). These behaviors may increase predation risk for affected rodents and the opportunity for secondary exposure of predators to ARs (Cox and Smith 1992). Owls and other raptors with sublethal secondary exposure to ARs may often have reduced blood-clotting activity and can die from

minor wounds such as those commonly inflicted by prey (Erickson and Urban 2004, Murray 2013, Thompson et al. 2014). Non-AR pesticides have a variety of physiological effects, such as disrupting endocrine function or damaging the central nervous system (Grue et al. 1997, Mnif et al. 2011). Chronic or sublethal exposure to carbamate or organophosphate pesticides has been shown to reduce immune response, cause neurological disorders, reduce thermoregulatory control, and impair anti-predator behavior in wildlife (Grue et al. 1997; reviewed in Thompson et al. 2014). Pesticides can also have additive or synergistic effects on animals (Larsen et al. 2003 cited in Mnif et al. 2011, Relyea 2009). This is a source of additional concern for NSOs and other forest predators active near outdoor marijuana cultivation sites, where multiple types of pesticide are often present (HSVTC 2012, Thompson et al. 2014). Mortalities associated with exposure to pesticides are likely underestimated because carcasses are often predated or scavenged before biological samples can be obtained and because sublethal exposure can predispose wildlife to death from other causes (Albert et al. 2010).

There is no information available concerning population-level impacts of secondary pesticide exposure for NSOs in California. As reviewed above, secondary exposure to pesticides can kill raptors and other wildlife both through lethal toxicosis and by increasing the risk of mortality due to other factors such as predation, hypothermia, disease, parasites, or injury. NSO population rates are particularly sensitive to changes in adult survival (Noon and Biles 1990) so it is possible that direct and indirect mortalities associated with pesticide exposure could contribute to population declines (Sibly et al. 2000, Thompson et al. 2014). Pesticide exposure could also negatively impact NSO reproduction. Gabriel et al. (2012) noted that fisher mortalities caused by AR poisoning occurred between mid-April and mid-May. The timing of

these deaths coincided with the planting phase of outdoor marijuana cultivation, when seedlings are most vulnerable to rodent pests and AR use is likely highest (Gabriel et al. 2012). This time of year is also when NSOs incubate and brood young (Gutiérrez et al. 1995). Reduced parental care during this phase, for example due to compromised behavior or death of one or both parents, could result in death of offspring due to ~~chilling~~exposure, undernourishment, or predation (Grue et al. 1997). NSO populations could also be negatively impacted by pesticide suppression of prey populations or changes in community ecology caused by reductions of insects, small mammals, carnivores, raptors, amphibians, and aquatic animals (Relyea and Diecks 2008).

Comment [MWG15]: Why would NSO populations decrease if a carnivore population decreases, or for the other examples mentioned. It is plausible for the small mammals due to them being prey items. Explain for the reader

Other Environmental Effects

Activities related to outdoor marijuana cultivation can have a variety of environmental impacts beyond exposure of wildlife to pesticides, including negative effects of illegal and poorly planned water diversion, logging, and road construction; pollution of water and soils; poaching of wildlife; and ignition of wildfires (reviewed below). Negative impacts occur on both public and private lands (Bauer cite, Gabriel et al. 2013). However, the potential environmental impacts of marijuana cultivation could vary considerably, depending on the operation's location, scale, and practices. For example, some marijuana industry organizations and growers advocate growing practices aimed at minimizing environmental damage from outdoor cultivation (e.g., http://emeraldgrowers.org/). ~~No~~ there does not appear to be any information available at this time regarding effects of ecological degradation from marijuana cultivation on NSOs. Negative effects on NSOs are possible given the subspecies' sensitivity to habitat modification (see *Timber Harvesting* and *Wildfires*, this volume) and close association with riparian areas (e.g.,

Hamer et al. 2007, Irwin et al. 2012), where the impacts of marijuana cultivation are often concentrated. Furthermore, safety concerns associated with marijuana cultivation can substantially impact the ability of land managers to effectively survey and manage spotted owls and other sensitive wildlife (Keane et al. 2011, Gabriel et al. 2013, D. Hansen pers. obs.; see below).

Personnel with the California Department of Fish and Wildlife (Bauer cite) recently estimated hydrologic impacts of marijuana cultivation in northwestern California using high-resolution aerial imagery in Google Earth™ (e.g., Figure 2) and marijuana industry estimates of marijuana plant water requirements. Using these methods, they estimated that more than 82,000 marijuana plants were cultivated in 2012 in just four watersheds in Humboldt and Mendocino Counties (Table 1). Based on estimated numbers of marijuana plants and assumed water usage of 6 gallons per day per plant, they calculated that marijuana cultivation uses approximately 29% and 21% of the water that flows in the Redwood Creek and Salmon Creek watersheds per day during periods of minimum streamflow (Table 2). Although based on several assumptions (marijuana cultivation water sources and usage, complete visibility of cultivation sites in aerial imagery, complete usage of greenhouses), these estimates raised considerable concern about potential negative impacts of marijuana cultivation on watershed health and aquatic animals (cite). NSOs often exhibit a preference for nesting, roosting, and foraging in and near riparian areas (e.g., Hamer et al. 2007, Irwin et al. 2007). Thus, it is plausible that ecological changes caused by widespread water diversion for marijuana cultivation have negative indirect effects on NSOs.

Comment [MWG16]: This sentence fits the concern that I had above about water usage. But this should definitely be mentioned above

Figure 2: Outdoor (A) and greenhouse (B) marijuana cultivation sites identified with Google Earth™ (from Bauer cite). *Add Google Earth image(s) of trespass grow site(s).*

Table 1: Estimated numbers of outdoor marijuana cultivation sites, outdoor marijuana plants, marijuana greenhouses, marijuana plants in greenhouses, and total number of marijuana plants in four watersheds in Humboldt and Mendocino Counties (from Bauer cite).

	Redwood Creek (67.3 km²)	Salmon Creek (95.6 km²)	Redwood Creek North (730 km²)	Outlet Creek (419 km²)
Total outdoor cultivation sites	231	306	120	633
Total outdoor plants	10,475	11,697	5,984	16,843
Plant : Land area $\left(\frac{1}{km^2}\right)$	173.7	122.4	8.2	40.2
Total Greenhouses	324	302	273	320
Estimated Total Plants in Greenhouses	8,053	8,851	11,029	9,180
Greenhouse : Land Area $\left(\frac{1}{km^2}\right)$	4.8	3.1	0.4	0.8
Total Plants per Watershed*	**18,528**	**20,548**	**17,013**	**26,023**

**Field data indicate these totals may be underestimates.*

Table 2: Estimated daily water use for marijuana cultivation per day and during an entire growing season compared with minimum streamflow in four watersheds in Humboldt and Mendocino Counties (from Bauer cite).

	Redwood Creek	Salmon Creek	Redwood Creek North	Outlet Creek
Daily Water Use (gpd)	111,167	123,289	102,078	156,138
Minimum Streamflow (gpd)	387,763	581,645	---	---
Percent Use	**28.7%**	**21.2%**	---	---
Water Use per 150 Day Season (gal)	16,675,308	18,493,344	15,311,700	23,420,700

Marijuana growers on both public and private lands often illegally clearcut vegetation in order to create growing space for marijuana plants and room for artificial ponds and other structures (Bauer cite, Gabriel et al. 2013; Figure 3). Illegal cutting, along with creation of roads to access grow sites, can increase sedimentation in streams and creeks and thereby degrade habitat quality for aquatic and amphibious animals (Bauer cite). The effect of illegal vegetation clearing on NSOs is unknown. Given the close association of both marijuana cultivation and NSOs with riparian areas and surrounding uplands (e.g., Hamer et al. 2007, Irwin et al. 2007), it is plausible that widespread marijuana cultivation results in habitat loss or fragmentation for NSOs.

Figure 3: Areas cleared for outdoor marijuana cultivation.

From cite.

Clearing of a riparian area for marijuana cultivation at a trespass grow site.
Courtesy of Craig Thompson.

Widespread outdoor marijuana cultivation can further damage watershed health by polluting water and soils. In addition to pesticides, tremendous quantities of fertilizer are often applied at marijuana grow sites (HSVTC 2012, Thompson et al. 2014). Fertilizers, along with low flows caused by drought conditions and water diversion, may contribute to algae blooms and reduced oxygen levels in creeks and rivers (cite). Other pollution, including human waste, trash, and spilled diesel fuel from generators, is also frequently observed in and around streams at raided

outdoor marijuana grow sites (HSVTC 2012, C. Thompson, pers. comm.). Like water diversion and increased stream sedimentation, pollution from outdoor marijuana cultivation is primarily a source of concern for aquatic and amphibious animals but could have indirect ecological effects on NSOs and other wildlife.

Multiple recent wildfires in California have been attributed to marijuana growers. For example, in 2014, a marijuana grower was indicted on charges of starting the Nicolls Fire that burned nearly 1,700 acres in the Sequoia National Forest (SacBee 2014b). This grower allegedly set multiple fires in an attempt to avoid capture by other growers that he claimed were trying to kill him. Another marijuana grower was recently arrested for igniting the 2014 Bully Fire that burned nearly 13,000 acres in Shasta County (SacBee 2014a). This fire was apparently started when the grower's rental truck ignited dry grass when driven off-road in order to deliver soil amendments to a grow site. In 2009, a marijuana grower's camp stove ignited the 90,000-acre La Brea Fire in the Los Padres National Forest in southern California (inciweb). Large wildfires (e.g., thousands of acres) can burn through multiple NSO territories and can negatively affect NSOs in a variety of ways, particularly when they burn large areas at moderate to high severity (reviewed in *Threats: Wildfires*).

Illegal marijuana growers are often heavily armed in order to protect their crops and for poaching wildlife for food or to prevent wildlife damage to plants, equipment, or food caches (Gabriel et al. 2013, Boehm 2014; Figure 4). Many biologists and other field personnel working in California's forests have been interrogated, pursued, or shot at by marijuana growers (Gabriel et al. 2013, D. Hansen pers. obs.). Safety concerns associated with widespread illegal marijuana

cultivation can substantially curtail the ability of researchers and land managers to effectively locate, study, and manage spotted owls and other wildlife. For example, Six Rivers National Forest biologists were repeatedly excluded from entire pre-project NSO survey units in 2013 due to evidence of trespass outdoor marijuana cultivation (D. Hansen pers. obs.). Similarly, Keane et al. (2011) stated that their California spotted owl (*S. o. occidentalis*) survey crew was excluded from large portions of a study area in the Sierra Nevada in 2010 due to extensive illegal marijuana cultivation operations. Gabriel et al. (2013; Gabriel cite) estimated that safety concerns due to trespass outdoor marijuana cultivation resulted in exclusion of researchers from 15-25% of one fisher study area in California and a projected additional cost of $500,000-750,000 for the life of the combined budgets of two of California's fisher research projects. Wildlife surveyors who were able to work alone in the past must now frequently work in pairs for safety reasons, reducing survey efficiency and increasing project costs (Gabriel et al. 2013, D. Hansen pers. obs.). Exclusion from study areas can also compromise the ability of researchers to properly design and complete research investigating important conservation issues, such as effects of pesticides on fishers (Gabriel et al. 2013) and wildfires on spotted owls (Keane et al. 2011).

Figure 4: Armed marijuana growers posing in front of a poached deer (from Gabriel et al. 2013).

Magnitude and Location of Threat

Estimates of marijuana production and value are generally based on either federal marijuana seizure data (e.g., assuming that seizures represent 10 or 15% of the total amount produced) or marijuana consumption surveys and estimates of plant yields and market value (Gettman 2006) (reviewed in PBS 2014). Estimates from both of these methods indicate that California is, by far, the primary marijuana-producing state in the U.S. and that most of this production is from outdoor cultivation (NDIC 2011, Gettman 2006). Gettman (2006) estimated that, in 2006 alone, California produced an estimated 8.6 million pounds of marijuana with a value of more than 13.8 billion dollars. An estimated 89% of this product and value was from outdoor cultivation. If correct, marijuana is the largest cash crop in California (Gettman 2006), which is remarkable given that California is the most productive agricultural state in the U.S. (USDA 2014).

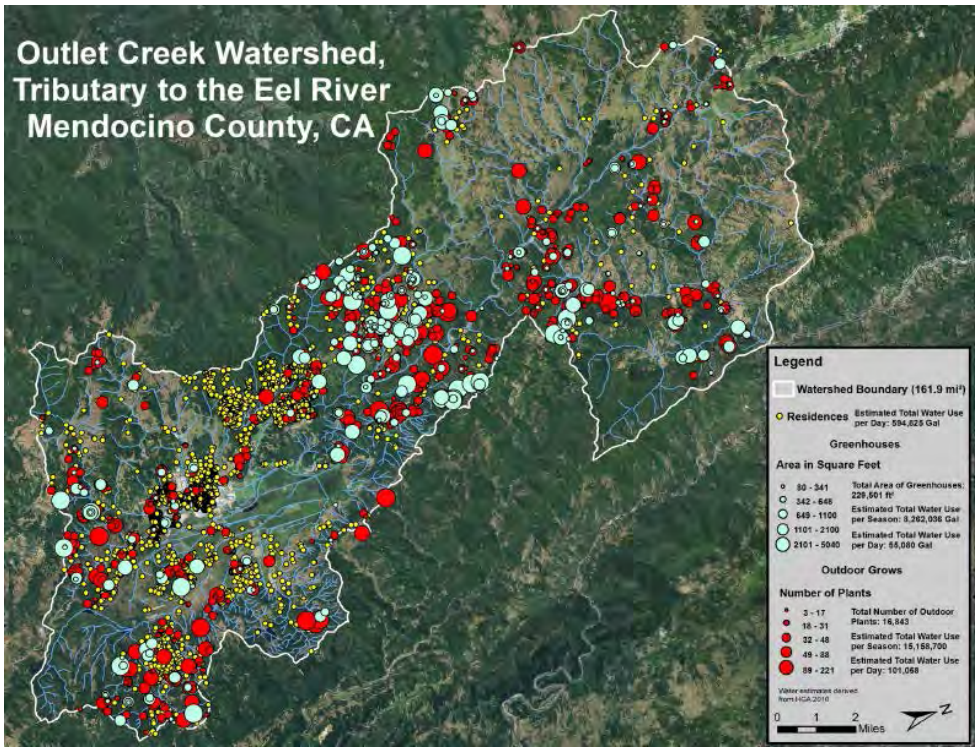
Outdoor marijuana cultivation in California has increased dramatically in recent years, including on both public and private lands (Bauer cite, NDIC 2011). This rapid growth was due to increased demand for domestically grown marijuana; possibly driven by state legalization of marijuana for medical use, changes in public perception of health or legal risk associated with marijuana use, or reduced imports from other countries due to tighter border control measures implemented after 9/11 (NDIC 2007, 2011, SacBee 2012). However, rapid growth of marijuana production in California apparently outstripped consumer demand in the last few years, particularly following federal crackdowns on medical marijuana dispensaries in the state (SacBee 2012). Desire among growers to maintain high profits in the face of increasing supply and decreasing prices could be a factor driving recent increases in the size and intensity (e.g., use of pesticides, fertilizer, and water) of many outdoor marijuana cultivation operations (cite, Bauer cite).

The number of outdoor marijuana plants eradicated in the U.S. increased by 250% between 2005 and 2010 (NDIC 2011). Federal eradication data suggest that trespass outdoor marijuana cultivation is increasing particularly rapidly on National Forests in California (NDIC 2011). Between 2005 and 2013, over 16 million marijuana plants were eradicated at approximately 3,356 sites on National Forests in California (Boehm 2014). Federal agencies have largely attributed increased numbers of trespass outdoor marijuana cultivation sites to expansion of operations by international drug trafficking organizations (e.g., Mexican drug cartels) into remote mountainous areas (particularly in northern California) in order to avoid detection by law enforcement personnel (NDIC 2007, Boehm 2014). However, the degree to which increases in amounts of eradicated or seized marijuana reflect increased production versus increased drug

enforcement effort is unclear, as is the scale of international drug trafficking organizations' role in outdoor marijuana cultivation in California (cite, NDIC 2010).

Outdoor marijuana production in California is also growing rapidly on private lands (NDIC 2007, Bauer cite). Personnel with the California Department of Fish and Wildlife (Bauer cite) used aerial imagery in Google Earth™ to estimate changes in the number and sizes of marijuana cultivation operations in four watersheds in Humboldt and Mendocino Counties during 2009-2012. In 2012 they identified nearly 1,300 outdoor grow sites and more than 1,200 greenhouses likely used for marijuana cultivation in these watersheds (Table 1; e.g., Figure 5). The number and size of marijuana cultivation operations identified increased in all four watersheds by 68-104% between 2009 and 2012. The total number of greenhouses and the number of greenhouses greater than 1,000 ft^2 increased by 69% and 87%, respectively. Continued use of aerial imagery and flyovers will shed greater light on the number, size, and location of outdoor marijuana operations on both public and private lands. For example, the California Department of Fish and Wildlife (2012) noted that law enforcement officers spotted more than 200 new marijuana grow operations in the Mattole Watershed in Humboldt County during a single flyover. *Describe proportion of marijuana cultivation sites identified by Bauer which were located on properties owned by private citizens vs. trespass grows on federal and/or timber co. lands. Incorporate other law enforcement information (e.g., any additional FOIA information from USFS law enforcement).*

Figure 5: Locations and sizes of marijuana cultivation operations identified in the Outlet Creek Watershed in Mendocino County using aerial imagery in Google Earth™ (from Bauer cite).



Summary and Management Implications

There is currently little direct information regarding potential impacts of illegal outdoor marijuana cultivation on NSOs. However, widespread application of ARs and other toxicants at outdoor grow sites are negatively impacting fishers, which have overlapping home ranges and diets with NSOs in northwestern California (Gabriel et al. 2012, 2013, Thompson et al. 2014). There is also evidence of widespread exposure to toxicants among barred owls in Humboldt County, and an NSO from Mendocino County recently tested positive for ARs (Gabriel cite, Calforests 2014). Thus, it is likely that NSOs in California are widely exposed to toxicants

applied at illegal outdoor marijuana grow sites. ARs and other pesticides can directly kill owls and other raptors or increase their vulnerability to other sources of mortality such as predation, disease, parasites, hypothermia, or injury (reviewed above). Furthermore, illegal outdoor marijuana cultivation is apparently causing widespread environmental degradation through toxicant exposure in other animals, reduced streamflows, pollution, poorly planned logging and road construction, and wildlife poaching (Bauer cite, Gabriel et al. 2013). Safety concerns associated with the widespread presence of heavily armed marijuana growers may also be impacting conservation of spotted owls and other wildlife by reducing the efficiency and effectiveness of research and survey efforts (Keane et al. 2011, Gabriel et al. 2013, D. Hansen pers. obs.).

Increased funding and effort are needed for evaluation of effects of outdoor marijuana cultivation on NSOs, other wildlife, and ecosystems (cite). Greater funding and coordination are also needed for interdiction, clean-up, and restoration at illegal outdoor grow sites (cite). These efforts require a substantial, multi-agency law enforcement presence, experts capable of identifying and properly disposing of toxicants, personnel and equipment for removing large amounts of trash and other material, and natural resource specialists for rehabilitating or restoring sites (Gabriel et al. 2013, Boehm 2014). Even if marijuana is legalized in California, tremendous resources, effort, and coordination may still be needed to regulate the industry and to continue to locate, clean up, and restore abandoned or interdicted illegal grow sites. Only a small portion of interdicted outdoor grow sites in California have been cleaned up thus far and even less have been restored (cite). Many of these sites may continue to pose an environmental threat long after they are abandoned by growers (Gabriel et al. 2013). For example, trespass

outdoor growers often cache ARs and other toxicants in water-proof containers, which bears can eventually find and open, allowing further poisoning and exposure of wildlife even after growing operations have ceased at the site (cite, HSVTC 2012).

Comment [MWG17]: They don't really cache these toxicants, the toxicants are manufactured in child proof or waterproof/resistance containers that leave the material still viable for years. This is citable by percom from many folks, including myself and craig.

The Environmental Protection Agency (EPA) and California Department of Pesticide Regulation (CDPR) have recently taken steps to reduce threats from SGARs to wildlife, children, and pets. Since 2011, EPA regulations have prohibited the sale of SGARs to the general consumer. Under EPA regulations, SGARs may only be purchased at agricultural stores, in bait station form rather than as loose pellets, and in relatively small quantities (Bradbury 2008). Most AR manufacturers quickly complied with these regulations and brought replacement products to market containing FGARs or neurotoxins, rather than SGARs (CDPR 2013, Murray 2013). However, the EPA only recently reached an agreement with Reckitt Benckiser to end distribution of their popular d-Con® products containing SGARs and sold without a protective bait station by March 31, 2015 (EPA 2014). On July 1, 2014, the CDPR further limited access to SGAR products in California by classifying them as restricted materials (California Department of Consumer Affairs 2014). In California, products containing SGARs can only be purchased from CDPR-licensed pest control dealers by certified applicators (California Department of Consumer Affairs 2014). Increased restrictions on public access to products containing SGARs should help to reduce exposure of wildlife to these compounds. However, considering that banned pesticides are commonly found at trespass outdoor marijuana cultivation sites (HSVTC 2012, Thompson et al. 2014) growers will likely continue to widely apply SGARs in forests occupied by NSOs, fishers, and other sensitive wildlife.

Comment [MWG18]: Cite Gabriel 2013 for banned pesiticides too. Showing a 3 years of publications documenting these toxicants.

Comment [MWG19]: Or other new emerging toxicants, or massive amounts of legal , high poundage FGARs.

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Outdoor Marijuana Cultivation

Introduction

Although marijuana is perhaps the largest cash crop in California (Gettman 2006), its cultivation is largely unregulated and little is known about its environmental effects. Recent research has indicated that outdoor marijuana cultivation is currently having widespread and profound environmental impacts in California (Bauer cite, Gabriel et al. 2012, 2013, Thompson et al. 2014). Negative impacts of outdoor marijuana cultivation include wildlife deaths caused by pesticide exposure and poaching; habitat degradation caused by logging, road construction, pollution, and water diversion; and heightened safety concerns for research and resource personnel (Bauer cite, Gabriel et al. 2012, 2013, Thompson et al. 2014). The specific effects of outdoor marijuana cultivation on northern spotted owls (*Strix occidentalis caurina*; NSOs) are unknown. Recent findings of widespread pesticide exposure among fishers (*Martes pennanti*) and barred owls (*Strix varia*) in northwestern California suggest that NSOs in the state are likewise exposed and could be negatively affected at both territory and population levels (Gabriel cite, Gabriel et al. 2012; reviewed below). NSOs could also be directly affected by environmental degradation from outdoor marijuana cultivation, such as through habitat modification or suppression of rodent prey populations, or indirectly affected through ecological changes caused by reduced streamflows or pollution. Safety concerns associated with illegal marijuana cultivation may also be impacting NSOs and other wildlife through reduced research and survey efficiency and effort (Gabriel et al. 2013).

Pesticides

Pesticide application is usually intended to suppress populations of rodents, insects, mollusks, and other agricultural and urban pests, but can have inadvertent negative impacts on humans, pets, and other non-target animals (Erickson and Urban 2004, Albert et al. 2010, Mnif et al. 2011, Gabriel et al. 2012). Widespread secondary exposure to pesticides has been reported for raptors, carnivores, and other wildlife that consume poisoned rodents around farms and human dwellings (Albert et al. 2010, Murray 2013, Thompson et al. 2014). Researchers have generally assumed that pesticides pose little threat to wildlife outside of agricultural and urban areas (Gabriel et al. 2013). However, a recent publication reported that 79% of fishers tested in two study areas on federal and tribal forest lands in California had been exposed to anticoagulant rodenticides (ARs), including four that apparently died from lethal toxicosis (Gabriel et al. 2012; note: at least two more fishers in California died from AR poisoning following publication of this study: Gabriel et al. 2013). Most fishers in the study had been exposed to multiple AR compounds (range = 1-4, mean = 1.6). These findings not only raised concern for the West Coast fisher population, which the U.S. Fish and Wildlife Service recently proposed to list as threatened under the federal Endangered Species Act, but for the NSO, which has an overlapping distribution and diet with the fisher (Gabriel et al. 2013, Calforests 2014, USFWS 2014). Subsequently, ARs have been detected in a dead NSO recovered in Mendocino County (Calforests 2014) and xx of xx (xx%) barred owls tested for exposure in Humboldt County (Gabriel cite). Although barred owls are being tested as a proxy for NSOs (Gabriel cite), NSOs may be more widely exposed to ARs given their greater dietary specialization on rodents (see USFWS 2013). Strong circumstantial evidence implicates pervasive illegal outdoor marijuana

cultivation as the primary source of pesticide exposure for forest predators in California (Gabriel et al. 2012, 2013, Thompson et al. 2014).

ARs detected in forest predators in northern California include brodifacoum, bromadiolone, difethialone, chlorophacinone, diphacinone, warfarin, and coumachlor (Gabriel cite, Gabriel et al. 2012). Brodifacoum, bromadiolone, difethialone are classified as second-generation anticoagulant rodenticides (SGARs). SGARs were introduced in the 1970s due to widespread development of resistance among rodents to first-generation anticoagulant rodenticides (FGARs), such as warfarin, chlorophacinone, and diphacinone (Buckle et al. 1994). SGARs are more acutely toxic than FGARs and generally require only a single dose to kill rodents (Erickson and Urban 2004). However, rodents usually survive 5-10 days after consuming a lethal dose, during which time they may continue to consume additional rodenticide and remain available to predators (Cox and Smith 1992, Erickson and Urban 2004). SGARs are more persistent in animal tissues than FGARs and insecticides, which are more rapidly metabolized and excreted (Erickson and Urban 2004). Thus, exposure to FGARs and other non-SGAR pesticides is more difficult to detect than for SGARs and exposure to them could be underestimated (Albert et al. 2010, Thompson et al. 2014). Pesticides are often applied along with large quantities of fertilizer at the base of marijuana plants grown outdoors, suggesting that marijuana plants may be taking up pesticidal compounds from the soil (Thompson et al. 2014; Figure 1). ~~If this occurs, NSOs and other wildlife could be exposed to pesticides through consumption of insects and rodents that eat marijuana plants, as well as by eating rodents that ingest AR bait (cite).~~

Comment [UFS1]: Can't cite me here, I did not talk about uptake in the paper. As far as I know, this is strongly suspected but hasn't been proven.

Large quantities of ARs, particularly SGARs, are often spread across large areas in and around illegal outdoor marijuana grow sites (Gabriel et al. 2012, Thompson et al. 2014; Figure 1). Gabriel et al. (2012) noted that thousands of pounds of pesticides were found at illegal outdoor marijuana grow sites in California in 2008 and that 150 pounds of pesticide were found during a single three-week eradication operation on the Mendocino National Forest in 2011. Three sites raided in Humboldt County in 2013 contained a total of at least 17 pounds of SGAR bait, which researchers estimated was sufficient to kill 2,753 woodrats, 14 fishers, or five spotted owls (Humboldt Sentinel August 2, 2013). Other pesticides, such as organochlorine, organophosphate, and carbamate insecticides, some of which are banned in the U.S., are also frequently found at illegal outdoor marijuana grow sites (~~cite~~HSVTC 1012, Thompson et al. 2014).

Figure 1: (A) Rodenticide and other pesticides found at a trespass outdoor marijuana grow site in Humboldt County (photo: Humboldt County Sheriff's Office) and (B) rodenticide bait and dry fertilizer strewn together below approximately 2,000 marijuana plants at a trespass outdoor grow site in Humboldt County (from Gabriel et al. 2012).

ARs are vitamin K antagonists, which cause impairment of the blood's ability to clot (Murray 2013). A lethal dose of AR causes animals to die from hemorrhage (Erickson and Urban 2004). Animals may also exhibit weakness prior to death or with a sublethal dose (Erickson and Urban 2004). Rodents exposed to ARs show altered behavior, such as spending more time in the open, freezing rather than bolting when threatened, and staggering (Cox and Smith 1992). These behaviors may increase predation risk for affected rodents and the opportunity for secondary exposure of predators to ARs (Cox and Smith 1992). Owls and other raptors with sublethal secondary exposure to ARs may often have reduced blood-clotting activity and can die from

minor wounds such as those commonly inflicted by prey (Erickson and Urban 2004, Murray 2013, Thompson et al. 2014). It is also worth noting that invertebrates respond differently and are not negatively impacted by the uptake of vitamin K antagonists. They are therefore capable of accumulating both FGAR and SGAR compounds either through direct consumption or potentially or the consumption of vegetation where uptake of pesticidal compounds has occurred. NSOs and other wildlife may therefore be exposed to pesticides through consumption of live or dead insects in the vicinity of grow sites.

Non-AR pesticides have a variety of physiological effects, such as disrupting endocrine function or damaging the central nervous system (Grue et al. 1997, Mnif et al. 2011). Chronic or sublethal exposure to carbamate or organophosphate pesticides has been shown to reduce immune response, cause neurological disorders, reduce thermoregulatory control, and impair anti-predator behavior in wildlife (Grue et al. 1997; reviewed in Thompson et al. 2014). Pesticides can also have additive or synergistic effects on animals (Larsen et al. 2003 cited in Mnif et al. 2011). This is a source of additional concern for NSOs and other forest predators active near outdoor marijuana cultivation sites, where multiple types of pesticide are often present (HSVTC 2012, Thompson et al. 2014). Mortalities associated with exposure to pesticides are likely underestimated because carcasses are often predated or scavenged before biological samples can be obtained and because sublethal exposure can predispose wildlife to death from other causes (cite, Albert et al. 2010).

There is no information available concerning population-level impacts of secondary pesticide exposure for NSOs in California. As reviewed above, secondary exposure to pesticides can kill

raptors and other wildlife both through lethal toxicosis and by increasing the risk of mortality due to other factors such as predation, hypothermia, disease, parasites, or injury. NSO population rates are particularly sensitive to changes in adult survival (Noon and Biles 1990) so it is possible that direct and indirect mortalities associated with pesticide exposure could contribute to population declines (Sibley et al. 2000~~cite~~, Thompson et al. 2014). Pesticide exposure could also negatively impact NSO reproduction. Gabriel et al. (2012) noted that fisher mortalities caused by AR poisoning occurred between mid-April and mid-May. The timing of these deaths coincided with the planting phase of outdoor marijuana cultivation, when seedlings are most vulnerable to rodent pests and AR use is likely highest (Gabriel et al. 2012). This time of year is also when NSOs incubate and brood young (cite). Reduced parental care during this phase, for example due to compromised behavior or death of one or both parents, could result in death of offspring due to chilling, undernourishment, or predation (Grue et al. 1997~~cite~~). NSO populations could also be negatively impacted by pesticide suppression of prey populations or changes in community ecology caused by reductions of insects, small mammals, carnivores, raptors, amphibians, and aquatic animals (Relyea and Diecks 2008~~cite~~).

Other Environmental Effects

Activities related to outdoor marijuana cultivation can have a variety of environmental impacts beyond exposure of wildlife to pesticides, including negative effects of illegal and poorly planned water diversion, logging, and road construction; pollution; poaching; and ignition of wildfires (reviewed below). Negative impacts occur on both public and private lands (cite, Bauer cite, Gabriel et al. 2013). The potential environmental impacts of marijuana cultivation

could vary considerably, depending on the operation's location, scale, and practices. We are unaware of any information regarding effects of ecological degradation from marijuana cultivation on NSOs. Negative effects on NSOs are possible given the subspecies' sensitivity to habitat modification (cite) and close association with riparian areas (cite), where the impacts of marijuana cultivation are often concentrated. Furthermore, safety concerns associated with marijuana cultivation can substantially impact the ability of land managers to effectively survey and manage spotted owls and other sensitive wildlife (Keane et al. 2011, Gabriel et al. 2013, D. Hansen pers. obs.).

Personnel with the California Department of Fish and Wildlife (Bauer cite) recently estimated hydrologic impacts of marijuana cultivation in northwestern California using high-resolution aerial imagery in Google Earth™ (e.g., Figure 2) and marijuana industry estimates of marijuana plant water requirements. Using these methods, they estimated that more than 82,000 marijuana plants were cultivated in 2012 in just four watersheds in Humboldt and Mendocino Counties (Table 1). Based on estimated numbers of marijuana plants and assumed water usage of 6 gallons per day per plant, they calculated that marijuana cultivation uses approximately 29% and 21% of the water that flows in the Redwood Creek and Salmon Creek watersheds per day during periods of minimum streamflow (Table 2). Although based on several assumptions (marijuana cultivation water sources and usage, complete visibility of cultivation sites in aerial imagery, complete usage of greenhouses), these estimates raised considerable concern about potential negative impacts of marijuana cultivation on watershed health and aquatic animals (cite). This concern is currently heightened given California's ongoing severe drought (cite). NSOs often exhibit a preference for nesting, roosting, and foraging in and near riparian areas (cite). Thus, it

is plausible that ecological changes caused by widespread water diversion for marijuana cultivation have negative indirect effects on NSOs.

Figure 2: Outdoor (A) and greenhouse (B) marijuana cultivation sites identified with Google Earth™ (from Bauer cite). *Add Google Earth image(s) of trespass grow site(s).*

Table 1: Estimated numbers of outdoor marijuana cultivation sites, outdoor marijuana plants, marijuana greenhouses, marijuana plants in greenhouses, and total number of marijuana plants in four watersheds in Humboldt and Mendocino Counties (from Bauer cite).

	Redwood Creek (67.3 km²)	Salmon Creek (95.6 km²)	Redwood Creek North (730 km²)	Outlet Creek (419 km²)
Total outdoor cultivation sites	231	306	120	633
Total outdoor plants	10,475	11,697	5,984	16,843
Plant : Land area $\left(\frac{1}{km^2}\right)$	173.7	122.4	8.2	40.2
Total Greenhouses	324	302	273	320
Estimated Total Plants in Greenhouses	8,053	8,851	11,029	9,180
Greenhouse : Land Area $\left(\frac{1}{km^2}\right)$	4.8	3.1	0.4	0.8
Total Plants per Watershed*	**18,528**	**20,548**	**17,013**	**26,023**

**Field data indicate these totals may be underestimates.*

Table 2: Estimated daily water use for marijuana cultivation per day and during an entire growing season compared with minimum streamflow in four watersheds in Humboldt and Mendocino Counties (from Bauer cite).

	Redwood Creek	Salmon Creek	Redwood Creek North	Outlet Creek
Daily Water Use (gpd)	111,167	123,289	102,078	156,138
Minimum Streamflow (gpd)	387,763	581,645	---	---
Percent Use	**28.7%**	**21.2%**	---	---
Water Use per 150 Day Season (gal)	16,675,308	18,493,344	15,311,700	23,420,700

Marijuana growers on both public and private lands often illegally clearcut vegetation in order to create growing space for marijuana plants and room for artificial ponds and other structures (cite, Gabriel et al. 2013; Figure 3). Illegal cutting, along with creation of roads to access grow sites, can increase sedimentation in streams and creeks and thereby degrade habitat quality for aquatic and amphibious animals (cite). The effect of illegal vegetation clearing on NSOs is unknown. Given the close association of both marijuana cultivation and NSOs with riparian areas and surrounding uplands, it is plausible that widespread marijuana cultivation results in habitat loss or fragmentation for NSOs.

Figure 3: Area cleared for outdoor marijuana cultivation (from cite). *Find and add photo from trespass grow site adjacent to creek.*

Widespread outdoor marijuana cultivation can further damage watershed health by polluting water and soils. In addition to pesticides, tremendous quantities of fertilizer are often applied at marijuana grow sites (~~cite~~HSVTC 2012, Thompson et al. 2014). Fertilizers, along with low flows caused by drought conditions and water diversion, can contribute to algae blooms and reduced oxygen levels in creeks and rivers (cite). Other pollution, including human waste, trash, and spilled diesel fuel from generators, is also frequently observed in and around streams at raided outdoor marijuana grow sites (~~cite~~HSVTC 2012, C. Thompson pers com). Like water diversion and increased stream sedimentation, pollution from outdoor marijuana cultivation is primarily a source of concern for aquatic and amphibious animals but could have indirect ecological effects on NSOs and other wildlife.

Multiple recent wildfires in California have been attributed to marijuana growers. For example, in 2014, a marijuana grower was indicted on charges of starting the Nicolls Fire that burned nearly 1,700 acres in the Sequoia National Forest (SacBee 2014b). This grower allegedly set

multiple fires in an attempt to avoid capture by other growers that he claimed were trying to kill him. Another marijuana grower was recently arrested for igniting the 2014 Bully Fire that burned nearly 13,000 acres in Shasta County (SacBee 2014a). This fire was apparently started when the grower's rental truck ignited dry grass when driven off-road in order to deliver soil amendments to a grow site. In 2009, a marijuana grower's camp stove ignited the 90,000-acre La Brea Fire in the Los Padres National Forest in southern California (inciweb). Large wildfires (e.g., thousands of acres) can burn through multiple NSO territories and can negatively affect NSOs in a variety of ways, particularly when they burn large areas at moderate to high severity (reviewed in *Threats: Wildfires*).

Illegal marijuana growers are often heavily armed in order to protect their crops and for poaching wildlife for food or to prevent damage to plants, equipment, or food caches (Boehm cite, Gabriel et al. 2013; Figure 4). Many biologists and other field personnel working in California's forests have been interrogated, pursued, or shot at by marijuana growers (cite, Gabriel et al. 2013, D. Hansen pers. obs.). Safety concerns associated with widespread illegal marijuana cultivation can substantially curtail the ability of researchers and land managers to effectively locate, study, and manage spotted owls and other wildlife. For example, Six Rivers National Forest biologists were repeatedly excluded from entire pre-project NSO survey units in 2013 due to evidence of trespass outdoor marijuana cultivation (D. Hansen pers. obs.). Similarly, Keane et al. (2011) stated that their California spotted owl (*S. o. occidentalis*) survey crew was excluded from large portions of a study area in the Sierra Nevada in 2010 due to extensive illegal marijuana cultivation operations. Gabriel et al. (2013; Gabriel cite) estimated that safety concerns due to trespass outdoor marijuana cultivation resulted in exclusion of researchers from 15-25% of one

fisher study area in California and a projected additional cost of $500,000-750,000 for the life of the combined budgets of two of California's fisher research projects. Wildlife surveyors who were able to work alone in the past must now frequently work in pairs for safety reasons, reducing survey efficiency and increasing project costs (Gabriel et al. 2013, D. Hansen pers. obs.). Exclusion from study areas can also compromise the ability of researchers to properly design and complete research investigating important conservation issues, such as effects of pesticides on fishers (Gabriel et al. 2013) and wildfires on spotted owls (Keane et al. 2011).

Figure 4: Armed marijuana growers posing in front of a poached deer (from Gabriel et al. 2013).

Magnitude and Location of Threat

Estimates of marijuana production and value are generally based on either federal marijuana seizure data (e.g., assuming that seizures represent 10% of the total amount produced) or marijuana consumption surveys and estimates of plant yields and market value (Gettman 2006) (reviewed in PBS 2014). Estimates from both of these methods indicate that California is, by

far, the primary marijuana-producing state in the U.S. and that most of this production is from outdoor cultivation (cite, NDIC 2011, Gettman 2006). Gettman (2006) estimated that, in 2006 alone, California produced an estimated 8.6 million pounds of marijuana with a value of more than 13.8 billion dollars. An estimated 89% of this product and value was from outdoor cultivation. If correct, marijuana is the largest cash crop in California (Gettman 2006), which is remarkable given that California is the most productive agricultural state in the U.S. (USDA 2014).

Outdoor marijuana cultivation in California has increased dramatically in recent years, including on both public and private lands (cite, Bauer cite, NDIC 2011). This rapid growth was due to increased demand for domestically grown marijuana; possibly driven by state legalization of marijuana for medical use, changes in public perception of health or legal risk associated marijuana use, or reduced imports from other countries due to tighter border control measures implemented after 9/11 (cite, NDIC 2007, 2011, SacBee 2012). However, rapid growth of marijuana production in California apparently outstripped consumer demand in the last few years, particularly following federal crackdowns on medical marijuana dispensaries in the state (SacBee 2012). Desire among growers to maintain high profits in the face of increasing supply and decreasing prices could be a factor driving recent increases in the size and intensity (e.g., use of pesticides, fertilizer, and water) of many outdoor marijuana cultivation operations (cite, Bauer cite).

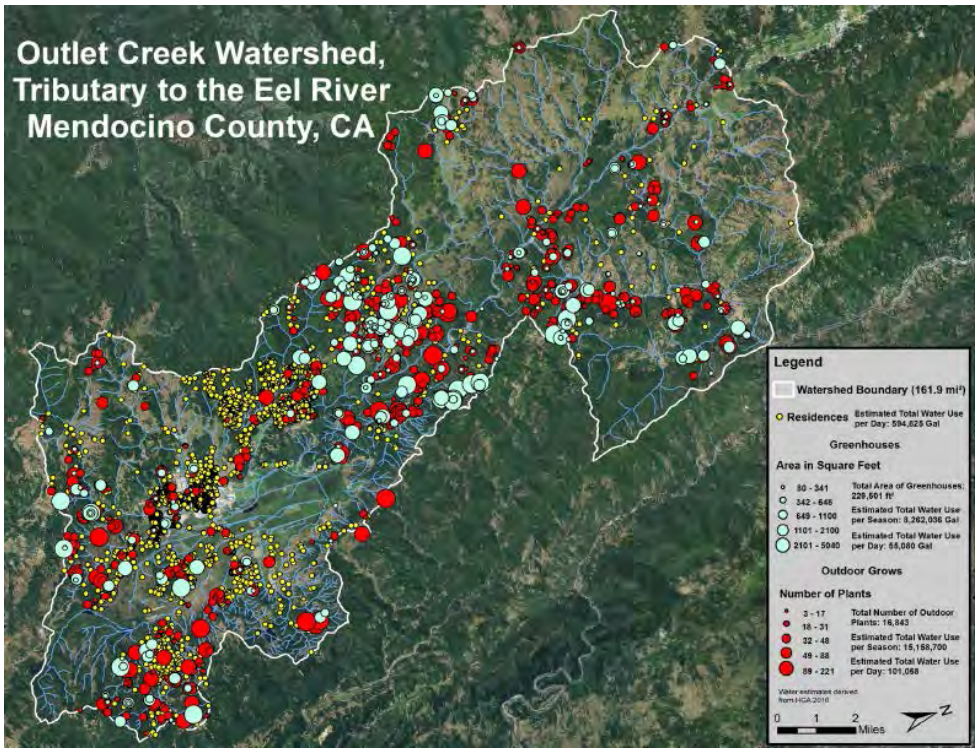
The number of outdoor marijuana plants eradicated in the U.S. increased by 250% between 2005 and 2010 (NDIC 2011). Federal eradication data suggest that trespass outdoor marijuana

cultivation is increasing particularly rapidly on National Forests in California (NDIC 2011). Between 2005 and 2013, over 16 million marijuana plants were eradicated at approximately 3,356 sites on National Forests in California (Boehm 2014). Federal agencies have largely attributed increased numbers of trespass outdoor marijuana cultivation sites to expansion of operations by international drug trafficking organizations (e.g., Mexican drug cartels) into remote mountainous areas (particularly in northern California) in order to avoid detection by law enforcement (NDIC 2007, Boehm cite). However, the degree to which increases in amounts of eradicated or seized marijuana reflect increased production versus increased drug enforcement effort is unclear, as is the scale of international drug trafficking organizations' role in outdoor marijuana cultivation in California (cite, NDIC 2010).

Outdoor marijuana production in California is also growing rapidly on private lands (NDIC 2007, Bauer cite). Personnel with the California Department of Fish and Wildlife (Bauer cite) used aerial imagery in Google Earth™ to estimate changes in the number and sizes of marijuana cultivation operations in four watersheds in Humboldt and Mendocino Counties during 2009-2012. In 2012 they identified nearly 1,300 outdoor grow sites and more than 1,200 greenhouses likely used for marijuana cultivation in these watersheds (Table 1; e.g., Figure 5). The number and size of marijuana cultivation operations identified increased in all four watersheds by 68-104% between 2009 and 2012. The total number of greenhouses and the number of greenhouses greater than 1,000 ft^2 increased by 69% and 87%, respectively. Continued use of aerial imagery and flyovers will shed greater light on the number, size, and location of outdoor marijuana operations on both public and private lands. For example, the California Department of Fish and Wildlife (2012) noted that law enforcement officers spotted more than 200 new marijuana grow

operations in the Mattole Watershed in Humboldt County during a single flyover. *Describe proportion of marijuana cultivation sites identified by Bauer which were located on properties owned by private citizens vs. trespass grows on federal and/or timber co. lands. Incorporate other law enforcement information (e.g., FOIA information from USFS law enforcement).*

Figure 5: Locations and sizes of marijuana cultivation operations identified in the Outlet Creek Watershed in Mendocino County using aerial imagery in Google Earth™ (from Bauer cite).



Summary and Management Implications

There is currently little direct information regarding potential impacts of illegal outdoor marijuana cultivation on NSOs. However, widespread application of ARs and other toxicants at

outdoor grow sites are negatively impacting fishers, which have overlapping home ranges and diets with NSOs in northwestern California (Gabriel et al. 2012, 2013, Thompson et al. 2014). There is also evidence of widespread exposure to toxicants among barred owls in Humboldt County, and an NSO from Mendocino County recently tested positive for ARs (Gabriel cite, Calforests 2014). Thus, it is likely that NSOs in California are widely exposed to toxicants applied at illegal outdoor marijuana grow sites. ARs and other pesticides can directly kill owls and other raptors or increase their vulnerability to other sources of mortality such as predation, disease, parasites, hypothermia, or injury (reviewed above). Furthermore, illegal outdoor marijuana cultivation is apparently causing widespread environmental degradation through toxicant exposure in other animals, reduced streamflows, pollution, poorly planned logging and road construction, and wildlife poaching (cite, Bauer cite, Gabriel et al. 2013). Safety concerns associated with the widespread presence of heavily armed marijuana growers may also be impacting conservation of spotted owls and other wildlife by reducing the efficiency and effectiveness of research and survey efforts (Keane et al. 2011, Gabriel et al. 2013, D. Hansen pers. obs.).

Increased funding and effort are needed for evaluation of effects of outdoor marijuana cultivation on NSOs, other wildlife, and ecosystems (cite). Greater funding and coordination are also needed for interdiction, clean-up, and restoration at illegal outdoor grow sites (cite). These efforts require a substantial, multi-agency law enforcement presence, experts capable of identifying and properly disposing of toxicants, personnel and equipment for removing large amounts of trash and other material, and natural resource specialists for rehabilitating or restoring sites (Gabriel et al. 2013, Boehm 2014). Even if marijuana is legalized in California,

tremendous resources, effort, and coordination may still be needed to regulate the industry and to continue to locate, clean up, and restore abandoned or interdicted illegal grow sites. Only a small portion of interdicted outdoor grow sites in California have been cleaned up thus far and even less have been restored (cite). Many of these sites may continue to pose an environmental threat long after they are abandoned by growers (Gabriel et al. 2013). For example, trespass outdoor growers often cache ARs and other toxicants in water-proof containers, which bears can eventually find and open, allowing further poisoning and exposure of wildlife even after growing operations have ceased at the site (cite).

The Environmental Protection Agency (EPA) and California Department of Pesticide Regulation (CDPR) have recently taken important steps to reduce threats from SGARs to wildlife, children, and pets. Since 2011, EPA regulations have prohibited the sale of SGARs to the general consumer. Under EPA regulations, SGARs may only be purchased at agricultural stores, in bait station form rather than as loose pellets, and in relatively small quantities (Bradbury 2008). Most AR manufacturers quickly complied with these regulations and brought replacement products to market containing FGARs or neurotoxins, rather than SGARs (CDPR 2013, Murray 2013). However, the EPA only recently reached an agreement with Reckitt Benckiser to end distribution of their popular d-Con® products containing SGARs and sold without a protective bait station by March 31, 2015 (EPA 2014). On July 1, 2014, the CDPR further limited access to SGAR products in California by classifying them as restricted materials (California Department of Consumer Affairs 2014). In California, products containing SGARs can only be purchased from CDPR-licensed pest control dealers by certified applicators (California Department of Consumer Affairs 2014). Increased restrictions on public access to products containing SGARs

should help to reduce exposure of wildlife to these compounds. However, considering that banned pesticides are commonly found at trespass outdoor marijuana cultivation sites (HSVTC 2012~~cite~~, Thompson et al. 2014), growers will likely continue to apply SGARs in forests occupied by NSOs, fishers, and other sensitive wildlife.

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Ch. 1: Status and Trends in California

Introduction

Several lines of evidence are available for evaluating the northern spotted owl's (*Strix occidentalis caurina*; NSO) status and trends in California. These include changes in the subspecies' geographic range and distribution, density and abundance, occupancy and demographic rates, meta-population dynamics, and genetics. The most reliable information available for examining the NSO's status and trends is provided by long-term demographic studies. Data from these studies are periodically analyzed together in meta-analyses for describing larger demographic patterns within ecoregions and states. A new demographic meta-analysis is expected to be released in mid-2015. This document will provide the best available information for determining the NSO's current status and trends. However, only a small portion of the NSO's range in California occurs within demographic study areas and those study areas all occur in relatively productive forests in the northwestern part of the state. It is therefore important to consider other sources of information, such as data collected for monitoring NSOs in National Parks and on industrial timber company lands located in different regions of northern California. The NSO's status and trends likely vary among regions, forest types, and ownerships and could be influenced by a host of factors, such as differences in forest ecology, management history, and stressors such as competition with invasive barred owls (*Strix varia*). It is also important to remember that available sources of information for evaluating the NSO's status and trends in California vary substantially in terms of their purpose and scientific rigor.

Range

The current range of the NSO includes southwestern British Columbia and the Cascade Mountains, coastal ranges, and intervening forests of Washington, Oregon, and California (USFWS 2011a). In California, the NSO's range extends from the Oregon border through the Northern Coast Ranges to Marin County, across the Klamath Mountains, and down the southern Cascades to the vicinity of the Pit River, where it contacts the range of the California spotted owl (*S. o. occidentalis*) (Figure 1.1).

The precise historical range of the NSO is unknown. Thus, despite substantial loss, degradation, and fragmentation of NSO habitat (see Chapters 2 and 3 of this volume), there is no evidence that the subspecies' range has contracted since Euro-American settlement (Thomas et al. 1990). However, British Columbia's NSO population has declined to very low numbers and is highly vulnerable to extirpation (Chutter et al. 2004). NSO populations in the Cascades and Olympic Peninsula of Washington and the Northern Coast Range of Oregon are also rapidly declining and may become vulnerable to extirpation (Forsman et al. 2011; see *Demography*, below). Loss of NSO populations could cause substantial contraction of the subspecies' range. For example, extirpation of NSOs from British Columbia alone would reduce the subspecies' range by approximately 8% (Cooper 2006).

Comment [LVD1]: Yes, and we also can't rule out that there may have been some localized expansions of the species range. Historically, prairies were much more extensive in coastal CA (see Redwood National Parks prairie management plan). In fact, the coastal prairies that occur primarily on the ridges and south-facing slopes in the redwood region are part of the California coast grassland that was ranked as one of the most endangered ecosystems in America (Noss and Peters 1995 report on endangered ecosystems). Currently, there are NSO living in prairie intrusion forests throughout coastal CA that would not have been forest lands at all 100+ years ago.

Distribution

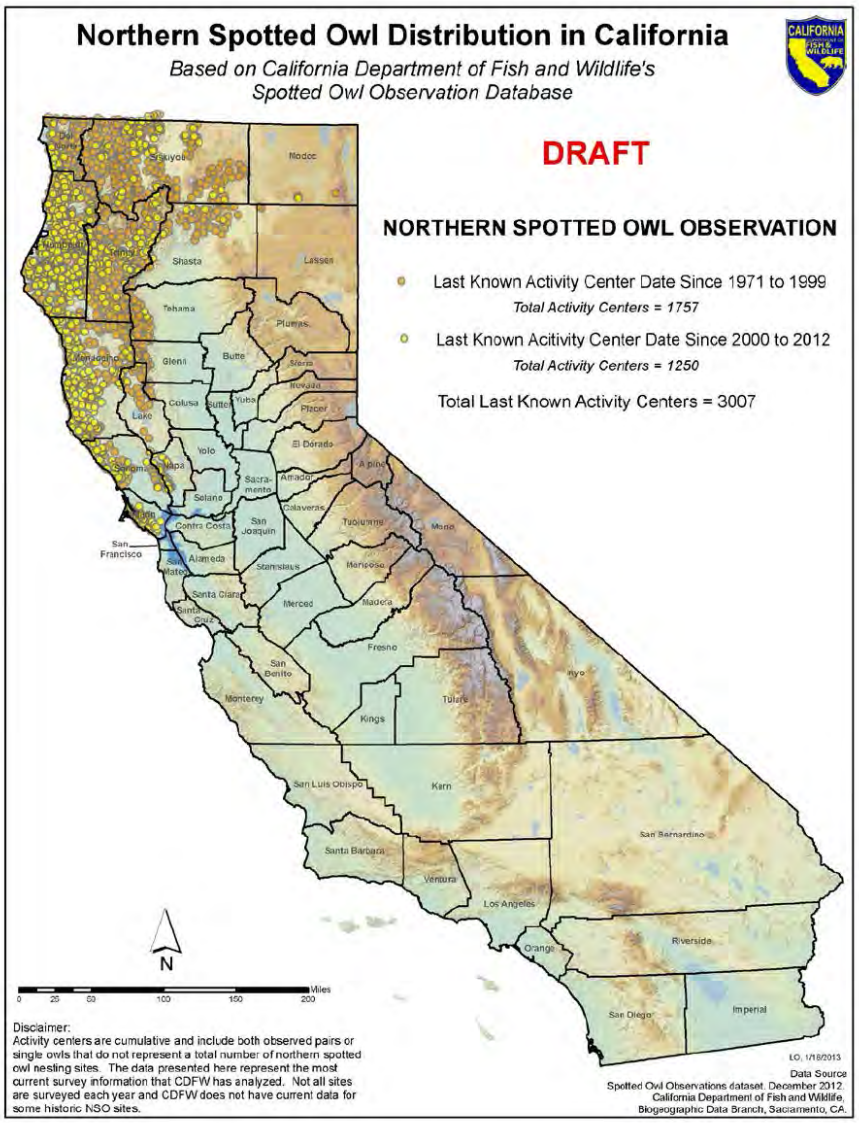
NSOs are thought to have been well distributed throughout most coniferous forests in the Pacific Northwest and northwestern California prior to Euro-American settlement (USFWS 2011a). The abundance and distribution of NSOs have likely declined due to removal of most (ca. 60-88%) old forest within its range (USFWS 1990; see Chapter 2 of this volume). For example, the Puget Trough in Washington and the Willamette Valley in Oregon no longer support NSOs due to land conversion and timber harvesting and very few NSOs remain in British Columbia (Thomas et al. 1990). The NSO's distribution has decreased in other areas of Washington and Oregon as well, due primarily to negative effects of timber harvesting, wildfires, and competition with barred owls (*Strix varia*) (Thomas et al. 1990).

Comment [LVD2]: I think the statement is accurate, but it doesn't seem like a 1990 publication would be the best source to support the conclusion. I would recommend using several publications including the status review (Courtney et al. 2004), Revised NSO recovery plan and possibly Forsman et al. 2011.

It is unknown if the NSO's distribution has changed in California. A difference is evident in the distribution of known historically (1971-1999) and recently (2000-2012) occupied activity centers (ACs) in the Eastern Klamath, Interior Northern Coast Ranges, and Southern Cascades regions of the state (Figure 1.1; see USFWS 2011a Appendix C for ecoregional boundaries generally followed in this synthesis). It is unclear from these data, however, whether the distribution of NSOs has in fact decreased in these areas or if the apparent decline in distribution is due to some other factor such as decreased survey effort or reporting of detections. It is also possible that this difference is due to the greater number of years included in the historical period than in the recent period (29 vs. 13 yrs). However, the two periods are similar in length relative to federal listing of the NSO (10 vs. 13 yrs) when survey effort presumably became more intensive and widespread. Some portions of the Klamath, Interior Northern Coast Ranges, and Southern Cascades have experienced widespread intensive timber harvesting or large wildfires, which could have reduced the NSO's distribution (see Chapters 2 and 3 of this volume). These forms of disturbance, along with competition with invasive barred owls, have likely contributed to declining occupancy by NSOs in some areas of California (see *Occupancy*, below). Nonetheless, the Klamath and Interior Northern Coast Ranges (but not the Southern Cascades) still appear to contain relatively large amounts of well connected suitable habitat and likely function as crucial population sources for NSOs (Schumaker et al. 2014; see *Source-Sink Dynamics*, below).

Comment [LVD3]: In balance, I think it should be mentioned that some level of disturbance in portion of the NSO range in CA contributes to increased habitat heterogeneity that actually improves habitat fitness for NSO (Franklin et al. 2000). This same phenomenon has been demonstrated by Olson et al. 2004, Hoopa and Green Diamond (10-year status review).

Figure 1.1: Distribution of northern spotted owl activity centers in the California Department of Fish and Wildlife's Spotted Owl Observation Database (from California Department of Fish and Wildlife 2013).



Density and Abundance

Species are rarely uniformly distributed across their range. Knowledge of variation in the density and abundance of NSOs is of potential conservation value because it can help identify areas where limited conservation resources should be focused. For example, while declines in low-abundance areas may be more likely to cause contraction of a species' range or distribution (see *Range* and *Distribution*, above), declines in high-abundance areas may disproportionately impact the species' probability of long-term persistence; particularly when high-abundance areas function as population sources (Pulliam 1988, Rodríguez 2002, Schumaker et al. 2014; see *Source-Sink Dynamics*, below).

Several studies have estimated either crude densities (owls or occupied territories per unit area) or ecological densities (owls per unit area of specified habitat class[es]) of NSOs in California (Blakesley et al. 2004; Table 1.1). These estimates are interesting in that they appear to reflect geographic variation in the ecology of NSOs (see below). However, they have limited utility for evaluating the NSO's status or trends in California. Available density estimates for the state are largely restricted to relatively mesic areas of northwestern California, which differ ecologically from drier interior forests (e.g., in terms of climate, forest productivity, and prey communities). Inferences from most density estimates are also limited because they are based on empirical counts of unmarked NSOs, which can bias estimates (Franklin et al. 1990, Diller and Thome 1999). Many of the currently available density and occupancy estimates for NSOs in California were provided by timber companies (Tables 1.1 and 1.2). While potentially useful for evaluating effects of management activities on timber company lands, these estimates do not describe population trends. Rigorous evaluation of NSO population trends require~~s~~ ~~adequate~~ long term statistically valid sampling designs ~~effort~~ from which with estimates of abundance or population lambda with confidence intervals can be repeatedly obtained within the same study area ~~year after year~~. In contrast, timber companies generally shift their NSO survey areas over time as timber harvest projects are completed in some areas and begun in others.

Based on limited information, both crude and ecological densities of NSOs appear to be substantially higher in northwestern California than in the Oregon Coast Ranges (Blakesley et al. 2004; Table 1.1). Lower densities in the Oregon Coast Ranges could be partially related to widespread intensive timber harvesting, which apparently contributed to a major decline in densities during the early 1990s (Thrailkill et al. 1998). Some areas of northwestern California have also experienced widespread intensive timber harvesting (see Chapter 2 of this volume) but its effect on NSOs might have differed from that in the Oregon Coast Ranges. In general, NSOs in California primarily subsist on dusky-footed woodrats (*Neotoma fuscipes*) (in terms of biomass contribution to diets). NSOs that primarily subsist on dusky-footed woodrat often have smaller home ranges, and apparently occur at higher densities, than those that primarily rely on smaller-bodied prey (Carey et al. 1992, Zabel et al. 1995). Furthermore, in contrast with other primary prey species, such as northern flying squirrels (*Glaucomys sabrinus*) and tree voles (*Arborimus* spp.), dusky-footed woodrats seem to respond positively, albeit temporarily, to some forms of intensive timber harvesting (see Chapter 2 of this volume).

Comment [LVD4]: Again this is where the issue of habitat heterogeneity (Franklin et al. 2000) should be mentioned in terms of the differential NSO response in NW CA versus areas where NSO feed primarily on flying squirrels. The mixture of older stands for roosting and nesting and young stands for woodrats provides the best habitat. As you noted, this woodrat response is only temporary, which makes the best NSO habitat highly dynamic in this region.

Densities of NSOs are also thought to be higher in northwestern California than in the state's interior (Calforests 2014). However, there are apparently only two density estimates currently

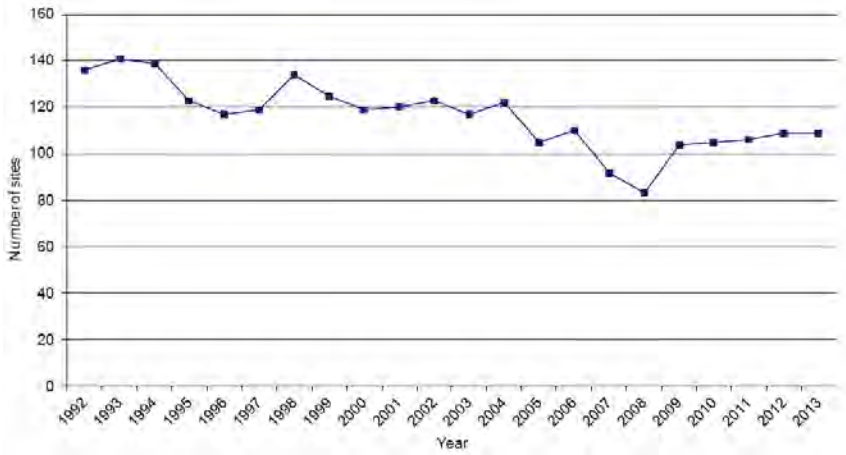
available for interior northern California and both of these were for crude densities of occupied territories, rather than for individual owls as estimated by most studies in northwestern California (Table 1.1). These crude territory densities are substantially lower than those found on two timber companies' lands in the Redwood Region (Table 1.1). NSO densities may be relatively low in the Southern Cascades of California due to the prevalence of drier, less productive forests, a history of widespread intensive harvesting, and effects of recent large wildfires (see Chapters 2 and 3 of this volume). Additional density estimates are needed for the Eastern Klamath of California. It is uncertain whether Sierra Pacific Industries' (2013) estimates are representative of densities across the region as a whole. Most NSO activity centers (ACs) included in Sierra Pacific's density estimates were located near the margins of the company's lands or on adjacent ownerships, rather than within the interiors of the company's holdings (see Maps 2-5 in Sierra Pacific Industries 2013, which are copyrighted and cannot be reproduced without permission). This pattern suggests that densities could be higher on neighboring lands such as the Shasta-Trinity National Forest.

Comment [LVD5]: This may also be a case where the adjacent FS lands provide the roosting and nesting habitat while SPI is producing the woodrats.

The California Forestry Association cited annual density estimates in timber company monitoring reports as evidence of stable or increasing NSO populations on private timberlands in the state (Calforests 2014). Reported crude densities on Humboldt Redwood Company, Mendocino Redwood Company, and The Conservation Fund lands in the Redwood Region were indeed relatively similar among years (Calforests 2014). However, it is unclear how changing survey methods and survey areas, as well as changing detectability of NSOs, influenced these companies' estimates over time (see Franklin et al. 1990). For example, recent adoption of survey protocols requiring more survey passes and use of electronic callers likely increased detection rates, and thus density estimates, on some of these lands. Estimates of crude densities of NSOs and numbers of ACs on Green Diamond Resource Company lands in the Redwood Region suggest that NSO densities have declined on that ownership (Figure 1.2; Table 1.1). The number of NSO ACs on Green Diamond lands briefly increased in 1998, apparently due to the company's acquisition of 70,000 acres of timberland that year (Green Diamond Resource Company 2014). Following a substantial decline during 2004-2008, the number of ACs began to gradually increase in 2009 (Figure 1.2). This increase appears to have been due to the company's adoption of a more rigorous survey protocol and implementation of a barred owl removal experiment during that same year (Green Diamond Resource Company 2014; see Chapter 4 of this volume). Sierra Pacific Industries' (2013) density trends for its ownerships in the Eastern Klamath are difficult to evaluate and are therefore not included here. Sierra Pacific Industries' (2013) estimates are empirical, potentially influenced by changing survey effort and areas, mostly descriptive of ACs at the margin of or outside the company's ownership, and were compared among blocks of years, rather than annually.

Comment [LVD6]: It would be useful to know which estimates are empirical counts with no statistical estimates of variance (i.e., no confidence intervals and therefore no way to assess the probability that the estimate represents the true value of the parameter).

Figure 1.2: Number of NSO activity centers ("sites") on Green Diamond Resource Co. lands during 1992-2013 (from Green Diamond Resource Co. 2014).



Rigorous ecological density estimates can be used to estimate population sizes for ecologically similar areas (Franklin et al. 1990). However, there are currently insufficient data for producing such an estimate for California or any of its regions. The California Forestry Association estimated that as many as 6,000 NSO territories currently exist in the state (Calforests 2014). This figure was based on an estimated statewide crude density of 0.28 territories per mile². This density estimate was, in turn, based on the cumulative number of known NSO ACs in California (see *Distribution*, above) and the proportion of "potential" habitat in the state that has been surveyed. The number of ACs known to have been recently occupied is substantially lower than the cumulative number that have been identified since the early 1970s (USFWS 2011a; see *Distribution*, above). This could be due to multiple factors, including declining occupancy rates (see *Occupancy*, below) and NSOs' use of different ACs over time. Thus, the timber industry's estimate provides little or no insight into the current number of NSOs or occupied ACs in the state. Furthermore, while reasonable projections of suitable habitat exist for NSOs in California (Davis and Dugger 2011, USFWS 2011a, Schumaker et al. 2014), the California Forestry Association did not cite these data and it is unclear how it estimated the total and surveyed areas of suitable habitat in the state.

Table 1.1: Density estimates for NSOs in California and Oregon.

Study	Region	Owner	Method	Crude Density (owls/ mi²)*	Crude Density (occupied territories/ mi²)*	Ecological Density (owls/ mi²)**†
Diller and Thome 1999	N Redwood	Green Diamond	Mark-Recapture	0.54 (0.24-0.91)		0.97-2.72
Green Diamond Resource Co. 2014	N Redwood	Green Diamond	Empirical (marked)	0.34 (0.12-0.53)		
Tanner and Gutierrez 1995 cited in Diller and Thome 1999	N Redwood	Redwood National Park	Empirical	0.57		
Humboldt Redwood Co. 2013	N Redwood	Humboldt Redwood	Empirical	0.53-1.01	0.36-0.50	
Mendocino Redwood Co. 2014	N Redwood	Mendocino Redwood	Empirical	0.47-.077		
The Conservation Fund unpubl. data in Calforests 2014	N Redwood	The Conservation Fund	Empirical		0.29-.036	
Chow 2001	S Redwood	Public (Various)	Empirical	0.97		2.09
Franklin et al. 1990	W Klamath	Six Rivers National Forest, Other	Mark-Recapture	0.61		1.41-1.71
Sierra Pacific Industries 2013	E Klamath	Sierra Pacific Industries	Empirical		0.17-0.18	
Woodbridge and Cheyne 1995	So Cascades	Klamath National Forest	Empirical		0.05-0.20	
Thrailkill et al. 1998	OR Coast Ranges	Bureau of Land Management	Empirical	0.07-0.25		0.57-0.90
Anthony et al. 2000 cited in Blakesley et al. 2004	OR Coast Ranges	Oregon Dept. of Forestry	Empirical	0.13-0.27		

*Ranges = low-high survey areas (Woodbridge and Cheyn 1995, Thraillkill et al. 1998, Diller and Thome 1999, Anthony et al. 2000, Green Diamond Resource Co. 2014), low-high survey years (Humboldt Redwood Co. 2013, Mendocino Redwood Co. 2014). **Habitat definitions used to calculate ecological densities: Franklin et al. 1990: all conifer cover classes weighted by NSO use (based on telemetry), but mostly ≥20.6 in DBH; Diller and Thome 1999: all forest classes weighted by NSO use (based on nest locations) but mostly >40 yrs; Chow 2001: all forested area; Thrailkill et al. 1998: old, mature, old over young, mature over young. †Ranges of ecological densities: Franklin et al. 1990: with two different habitat definitions; Diller and Thome 1999: low-high survey areas.

Occupancy

NSO population trends are most directly evaluated with demographic data (see *Demography*, below). However, occupancy data are often more logistically and economically feasible to collect than demographic data and, with proper accounting of detection probability, can provide a useful index of spotted owl population rates (MacKenzie 2005, Olson et al. 2005, Mackenzie et al. 2012, Tempel 2014). Occupancy data that inadequately incorporate detection probabilities for spotted owls must be interpreted carefully since they can be strongly influenced by survey effort, habitat attributes, social and reproductive status of NSOs, presence of barred owls, and other factors (Mackenzie 2005, Olson et al. 2005). Recent research in NSO demographic study

areas suggests that competition with barred owls is driving NSOs to move large distances (several miles) between different territories within the same season (Davis et al. 2013, Higley and Mendia 2013). Higley and Mendia (2013) warned that occupancy estimates for unmarked populations may therefore be inflated (i.e., the same individual could appear to occupy multiple territories within the same season) and suggested using the presence of pairs, rather than individuals, to determine occupancy.

There is limited information available for describing occupancy trends for NSOs in California. Much of the available information is from annual monitoring reports provided by industrial timber companies (Table 1.2). These data show trends in annual proportions of known, surveyed, or previous year's ACs found to be occupied (see Table 1.2 footnote). It is important to acknowledge that much of the data presented in Table 1.2 provide only crude indices of occupancy in California and that most of them cannot be compared among ownerships due to differences in monitoring and analytical methods. Future efforts to evaluate the status of NSOs in California would benefit from greater consistency in occupancy monitoring and from reporting of modeled occupancy rates, which account for detectability of NSOs and other factors that can obscure occupancy trends (e.g., Figure 1.5).

Recent occupancy estimates are unavailable for the Redwood National and State Parks in the northern portion of the Redwood Region. The National Park Service has discontinued surveying most historical territories in these parks due to apparent widespread displacement of NSOs by barred owls (Schmidt 2013; see Chapter 4 of this volume). In contrast with an apparently strong decline in occupancy in the Redwood National and State Parks, NSO occupancy rates on National Park Service lands in the southern portion of the Redwood Region have fluctuated annually but suggest a stable trend over time (Ellis et al. 2013; Table 1.2; Figure 1.3). Perhaps due to the area's geographic isolation, barred owls are still relatively uncommon the southern Redwood Region (Ellis et al. 2013; see Chapter 4 of this volume). Occupancy by NSOs appears to be gradually declining on industrial timberlands in the northern Redwood Region (Table 1.2; Figures 1.2, 1.4, 1.5, and 1.7). Given the substantial and increasing presence of barred owls in NSO territories on these lands (see Chapter 4 of this volume), it is surprising that more dramatic declines in NSO occupancy are not evident (e.g., see Table 1.2 for occupancy rates in Washington and Oregon). It is possible that NSOs respond differently to barred owls on these lands than elsewhere within their range. It is also possible that a more rapid decline is currently occurring than is indicated by the crude data presented in these companies' reports. Yet another possibility is that a more rapid decline will occur on these lands after a post-colonization lag period has elapsed or a critical threshold level of barred owl presence is reached (USFWS 2013).

NSO occupancy in the Northwestern California demographic study in the Western Klamath Region has declined dramatically in recent years (Franklin et al. 2013, 2014; Table 1.2). This decline has coincided with increasing barred owl presence in the study area, suggesting that NSOs are being displaced by barred owls (see Chapter 4 of this volume). The recently increased rate of declining occupancy by NSOs in this study area appears to support the hypothesis that barred owls can have lag or threshold effects on NSO populations. Recent declines in occupancy in the Northwestern California study area may also be related to effects of multiple consecutive years of poor weather conditions on demographic rates (see *Demography*, below). Recent annual reports from the Hoopa demographic study did not include analyses of occupancy data for

NSOs (Higley and Mendia 2012, 2013). However, unmodeled occupancy rates in 2012 and 2013 were low (0.40 and 0.35, respectively). Low occupancy rates on the Hoopa Reservation may be related to substantial declines in numbers of NSOs, likely due to decreasing demographic rates (see *Demography*, below) and increasing numbers of NSO territories with barred owl detections (see Chapter 4 of this volume). Greater declines in numbers of NSOs and increases NSO territories with barred owl detections beginning in 2005 provide additional support for the hypothesis that barred owls have lag or threshold effects on NSOs.

There is currently no clear pattern in occupancy data available for the Eastern Klamath and Southern Cascades of California. Timber companies in those regions have reported evidence of stable occupancy rates (Sierra Pacific Industries 2013, Michigan-California Timber Company 2014; Figure 1.6; note: Sierra Pacific's estimates are not provided in Table 1.2 for reasons discussed in *Density and Abundance*, above). However, more rigorous, published research conducted primarily on industrial timberlands in the Eastern Klamath and Southern Cascades found substantial declines in both simple (total) and pair occupancy (Farber and Kroll 2012; Figure 1.7). The barred owl invasion appears to still be in the early colonization phase in the Eastern Klamath, where this study was primarily conducted (Farber and Kroll 2012; see Chapter 4 of this volume). Thus, declining occupancy during the study was likely caused by some other factor, such as timber harvesting on the industrial timberlands that comprised much of the study area or wildfires on neighboring public lands (see Chapters 2 and 3 of this volume). Research in other areas of the NSO's range indicates that occupancy is negatively affected by habitat loss and fragmentation (Dugger et al. 2011, Sovern et al. 2014).

Table 1.2: Estimates and indices of occupancy by northern spotted owls in California, Oregon, and Washington.

Study	Region	Owner	Years	Number of Sites	Proportion Occupied (Total)	Proportion Occupied (Pairs)	Modeled Occupancy (Total)	Modeled Occupancy (Pairs)	Apparent Trend
Mendocino Redwood Company 2013	N Redwood	Private	2001-2013 (proportion); 2001-2008 (modeled)		0.75 - 0.69*		0.88 - 0.78*†		Declining (weak)
Humboldt Redwood Company 2014	N Redwood	Private	2003-2013		0.81 - 0.63*†				Declining (weak)
Green Diamond Resource Company 2014	N Redwood	Private	1999-2013 (no. sites); 2009-2013 (occupancy)	135 - 108*†	0.88 - 0.83*‡				Declining (weak)
Ellis et al. 2013	S Redwood	NPS	1999-2012		0.86 - 0.94*	0.72 - 0.87*			Stable
Franklin et al. 2002, 2003, 2010-2014	W Klamath	USFS, BLM, Private	2001-2013		0.67 - 0.37*	0.59 - 0.28*			Declining (strong)
Farber and Kroll 2012	E Klamath, S Cascades	Private, USFS	1995-2009				0.81 - 0.50*	0.75 - 0.46*	Declining (strong)
Michigan-California Timber Company 2014	E Klamath, S Cascades	Private	2000-2013		0.35 - 0.52 (2001-2013: 0.66 - 0.52)*†				Stable
Davis et al. 2013a	OR Klamath	BLM, State, Private	2001-2013		0.86 - 0.49*	0.62 - 0.30*			Declining (strong)
Dugger et al. 2011	OR S Cascades	USFS	1991/1992-2006				w/o barred owls: 0.86 - 0.71*†; w/ barred owls: 0.87 - 0.11*†		Declining (strong)
Kroll et al. 2010	WA E Cascades	NPS, USFS, Private	1990/1-2003				w/o barred owls: 0.83 - 0.64*†; w/ barred owls: 0.73 - 0.30*†	w/o barred owls: 074 - 0.36*†	Declining (strong)

*Start and end values. †Estimated from graph. ‡Occupancy of previous year's sites.

Figure 1.3: Occupancy status at monitored northern spotted activity centers on National Park Service lands in Marin County, California during 1999-2012 (from Ellis et al. 2013).

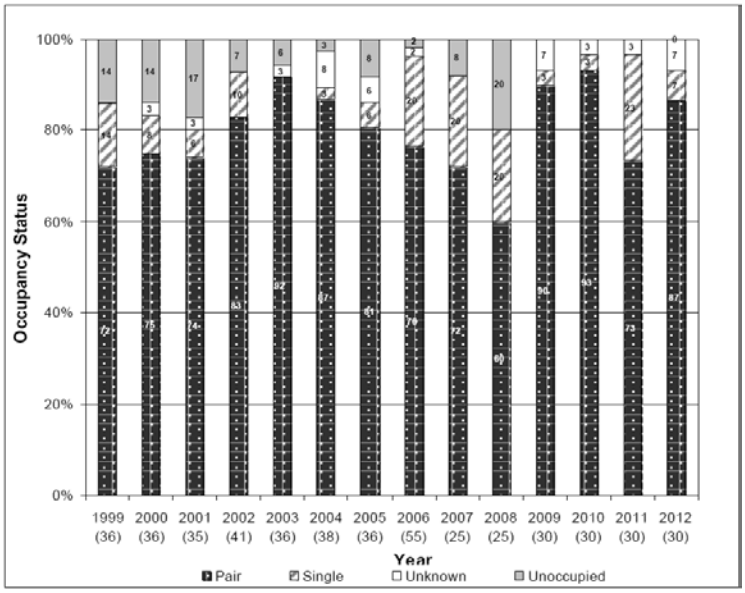


Figure 1.4: Annual numbers of known and occupied northern spotted owl activity sites (activity centers) on Humboldt Redwood Company lands during 2003-2013 (from Humboldt Redwood Company 2014).

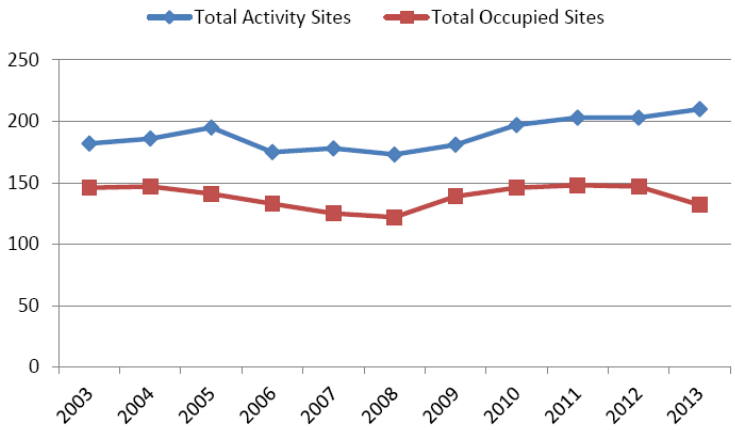


Figure 1.5: Annual proportion of northern spotted owl activity centers occupied (blue line) and modeled occupancy probability (red line) on Mendocino Redwood Company lands (from Mendocino Redwood Company 2013).

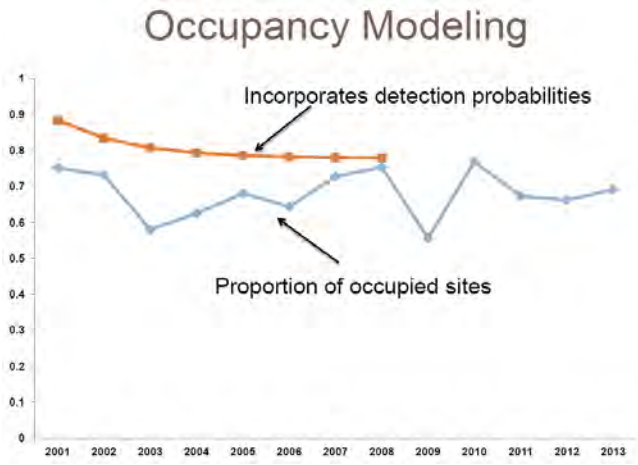


Figure 1.6: Percent of surveyed northern spotted owl sites occupied on Michigan-California Timber Company lands during 2000-2013 (from Michigan-California Timber Company 2014).

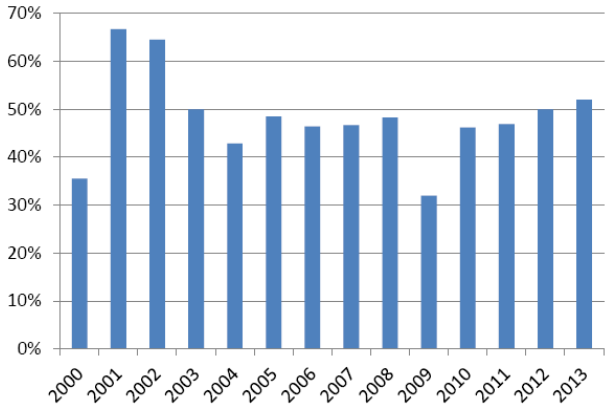
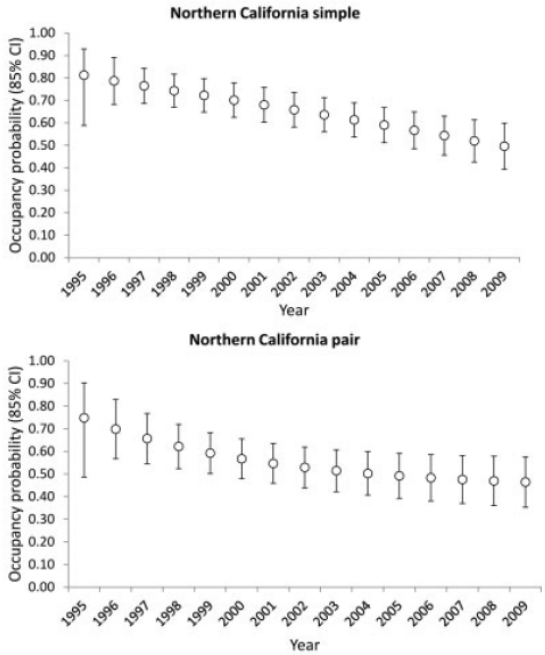


Figure 1.7: Estimated annual simple (total) and pair occupancy probabilities (with 85% confidence intervals) for northern spotted owls in the Eastern Klamath Region of California during 1995-2009 (from Farber and Kroll 2012).



Demography

Reproduction

Reproductive data are commonly collected as part of monitoring efforts for NSOs (e.g., Calforests 2014). They are easier and more cost-effective to obtain than those required for estimating survival or population trends. NSOs exhibit considerable annual fluctuations in reproduction (Forsman et al. 2011, Calforests 2014). Given often large annual fluctuations in reproduction, evaluation of trends in reproduction could require longer-term datasets than are available for many monitoring areas.

The 2011 demographic meta-analysis reported that fecundity of NSOs (number of female fledglings per female) significantly declined during 1985-2008 in four of 11 density study areas, may have declined in three other areas, and was stable in four areas (Forsman et al. 2011). Two of the four study areas with significant declines in fecundity were located in California (Northwestern California in the Western Klamath Region and Green Diamond in the Redwood Region). Two others were located in portions of southwestern Oregon (Klamath and South Cascades) that are nearby and ecologically similar to the Eastern Klamath and Southern Cascades of California (see USFWS 2011a and 2012a for regions). Also, the one area in

California with stable fecundity (Hoopa) had low fecundity estimates compared to other areas. Together these data, which represent the most reliable evidence currently available, indicate that NSO reproduction could be declining across much of California and southwestern Oregon.

Annual fluctuations in fecundity were evident in all three demographic studies in California and were remarkably synchronous (Forsman et al. 2011; Figure 1.8). Forsman et al. (2011) found that variation in fecundity was associated with a variety of variables, including the age of breeding females, whether the year was even or odd, weather or climate (e.g., early nesting season temperature or precipitation), percent cover of suitable habitat, and the presence of barred owls. Franklin et al. (2013) noted a pattern of "good" and "bad" reproductive years in the Northwestern California demographic study area, which is likely associated with annual variation in weather during the early nesting season (also see Franklin et al. 2000). Franklin et al. (2013) also observed that particularly poor reproductive years have occurred in their study area at four-year intervals, suggesting that "some other extrinsic factor may be operating, such as seed production governing small mammal populations." Forsman et al. (2011) reported that barred owl presence was in the top models explaining fecundity in the Green Diamond study area, suggesting that competition with barred owls contributed to declining reproduction on that ownership. Reports from the Klamath and South Cascades demographic studies in southern Oregon noted negative associations between reproduction and rainfall during the early nesting season (Davis et al. 2013b, Dugger et al. 2014). Declining reproduction in these study areas also appears to be related to increasing presence of barred owls.

Following publication of the 2011 meta-analysis, California's demographic studies reported three consecutive years (2011-2013) of very low reproduction (Franklin et al. 2013, Higley and Mendia 2013, Green Diamond Resource Company 2014). This dip in reproduction might have been partially driven by high rainfall during the early nesting season during 2010-2012 (see below). Those three consecutive years of low reproduction exacerbated the negative long-term trend that was already occurring on Green Diamond lands (Green Diamond Resource Company 2014; Figure 1.9). Negative trends in reproduction also occurred in the Klamath and South Cascades demographic study areas subsequent to the end of the 2011 meta-analysis study period (Davis et al. 2013b, Dugger et al. 2014; Figures 1.10 and 1.11). Davis et al. (2013b) concluded that particularly poor reproduction during recent years "…may indicate potentially serious problems with maintaining a stable population. This is even more alarming since these results are following a long term downward trend."

Figure 1.8: Mean annual fecundity in California's three northern spotted owl demographic studies during 1985-2008 (from Forsman et al. 2011).

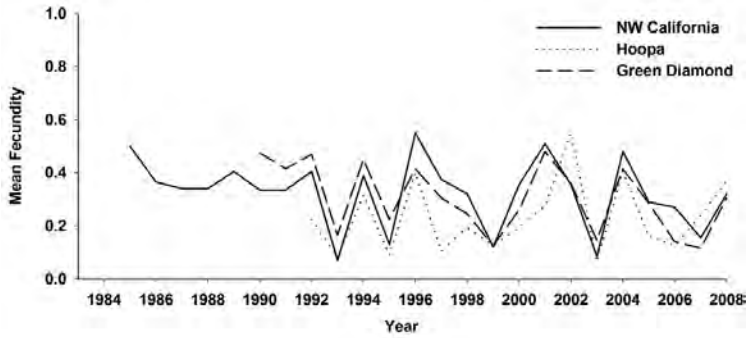


Figure 1.9: Number of fledglings produced per monitored pair of northern spotted owls on Green Diamond Resource Company lands during 1992-2013 (from Green Diamond Resource Company 2014).

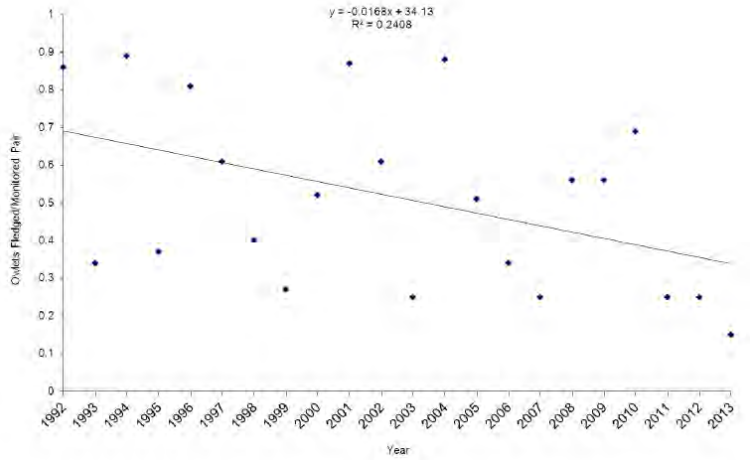


Figure 1.10: Fecundity of northern spotted owls ("STOC") in the Klamath demographic study area during 1990-2013 (from Davis et al. 2013a). Dashed line is a polynomial trend line (r^2 = 0.419). Vertical line represents the first year in which barred owls ("STVA") were detected in more than 10% of spotted owl territories.

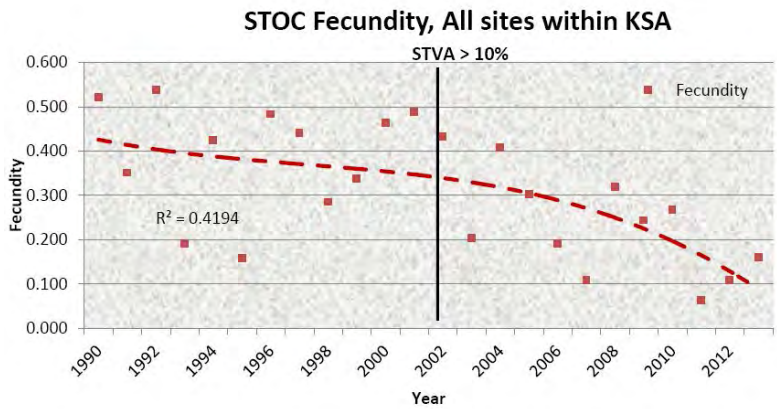
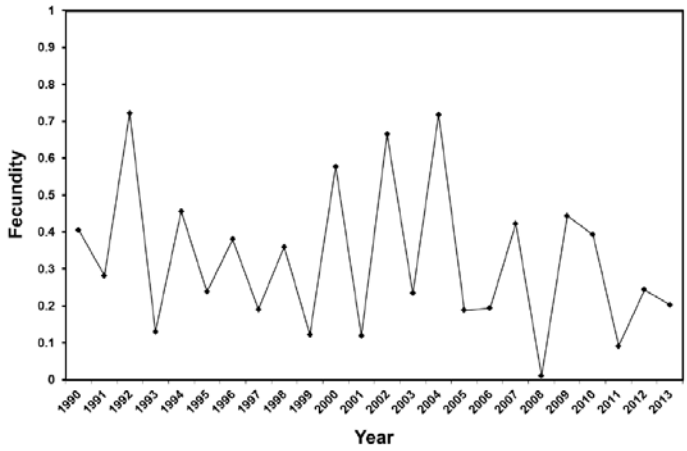


Figure 1.11: Fecundity of northern spotted owls in the South Cascades demographic study area during 1990-2013 (from Dugger et al. 2014).



Information is also available for describing recent trends in NSO reproduction in portions of California outside of demographic study areas. Ellis et al. (2013) found below average fecundity during 2007 and 2010-2012 on National Park Service lands in the southern Redwood Region (Figure 1.12). Humboldt Redwood Company (2013) and Mendocino Redwood Company (2014) likewise reported low reproduction during those years (Figures 1.13 and 1.14). These observations, along with those from demographic studies in California and southern Oregon described above, suggest that low reproduction during recent years was primarily driven by a

factor that acted at a very large spatial scale, rather than at the scale of individual ownerships or ecological regions. As noted above, high rainfall during the early nesting season was likely a primary cause of low reproduction during recent years. This apparent relationship is illustrated by the negative association between NSO reproductive success and early season rainfall observed on Mendocino Redwood Company lands (Figure 1.13).

Monitoring results suggest a stable long-term trend in reproduction on National Park Service lands in the southern Redwood Region (Figure 1.12). In the northern Redwood Region, Humboldt Redwood Company (2013) data likewise suggest little or no trend, although the period covered could be too short to capture long-term trends in reproduction (Figure 1.14). Mendocino Redwood Company (2014) provided a longer-term data set that suggests that a shallow decline in reproduction has occurred on their lands, primarily due to below average reproduction during seven of eight years during 2006-2013 (Figure 1.13). Data provided by the Fruit Grower's Supply Company (2014) suggests that a decline in reproduction occurred on their lands in the Eastern Klamath and Southern Cascades regions of California during 1990-2005 (Figure 1.15). It is important to note, however, that these are only descriptions of apparent trends based on patterns in relatively crude data. A more rigorous analysis of the data is needed to support strong conclusions about reproductive trends on industrial timberlands in the Redwood Region.

Figure 1.12: Fecundity of northern spotted owls on National Park Service lands in Marin County during 1999-2005 and 2007-2012 (from Ellis et al. 2013). The solid line indicates mean fecundity during these periods combined, the dashed lines are one standard deviation from the mean, error bars indicate ±1 standard error, and n is the total number of spotted owl territories.

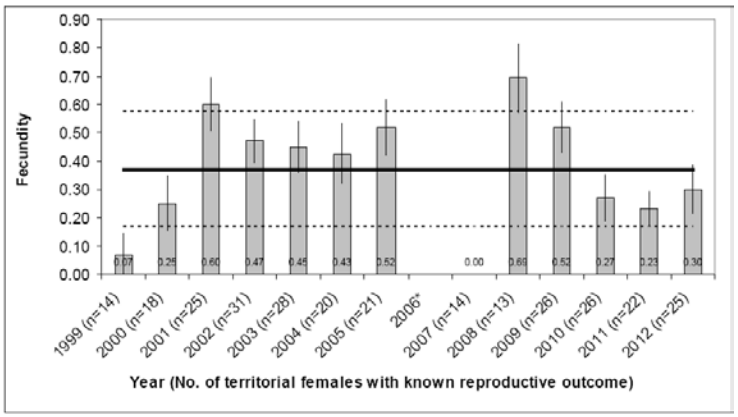


Figure 1.13: Reproductive success (average number of fledglings/pair) of northern spotted owls and amounts of rainfall during the early nesting season on Mendocino Redwood Company lands during 1989-2013 (from Mendocino Redwood Company 2014).

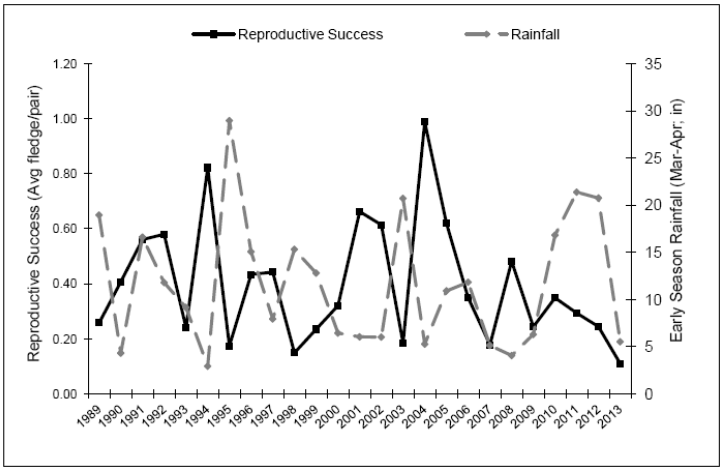


Figure 1.14: Reproductive rate and numbers of nesting pairs and juveniles on Humboldt Redwood Company lands during 2003-2012 (from Humboldt Redwood Company 2013).

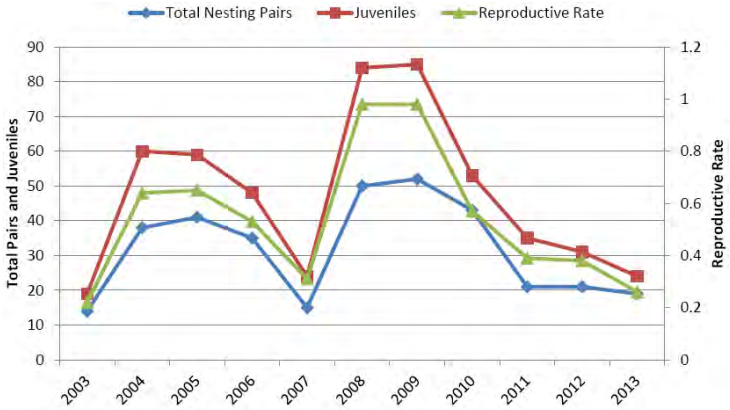
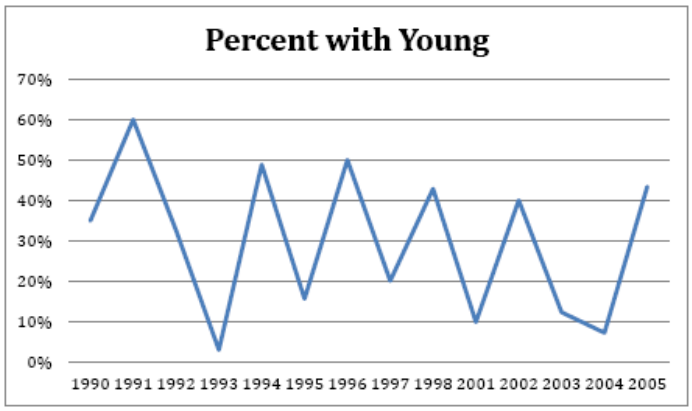


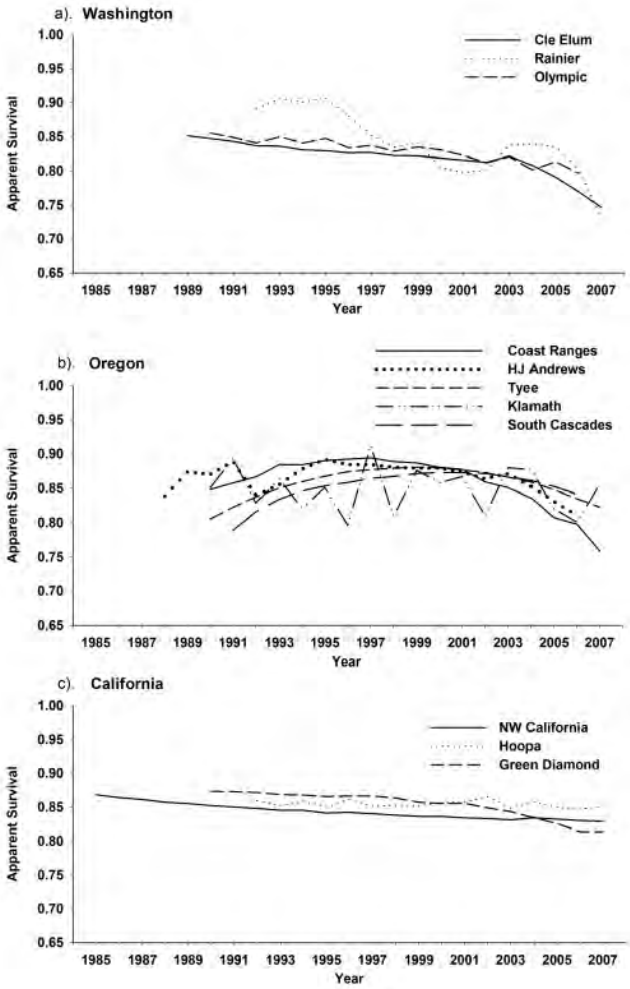
Figure 1.15: Fecundity of northern spotted owls on Fruit Growers Supply Company land during 1990-2005 (from Fruit Growers Supply Company 2014).



Survival

Available information concerning recent survival rates of NSOs is mostly limited to that provided in the 2011 demographic meta-analysis (Forsman et al. 2011). Survival data are not collected by timber companies other than Green Diamond Resource Company, which submits its data for analysis and reporting in the demographic meta-analyses. Forsman et al. (2011) reported statistically significant declines in apparent survival for 10 of 11 NSO demographic study areas, including all three study areas in California (Figure 1.16). Declines in many study areas were most precipitous during the last five years of the study period (i.e., 2003-2007 for survival; Figure 1.16). The Klamath in southern Oregon was the only study area that did not have a significantly declining survival rate through 2007. Forsman et al. (2011) stated that "collectively, the declines in apparent survival of Northern Spotted Owls across much of the subspecies' range are cause for concern because Spotted Owl populations are most sensitive to changes in adult survival rates (Noon and Biles 1990, Lande 1991)."

Figure 1.16: Model averaged estimates of apparent survival of adult female northern spotted owls three study areas in Washington (a), five study areas in Oregon (b), and three study areas in California (c) during 1985-2007 (from Forsman et al. 2011).



NSO demographic studies have largely deferred reporting of more recent survival data to the forthcoming meta-analysis, which is expected to be released in 2015. The limited information available prior to release of that meta-analysis suggests that survival has continued to decline since the 2011 meta-analysis study period. Davis et al. (2013b) reported that subsequent "…data regarding occupancy (in the Klamath study area) has shown a rapid decline, which suggests the stability of the survival rate may no longer be valid." Franklin et al. (2013) reported an alarming drop in apparent survival in 2011 on the Northwestern California demographic study area (Figure 1.17). Their subsequent annual report deferred reporting of 2012-2013 survival data to the forthcoming meta-analysis (Franklin et al. 2014). Higley and Mendia (2013) reported a statistically non-significant decline in survival of NSOs on the Hoopa Valley Indian Reservation in the Western Klamath (Figure 1.18). Their best model explaining survival of NSOs suggested that the decline was at least partially related to increasing numbers of barred owls in the study area.

Figure 1.17: Annual estimates (solid dots with 95% confidence intervals) of, and trend in (solid line), apparent survival for subadult and adult northern spotted owls in northwestern California during 1985-2012 (from Franklin et al. 2013).

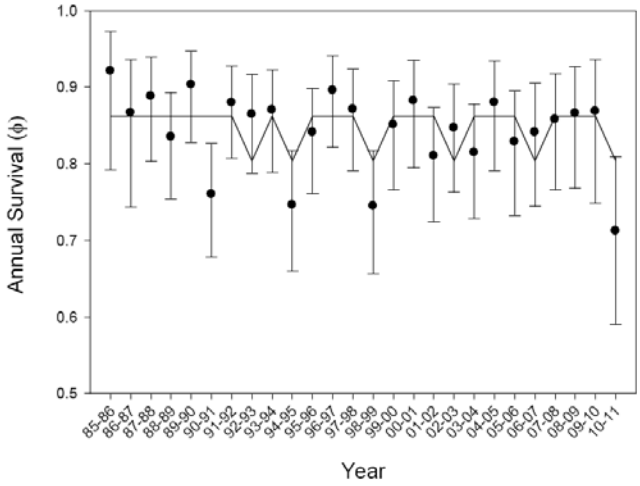
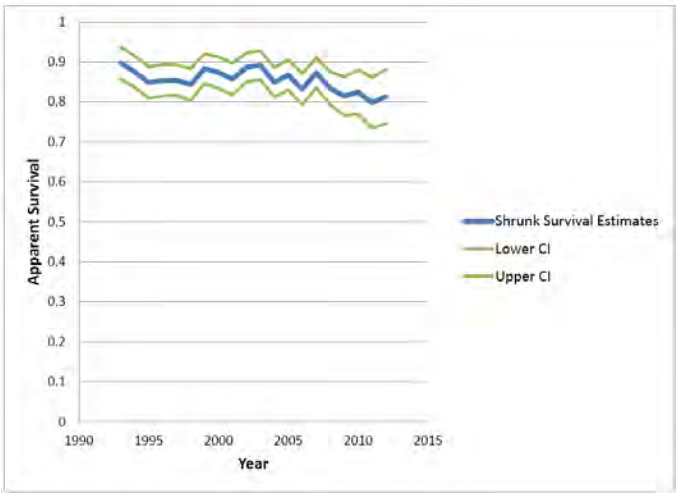


Figure 1.18: Estimates and 95% confidence intervals for NSO apparent survival on the Hoopa Valley Indian Reservation, Humboldt County, California during 1994-2012 (from Higley and Mendia 2013).



Forsman et al. (2011) reported that the presence of barred owls was included in the best model structures for several study areas, including the Green Diamond and Klamath, and was in a competitive model for Northwestern California (Forsman et al. 2011). Given evidence that barred owl presence continued to increase after the study period covered by Forsman et al. (2011) (see Chapter 4 of this volume), it is likely that the forthcoming meta-analysis will report continued declines in apparent survival for many, if not all, demographic study areas. Franklin et al. (2013) noted that apparent survival in the Northwestern California study area, like reproduction, is influenced by annual variation in weather during the early spring. Thus, recent consecutive years with poor weather during the early spring further suggest that survival has likely continued to decline since the period analyzed by Forsman et al. (2011).

Population Change

A new demographic meta-analysis is expected to be released in 2015. Until then, the 2011 meta-analysis (Forsman et al. 2011) provides the most current available estimates of population change for NSOs across their range. Except for the Green Diamond Resource Company, which submits its data for analysis and reporting in periodic meta-analyses, timber companies do not estimate population change for NSOs. Forsman et al. (2011) stated that their results likely "…reflected conditions on federal lands and areas of mixed federal and private lands within the range of the Northern Spotted Owl because the study areas were (1) large, covering ≈ 9% of the range of the subspecies, (2) distributed across a broad geographic region and within most of the geographic provinces occupied by the owl, and (3) the percent cover of owl habitat was similar between our study areas and the surrounding landscapes." Only one of the study areas included in the meta-analysis was entirely located on private lands (Green Diamond). Thus, it is unclear whether results from the 2011 meta-analysis reflect demographic trends on private lands across

the range of the NSO. Given weaker habitat conservation measures for NSOs on many private ownerships compared with federal lands, Forsman et al. (2011) stated that, "if anything, our results depict an optimistic view of the overall population status of the Northern Spotted Owl."

Forsman et al. (2011) reported estimates of the annual finite rate of population change (λ) for 11 study areas located across the NSO's range. Estimates of λ ranged from 0.929 to 0.996 (i.e., declines of 0.4 to 7.1% per year) for these study areas during the period of 1990-2006. There was strong evidence of population declines on seven of the study areas, including the Northwestern California (-1.7% per year) and Green Diamond (-2.8% per year) study areas in California. Negative population trends were also found on the Hoopa study area in California (-1.1% per year) and on the Klamath and South Cascades in southern Oregon (-1.0% and -1.8% per year, respectively) but they were not statistically significant. The weighted mean estimate of λ for all study areas combined was 0.971, indicating an average population decline of 2.9% per year during the study. Variables included in the best model in the meta-analysis of λ indicated effects of ecoregion (geographic location and major forest type) and the proportion of NSO territories with barred owl detections.

In addition to estimates of annual rate of population change, Forsman et al. (2011) provided estimates of realized population change, which describes population change over the study period (Figure 1.19). NSO populations in Washington and northern Oregon declined by approximately 40-60% during 1990-2006. Populations on the Northwestern California and Green Diamond study areas declined by 20-30% during the study period, although the 95% confidence intervals for these estimates slightly overlapped zero (Figure 1.19). Declines of 5-15% were evident on the Hoopa, Klamath and South Cascades study areas but these trends were not statistically significant (Figure 1.19).

Figure 1.19: Estimates of realized population change with 95% confidence intervals for northern spotted owls in California and southern Oregon (from Forsman et al. 2011).

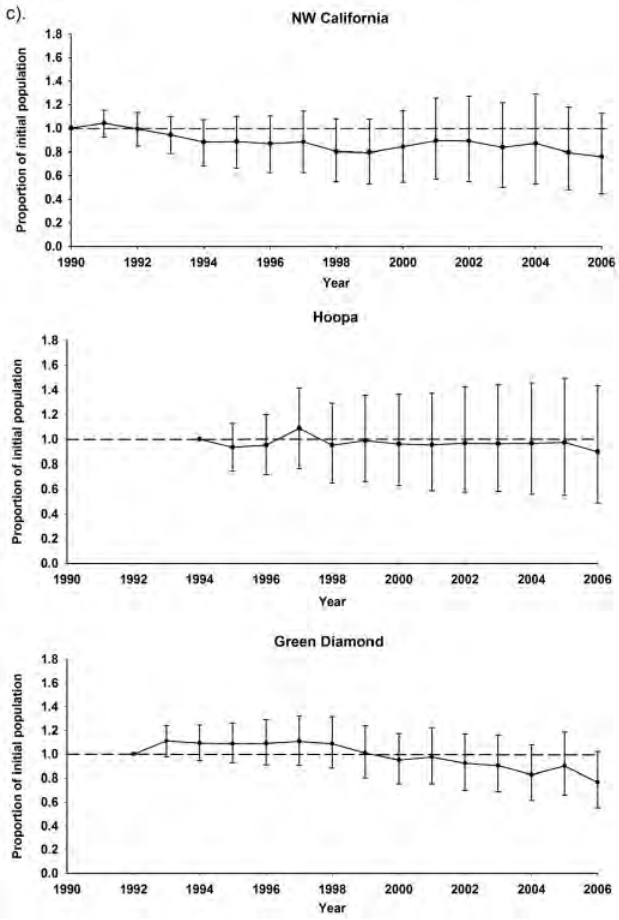
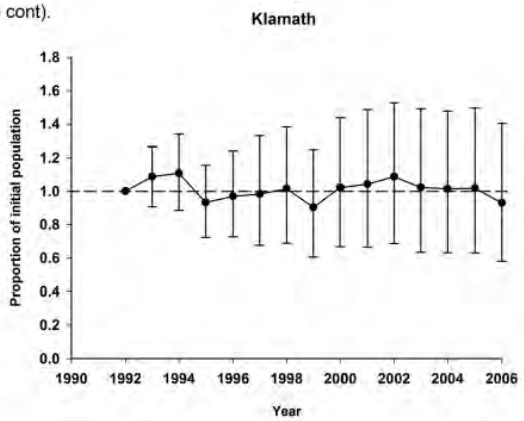
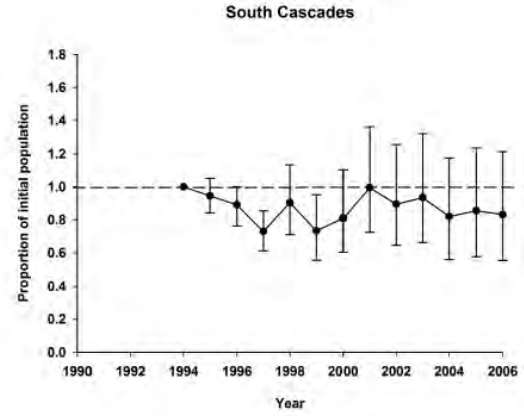


Figure 1.19 (cont.).

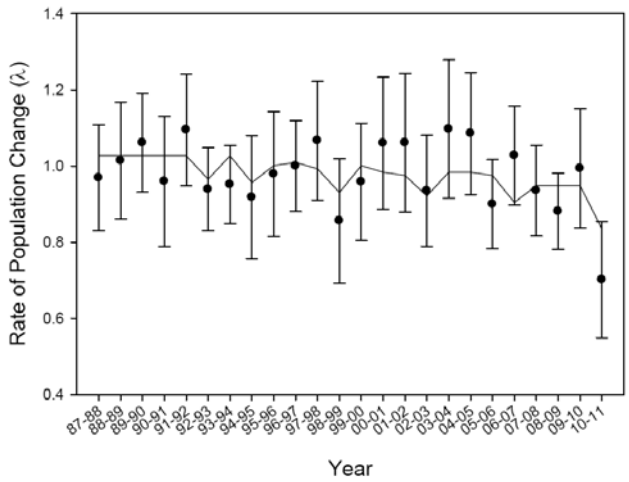
b cont).





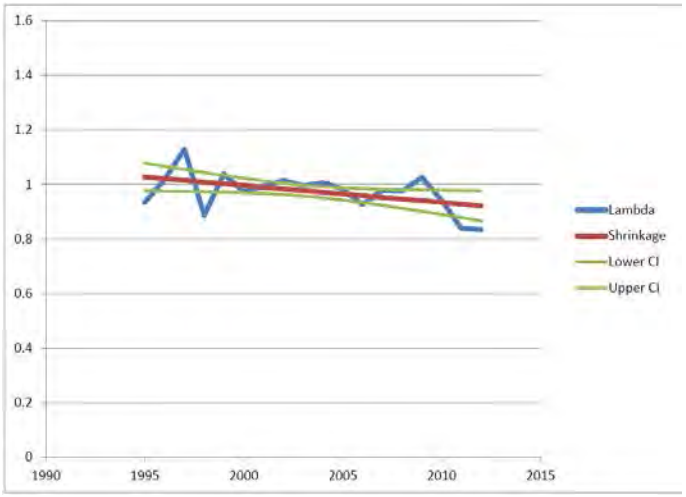
Following the 2011 meta-analysis study period (i.e., >2007), NSOs in the Northwestern California study area experienced a further decline in λ (mean = 0.978 or -2.2% per year) (Figure 1.20). The last year included in this analysis (2011) had the lowest annual estimate of λ found during the 24-year analysis period (Figure 1.20). The forthcoming meta-analysis should reveal whether the substantial drops in apparent survival and λ in the Northwestern California study area in 2011 were anomalous or indicative of an increased rate of population decline in the study area. Franklin et al. (2013) found that fecundity, apparent survival, and λ in the study area fluctuated during "good" and "bad" years, which was likely at least partially related to weather (see above). Annual rate of population change was also apparently negatively affected by increasing presence of barred owls. Given continued increases in barred owls (see Chapter 4 of this volume), poor weather during the early spring during 2010-2012, and poor reproduction by NSOs during 2011-2013 (see above), it is likely that λ continued to decline on this study area and probably others in California and southern Oregon.

Figure 1.20: Annual estimates of (dots with 95% confidence intervals) and trend in (solid line) rate of population change in the Northwestern California study area (from Franklin et al. 2013).



Higley and Mendia (2013) reported that the estimate of λRJS (Jolly-Seber Capture-Recapture model) for the Hoopa demographic study during 1995-2012 was 0.977, indicating a mean annual population decline of 2.3%. The decline was statistically significant in 2011 and 2012 (point estimates of λRJS not included in the 95% CI; Figure 1.20). Higley and Mendia (2013) noted that "the recent decline in survival, the point estimate of λRJS and the actual number of birds detected this past season all point to a population that is in fact, declining. This apparent decline in spotted owls corresponds with an increase in total annual barred owl detections and proportion of spotted owl territories with barred owl detections." They further noted that the forthcoming meta-analysis will show that it is "...very clear that northern spotted owls are in decline across all 11 study areas and that in many cases the decline is accelerating."

Figure 1.21: Trend in rate of population change on the Hoopa Valley Indian Reservation, Humboldt County, California during 1994-2012 (from Higley and Mendia 2013).



Source-Sink Dynamics

As described by Gutiérrez and Harrison (1996), source-sink dynamics exist for species "…that occupy both high-quality habitats (sources) where populations grow and produce emigrants, and low-quality habitats (sinks) where populations cannot sustain themselves in the absence of immigration." Population sinks potentially function as reservoirs for repopulation of sources that go extinct but may also reduce population growth rates (Pulliam 1988, Gutiérrez and Harrison 1996). Identifying source and sink areas is therefore, an important component of conservation research and planning.

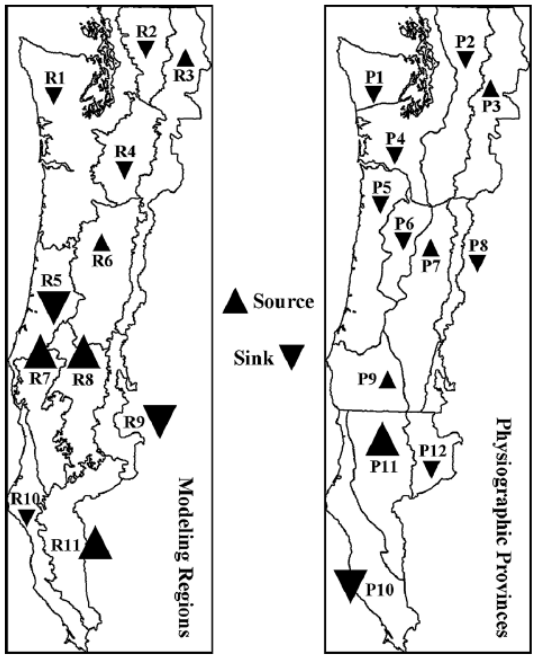
Schumaker et al. (2014) recently published a rangewide study of source-sink dynamics for NSOs. Their source-sink simulation modeling incorporated an array of regional data for NSO occupancy rates, movement distances and rates, life history attributes, habitat suitability and connectivity, encounter rates with barred owls, and environmental stochasticity. Source-sink dynamics in this study emerged from simulated interactions between individual NSOs and landscapes, rather than being predefined based on habitat suitability as was done in previous studies. The simulation models by Schumaker et al. (2014) ~~found~~ predicted that most ecological regions and physiographic provinces currently function as population sinks for NSOs (Figures 1.22 and 1.23). The study's results ~~indicated~~ projected that the Klamath Provinces of California and Oregon and the Interior Northern Coast Ranges of California are the subspecies' strongest population sources (Figure 1.23). The Klamath Provinces appear to be particularly important for maintaining NSO population stability due not only to being net population sources but to their high levels of population connectivity with multiple surrounding regions (Schumaker et al. 2014; Figure 1.23). The Redwood and Southern Cascades regions in California were both classified as moderate population sinks. Schumaker et al. (2014) identified the Klamath Provinces and

Comment [LVD7]: I think this section should also include a discussion of habitat fitness (Franklin et al. 2000), which is another method to quantify source versus sink habitats.

Comment [LVD8]: I personally don't think a simulation model should be used to draw management conclusions. In my opinion, they require so many assumptions to generate the necessary model parameters that they should only be used to develop testable hypotheses. The data we have accumulated over the years on population recruitment through immigration of subadults indicates that most of the birds are coming from within the redwood region. We don't have the data, but my guess is that the redwood region has contributed more recruits to the Klamath region than the reverse.

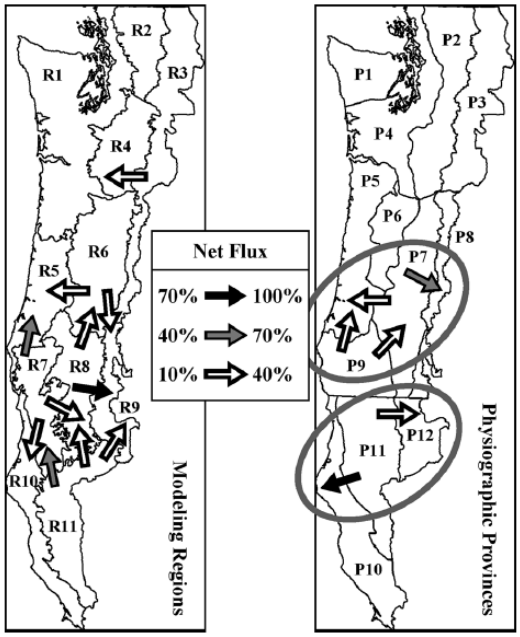
California Cascades as areas in which it could be particularly important to focus habitat protection and restoration efforts, respectively.

Figure 1.22: Relative source and sink values in northern spotted owl modeling regions and physiographic provinces (from Schumaker et al. 2014). The sizes of symbols denote major versus minor or moderate sources and sinks.



R7: Klamath West, R8: Klamath East, R9: Eastern Cascades South, R10: Redwood Coast, R11: Inner California Coast Ranges, P10: California Coast Range, P11: California Klamath, P12: California Cascades. See Schumaker et al. (2014) for other modeling regions and physiographic provinces.

Figure 1.23: Graphical representation of net movement ("Net Flux") of individual (simulated) northern spotted owls from one modeling region or physiographic province to another (from Schumaker et al. 2014). The largest Net Flux values are shown in black, intermediate values in gray, and smallest values in white. Gray ovals highlight two areas with strong patterns of Net Flux.

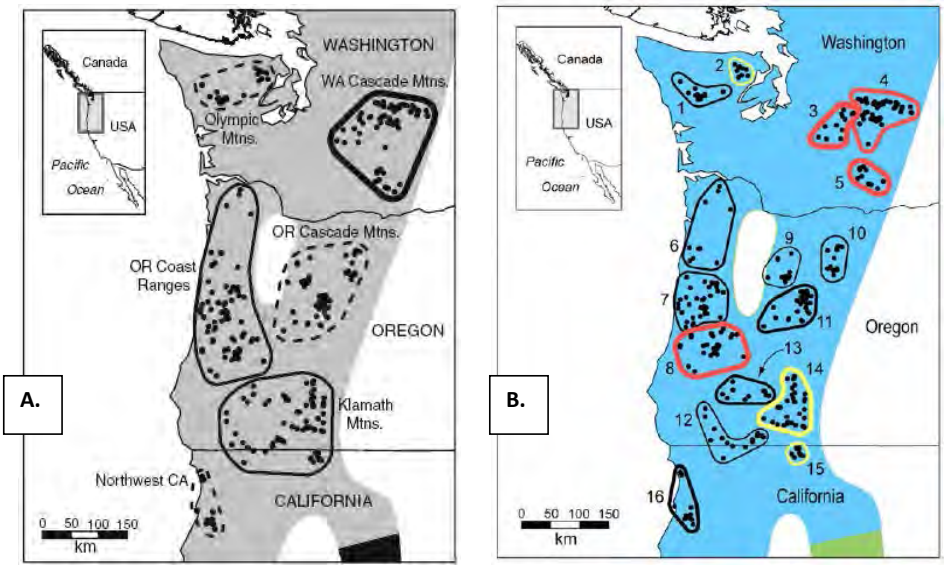


Genetics

Funk et al. (2010) found statistically significant evidence that NSOs have experienced genetic bottlenecks during recent decades in the Washington Cascades, Oregon Coast Ranges, and "Klamath Mountains" of Oregon and California (Figure 1.24). An earlier report on this study indicates that evidence of a bottleneck in the Klamath Mountains analysis area was primarily driven by data from the southern Cascades of Oregon and California, rather than from the Klamath Provinces (Funk et al. 2008; Figure 1.24). Evidence of recent genetic bottlenecks in the Washington Cascades, Oregon Coast Ranges, and southern Cascades are concordant with recent demographic declines in these regions (Forsman et al. 2011; see *Demography*, above). Surprisingly, Funk et al. (2010) did not find evidence of a genetic bottleneck in the Olympic Mountains of Washington, where NSOs have recently experienced dramatic population declines (Forsman et al. 2011). However, they noted that their small sample size for this region limited their power to detect a genetic bottleneck if one occurred. Funk et al. (2010) did not find statistically significant evidence of a recent genetic bottleneck in northwestern California (Western Klamath and Redwood regions). They suggested that this could likewise have been due to low statistical power or to the relatively gradual population declines reported for that area at the time (see *Demography*, above). The analyses of Funk et al. (2010) did not address whether

genetic bottlenecks were solely a result of population declines or were also contributing to them. Genetic declines can contribute to reduced demographic rates through effects of inbreeding depression and loss of adaptive genetic variation (reviewed in Funk et al. 2010).

Figure 1.24: Recent population bottlenecks in NSOs. Points represent 352 individual owls included in the analysis which are grouped into six (A) and 16 (B) regions. Statistically significant bottlenecks are represented by solid lines (A) or yellow ($p = 0.05$) and red ($p = 0.01$) lines (B). (A) represents significant bottlenecks under 5, 10, and 15% multi-step mutation models as solid bold lines and under 10 and 15% multi-step mutation models as finer solid lines (see Funk et al. 2010). (B) indicates greater magnitude bottlenecks with bolder lines. From Funk et al. 2010 (A) and 2008 (B).



Summary of Current Status and Trends

Rigorous long-term research has indicated that NSO populations are dramatically declining in Washington and northern Oregon and more gradually declining in southern Oregon and California (Forsman et al. 2011). Yet, while less precipitous than those in the northern portion of the NSO's range, the rapidity of population declines in southern Oregon and California are cause for grave concern regarding the subspecies' status and trends. A new demographic meta-analysis, which is due for public release during 2015, will replace the 2011 meta-analysis and provide the most reliable information for evaluating the NSO's current status and trends. Based on information available in annual research reports, it is clear that the forthcoming meta-analysis will show that populations in southern Oregon and California are declining more rapidly than was evident in the 2011 meta-analysis (Davis et al. 2013a, Franklin et al. 2013, Higley and Mendia 2013, Dugger et al. 2014, Green Diamond Resource Company 2014).

The NSO's status and trends are less clear in portions of California outside the state's three demographic study areas. Much of the information for these areas is provided by industrial timber companies, which have uniformly concluded that NSO populations on their lands are stable (Calforests 2014). However, the data provided by these companies are insufficient for drawing strong conclusions about the NSO's status and trends, and may in fact indicate gradual declines in occupancy and reproduction on some ownerships (see *Occupancy* and *Demography*, above). Forsman et al. (2011) suggested that, due to weaker habitat protection, NSO demographic trends could generally be worse on non-federal lands than on the federal and mixed federal/non-federal lands on which most demographic studies are conducted. This appears to be true in California, where NSOs experienced greater declines on Green Diamond Resource Company lands than on nearby tribal and Forest Service lands (Forsman et al. 2011; see *Occupancy* and *Demography*, above). However, the degree to which these differences were due to variation in land management, effects of competition with barred owls, or other factors is unclear.

It is likewise unclear if demographic trends in California's three demographic study areas accurately represent those in drier, less productive forests in the state's interior. An occupancy study in California's Eastern Klamath and Southern Cascades (Farber and Kroll 2012) and demographic studies in ecologically similar areas of southern Oregon (Davis et al. 2013a, Dugger et al. 2014) could provide the most reliable information currently available for evaluating NSO's status and trends in interior California (see *Occupancy* and *Demography*, above). These studies indicate that NSOs are currently declining in at least some portions of the Eastern Klamath and Southern Cascades regions (note: these regions cover portions of both California and southern Oregon as they are ecologically rather than politically defined; see USFWS 2011a Appendix C). Evidence of population declines in the Klamath regions (Forsman et al. 2011, Farber and Kroll 2012, Davis et al. 2013a, and Franklin et al. 2013) are particularly concerning in light of the critical contributions these areas likely provide to the NSO's long-term persistence (Schumaker et al. 2014; see *Source-Sink Dynamics*, above).

Although the Redwood Region ~~appears to currently~~is projected to function as a population sink, it still retains high densities and abundances of NSOs and is therefore important to the subspecies' conservation (Schumaker et al. 2014; see *Density and Abundance* and *Source-Sink Dynamics*, above). There is limited information available for evaluating the NSO's status and trends in portions of the Redwood Region outside of Green Diamond's lands. Monitoring on National Park Service lands and adjacent ownerships suggest that the population in Marin County is stable while NSOs in the Redwood National and State Parks have substantially declined. These differences appear to be largely due to negative effects of high barred owl densities in the Redwood National and State Parks and the relatively slow rate of the barred owl invasion in Marin County (see *Occupancy*, above). In contrast with the Green Diamond Resource Company, other timber companies in the northern portion of the Redwood Region have concluded that their NSO populations are stable (Calforests 2014). It is possible that NSOs have indeed fared better on these ownerships than on Green Diamond lands; for example, due to less intensive timber harvesting or more recent colonization by barred owls. However, the data provided by these companies are insufficient for drawing firm conclusions about the NSO's status and trends on these lands, and actually appear to indicate gradual declines in some areas. More consistent and rigorous monitoring (e.g., consistent survey areas and protocols; reporting

Comment [LVD9]: There are no data to support this assertion so I think simulation model projections need to be reported with the uncertainty they deserve. As the great statistician George E. P. Box stated: "All models are wrong, but some are useful."

of modeled occupancy rates) would assist future evaluations of the NSO's status and trends on industrial timberlands in California.

Acknowledgements

Source-Sink Dynamics

As described by Gutiérrez and Harrison (1996), source-sink dynamics exist for species "…that occupy both high-quality habitats (sources) where populations grow and produce emigrants, and low-quality habitats (sinks) where populations cannot sustain themselves in the absence of immigration." Population sinks potentially function as reservoirs for repopulation of sources that go extinct but may also reduce population growth rates (Pulliam 1988, Gutiérrez and Harrison 1996). Identifying source and sink areas is therefore, an important component of conservation research and planning.

Schumaker et al. (2014) recently published a rangewide study of source-sink dynamics for NSO. Their source-sink simulation modeling incorporated an array of regional data for NSO occupancy rates, movement distances and rates, life history attributes, habitat suitability and connectivity, encounter rates with barred owls, and environmental stochasticity. Source-sink dynamics in this study emerged from simulated interactions between individual NSOs and landscapes, rather than being predefined based on habitat suitability as was done in previous studies. The simulation models by Schumaker et al. (2014) predicted that most ecological regions and physiographic provinces currently function as population sinks for NSOs (Figures 1.22 and 1.23). The study's results projected that the Klamath Provinces of California and Oregon and the Interior Northern Coast Ranges of California are the subspecies' strongest population sources (Figure 1.23). The Klamath Provinces appear to be particularly important for maintaining NSO population stability due not only to being net population sources but to their high levels of population connectivity with multiple surrounding regions (Schumaker et al. 2014; Figure 1.23). The Redwood and Southern Cascades regions in California were both classified as moderate population sinks. Schumaker et al. (2014) identified the Klamath Provinces and California Cascades as areas in which it could be particularly important to focus habitat protection and restoration efforts, respectively.

Comment [JRD1]: They also may help identify areas where restoration of habitat, or management of barred owls, could be warranted.

Comment [JRD2]: I think Lowell's comment is reasonable here – maybe the point is that source-sink evaluations, and subsequently identifying sources and sinks is absolutely scale dependent. Thus, the sources and sinks we found in the Schumaker et al. paper, because the scale was so big (regions/provinces were millions of acres each) means that they were comprised of both sources and sinks. If we were to have looked at a smaller scale we would have more nuanced descriptions of sources/sinks – it is an important point.

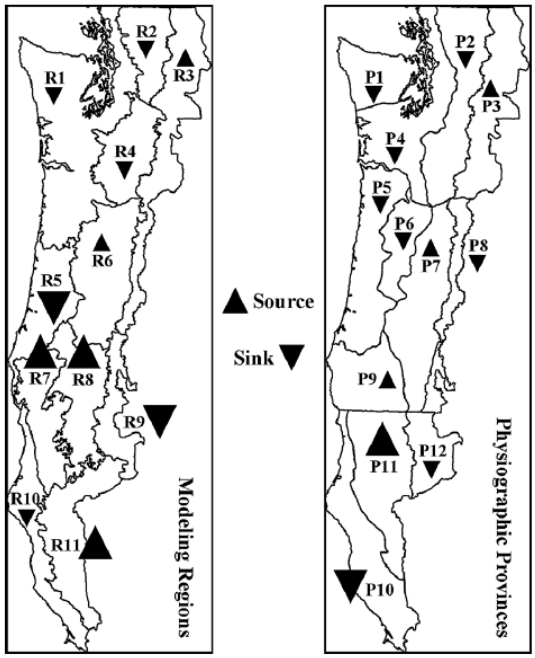
Comment [JRD3]: I might add to that sentence "…for NSO at the (large) spatial scale of modeling regions and ecogeographic provinces.

Comment [JRD4]: We didn't really use "occupancy rates" but we did include habitat suitability.

Comment [JRD5]: See previous comment on spatial scale.

Comment [JRD6]: Lowell's comment on not drawing management conclusions from simulations/models. I see his point, but none of the demographic studies is near big enough to do what he's saying – we did a range-wide analyses (not a tiny portion of the range, like individual DSAs are…and even cumulatively they're <12% of the range). Thus, I kind of think that saying the source/sink stuff should "only be used to develop testable hypotheses" – really means that it will never happen at the range-wide scale. We either go with the higher uncertainty simulation data, or simply leave it a "blank spot on the map."

Figure 1.22: Relative source and sink values in northern spotted owl modeling regions and physiographic provinces (from Schumaker et al. 2014). The sizes of symbols denote major versus minor or moderate sources and sinks.



R7: Klamath West, R8: Klamath East, R9: Eastern Cascades South, R10: Redwood Coast, R11: Inner California Coast Ranges, P10: California Coast Range, P11: California Klamath, P12: California Cascades. See Schumaker et al. (2014) for other modeling regions and physiographic provinces.

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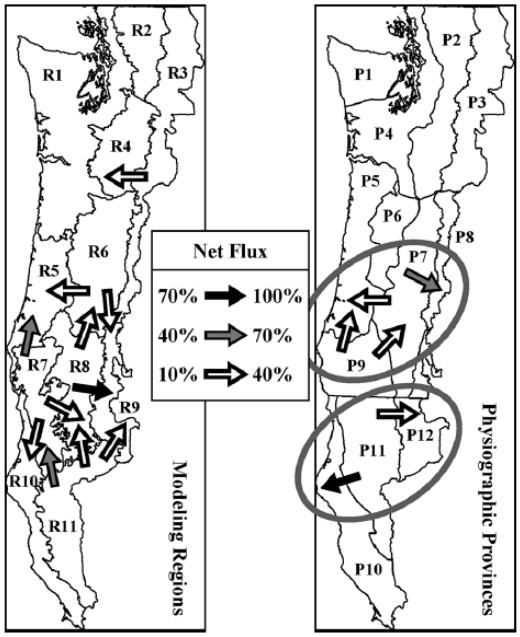


Timber Harvesting

Timber harvesting was a primary impetus for federal listing of the NSO and is still regarded as one of the major threats to the subspecies (Thomas et al. 1990, USFWS 1990, Courtney et al. 2004, USFWS 2011a). Timber harvesting can directly impact NSO populations by removing, degrading, or fragmenting habitat for them or their prey (reviewed below). Harvesting might also indirectly affect NSOs by increasing effects of other stressors, such as competitive pressure from barred owls (*Strix varia*) (Dugger et al. 2011, Forsman et al. 2011; see *Threats: Cumulative and Interactive Effects*). However, timber harvesting likely has complex effects on NSOs in the southern part of their range due to divergent effects of habitat conditions on survival versus reproduction (Franklin et al. 2000, Olson et al. 2004, Diller et al. 2010). The information reviewed herein suggests that some forms and amounts of harvesting are sustainable in northern California but that large-scale removal or fragmentation of habitat around activity centers can strongly impact NSOs (reviewed below and in USFWS 2009).

Comment [UFS1]: As in fire review… should define habitat in more specific terms when warranted.

The kinds of habitat concentrations associated with high survival and fitness of NSOs may be limited in some parts of the subspecies' range due to removal of the majority of old forest during the 19th and 20th centuries (USFWS 1990, Strittholt et al. 2006). Harvesting has been substantially reduced on federal lands since implementation of the Northwest Forest Plan (Healey et al. 2008, Davis and Dugger 2011, Moeur et al. 2011, Kennedy et al. 2012). However, removal of suitable NSO habitat continues on federal lands and is occurring at higher rates on non-federal lands (Davis and Dugger 2011). Habitat loss to logging is only partially offset by recruitment of new habitat ~~on non-federal lands~~ (Davis and Dugger 2011, Moeur et al. 2011;

Comment [UFS2]: Not just federal

reviewed below). This is cause for concern since non-federal lands contain a considerable portion of remaining suitable breeding habitat for the subspecies and because recovery of the NSO partially depends on voluntary conservation efforts on these lands (USFWS 2011a; see *Legal and Regulatory Framework*). The timber industry has cited relatively strict harvest regulations in California as evidence that listing of the NSO under the California Endangered Species Act is unnecessary (California Forestry Association 2014). Yet, contemporary harvesting has still resulted in a net loss of suitable breeding habitat for NSOs on non-federal lands in California (Davis and Dugger 2011, Moeur et al. 2011; reviewed below). Furthermore, the U.S. Fish and Wildlife Service (2009) recently concluded that California's regulations for avoiding take inadequately protect the subspecies and do not reflect the best available science (reviewed below; also see *Threats: Inadequacy of Regulatory Mechanisms*).

Comment [UFS3]: How much is "considerable"? Perhaps state as a percentage of total.

Responses of NSOs to Timber Harvesting

Interior Northern California

NSOs in interior northern California show a strong general preference for relatively old, structurally complex forest. This is illustrated by studies describing both plots around NSO locations (Solis and Gutierrez 1990, Rissler 1995, White 1996, Hershey et al. 1998; but see Irwin et al. 2013) and landscape-scale analysis areas around activity centers (Chávez-León 1989, Solis and Gutierrez 1990, Hunter et al. 1995, Gutierrez et al. 1998). This body of research can be used to inform conservation measures for NSOs in interior northern California (e.g., for evaluating appropriate habitat definitions in take-avoidance guidelines: USFWS 2009). However, the

following review is focused on studies of associations between landscape-scale habitat attributes and NSO demography in interior forests (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005, Schilling et al. 2013). These studies are based on rigorous demographic data and provide the best available insight into potential effects of timber harvesting on NSO populations (USFWS 2009). We supplement this review with information from studies of associations between landscape-level habitat characteristics in southern interior forests and the NSO's home range sizes (Carey et al. 1992, Carey and Peeler 1995, Schilling et al. 2013) and probability of occurrence (Zabel et al. 2003, Carroll and Johnson 2008).

Comment [UFS4]: Tempel et al in press might also be good here.

In the California Klamath, Franklin et al. (2000) found that NSO survival was highest when estimated breeding core areas (390 ac) contained large amounts of both "core" (>326 ft from edge) older forest (conifer or mixed forest with conifer QMD ≥21 in and canopy cover ≥70%) and edge with other vegetation classes. In contrast, reproduction was typically highest with lower amounts of core older forest and greater amounts of edge. Estimated core areas supporting high fitness for NSOs (a function of both survival and reproduction) contained both a large concentration of core older forest and considerable habitat edge provided by a mosaic of other vegetation patches with convoluted shapes. Franklin et al. (2000) emphasized the difference between total area of older forest versus area of core older forest. For example, they noted that large amounts of older forest edge cannot occur with low total amounts of older forest. This study did not directly address effects of timber harvesting on NSOs. Vegetation other than older forest was combined into a single class and edges occurred wherever that class and older forest met. Franklin et al. (2000) noted, however, that the dominant silvicultural system in their study

area at that time was large-scale clearcutting, which they concluded was unlikely to contribute to the kinds of habitat mosaics found in territories supporting high fitness.

In the interior of the Oregon Coast Range, Olson et al. (2004) found that NSO survival was positively associated with greater amounts of both "mid-seral" (9.5-31.5 in DBH) and "late-seral" (>31.5 in DBH) forest in landscapes around activity centers (≤4,921 ft) and lower amounts of early-seral forest and non-forest (<9.5 in DBH). Reproduction, in contrast, was negatively associated with area of mid- and late-seral forest and positively associated with edge between early-seral and non-forest and other vegetation classes. Olson et al. (2004) encountered technical difficulties with the habitat fitness potential portion of their modeling but noted that territories supporting high fitness must contain attributes associated with both high survival and high reproduction. This was supported by diagrams made from aerial photos of landscapes around activity centers, which showed remarkably similar habitat mosaics to those presented by Franklin et al. (2000).

Dugger et al. (2005) found a positive association between NSO survival in the Oregon Klamath Province and greater amounts of mature and old forest (≥100 yrs) within estimated core areas (413 ac) and a moderate amount of non-habitat (non-forest, early-seral vegetation, and older forest with harvest entries ≥40% basal area) in the landscape beyond the core area (3,430-ac ring). The specific contribution of timber harvesting (and of different harvest types and intensities) to the non-habitat class and thus, its effects on NSO fitness, were not reported. This study's findings differed from others in that reproduction was positively, rather than negatively, associated with greater amounts of older forest within estimated core areas. These findings

Comment [UFS5]: Differentiate between "core area" and "core habitat".

suggest that widespread harvesting of older forest within NSO core areas would negatively effect both survival and reproduction in this area but that some level of harvesting might be sustainable in the broader landscape (to the degree that it contributes to "optimal" amounts of non-habitat in the 3,430-ac ring surrounding estimated core areas).

Schilling et al. (2013) found additional evidence of a positive influence of both older forest and habitat heterogeneity on NSO survival in the Oregon Klamath. Their best performing model indicated that monthly survival probabilities for NSOs were highest when home ranges (based on radio-telemetry) contained more patches of mature and old forest (≥20 in DBH and ≥40% canopy cover). The second best performing model indicated a positive association between survival and clustering of (i.e., close distances between) older forest patches. Unlike other studies, they did not find an association between survival and total amount of older forest. They noted that this could have occurred due to their small sample size or because most NSO home ranges in their study had amounts of mature and old forest (mean = 72%) that likely exceeded threshold amounts required for survival. A third competitive model suggested that survival was also positively associated with a moderate amount of edge between forest (mean DBH ≥5 in) and other cover classes; thus providing additional support for the value of habitat heterogeneity for NSOs in southern interior forests.

Zabel et al. (2003) modeled probability of NSO occurrence (i.e., habitat suitability) across interior northern California based on habitat conditions at an estimated core area scale (500 ac). The best performing model in their study indicated that the probability of NSOs occurring in a given location was highest with large amounts of suitable nesting-roosting habitat (generally ≥17

in DBH and canopy cover ≥60%) and intermediate amounts of foraging habitat (≥10 in DBH and canopy cover ≥40%) at the core area scale. The second and third best performing models at the core area scale included habitat edge. The results of this modeling study provide further support for conclusions that a combination of both a large concentration of suitable habitat and some form of habitat heterogeneity is important to NSOs in interior northern California.

Carroll and Johnson (2008) also modeled probability of NSO occurrence in interior northern California. Based on their best model, predicted abundance of NSOs in the area was highest when most of the landscape (5,930-ac areas) consisted of mature and old forest (>50 yrs). However, predicted abundance slightly declined when area of mature and old forest increased beyond about 80% of the landscape. This study therefore, provides evidence of at least a slight positive effect of other vegetation classes on probability of NSOs occurring in a given area. These results contrasted with the study's findings for more northern parts of the NSO's range, where the probability of occurrence continued to increase (albeit diminishingly) with greater amounts of older forest.

Studies of home range sizes provide another line of evidence concerning habitat and harvesting influences on NSOs in interior southern forests. Home range studies in the Oregon Klamath found that home range size increased with habitat fragmentation (Carey et al. 1992, Schilling et al. 2013). NSOs in the area are known to use regenerating harvest units for foraging, particularly when closer to the activity center or outside the breeding season (Carey and Peeler 1995, Irwin et al. 2013). However, Carey and Peeler (1995) concluded that the energetic benefit of increased

access to dusky-footed woodrats (*Neotoma fuscipes*) in heavily fragmented forest is often outweighed by the energetic cost of increased travel.

In summary, studies in interior northern California have found that NSOs in the region benefit from both large amounts of older forest concentrated around activity centers and some form of habitat heterogeneity (Franklin et al. 2000, Zabel et al. 2003, Carroll and Johnson 2008). Similar results have been found in the Klamath (Dugger et al. 2005, Schilling et al. 2013) and interior Coast Range of Oregon (Olson et al. 2004). These findings suggest that timber harvesting is sustainable in southern interior forests, provided that suitable breeding habitat is retained in sufficiently large concentrations around NSO activity centers (USFWS 2009). However, whether and how timber harvesting contributes to beneficial habitat heterogeneity in interior southern forests is unclear. Available studies differed in their findings of types, amounts, and locations of beneficial heterogeneity and did not directly evaluate whether timber harvesting contributed to it. In contrast, it is clear from research of associations between landscape-level habitat attributes and NSO demography, presence, and home range size that harvesting within core concentrations of suitable habitat has the potential to strongly impact populations in southern interior forests (USFWS 2009). Despite the volume, rigor, and applicability of research showing associations between landscape-level habitat attributes and NSO fitness, California has yet to integrate it into take-avoidance regulations for interior timberlands (see *Threats: Inadequacy of Regulatory Mechanisms*).

Comment [UFS6]: Is this the proper word? It implies even flow through time. I think you mean compatible or something along those lines.

Comment [UFS7]: Positively or negatively? Be clear

Redwood Province

Most of what is known about NSOs in the Redwood Province is based on research on intensively harvested lands owned by the Green Diamond Resource Co. Studies on these lands found a preference among NSOs for landscapes with greater amounts of intermediate-age or older forest than expected based on general availability of those forest classes (Thome et al. 1999, Folliard et al. 2000, Keithley and Motroni 2000, Gonzales 2005, Diller et al. 2010). However, site fidelity and reproduction on these lands were positively associated with presence of younger forest classes and measures of habitat heterogeneity (e.g., edge) (Thome et al. 1999, 2000, Diller et al. 2010). Studies of the habitat associations of dusky-footed woodrats on these lands appear to provide additional support for the value of younger forest and habitat heterogeneity to NSOs in the area (Hamm et al. 2007, Hamm and Diller 2009). Unpublished but relatively rigorous modeling of associations between landscape-level habitat attributes and NSO fitness and population growth rate has confirmed that NSOs on Green Diamond lands have complex relationships with timber harvesting (Diller et al. 2010). NSOs in this area indeed appear to benefit from some level of habitat heterogeneity, which is currently maintained on Green Diamond lands through small-patch clearcutting (Diller et al. 2010). Yet, habitat quality on these lands (measured as habitat fitness potential *sensu* Franklin et al. 2000) is positively associated with protection of suitable breeding habitat and both habitat quality and population growth rate are negatively associated with harvesting of suitable habitat (i.e., take) (Diller et al. 2010). Thus, appropriate management of NSOs on Green Diamond lands appears to include avoiding take, setting aside suitable habitat from harvesting, and focusing economically-driven harvest requirements in relatively homogeneous blocks of unsuitable forest. Diller et al. (2010)

did not describe habitat conditions associated with habitat fitness potential ≥1 (i.e., conditions associated with NSOs replacing themselves or contributing to a population surplus). Peer reviewed reporting of these conditions is needed in order to identify appropriate take-avoidance guidelines for the northern part of the Redwood Province (see *Threats: Inadequacy of Regulatory Mechanisms*).

Less is known about the ecology and appropriate management of NSOs on other ownerships within the Redwood Province. Habitat selection by NSOs appears to vary among ownerships in the region (Keithley and Motroni 2000, see Appendix 1). The USFWS (2011a, 2012a) recently conducted habitat suitability modeling based on attributes of landscapes (494 ac) surrounding 392 activity centers distributed across much of the province. The model selected for the region included a suite of habitat variables and performed well in terms of its ability to discriminate between areas around NSO activity centers and random sites. The resulting map of relative habitat suitability was incorporated into the USFWS (2012a) process for designating critical habitat for NSOs but has limited utility for characterizing habitat selection by the subspecies. However, "deconstruction" of the habitat suitability modeling outputs (cf. Dunk and Hawley 2009, Woodbridge et al. 2012, Zielinski et al. 2012) allows evaluation of associations between habitat suitability and the full range of candidate variables, including ones not included in the best performing model. Deconstruction of the habitat modeling output for the Redwood Province shows that the probability of NSOs occurring in a given area in the region increases with larger amounts of forest with relatively dense canopy cover and large diameter trees (Appendix 2). Compared with those in the lowest suitability class, landscapes in the highest suitability class contained an average of 1.8 times more nesting-roosting habitat; 2.4 times higher

basal area of conifers ≥20 inches DBH; 2.3 times higher basal area of live trees ≥30 inches DBH; and 2.0, 1.8 and 1.9 times higher densities of conifers ≥20, 30, and 39 inches DBH, respectively. There was a high degree of variability (standard deviation) in terms of structural attributes within habitat suitability classes, particularly for rare habitat elements such as very large diameter trees. This variability likely reflects the high diversity of forest types, management histories, and natural disturbance regimes in the region (see Sawyer 2006, 2007, Stuart and Stephens 2006). Nonetheless, consistent patterns of association between habitat suitability and mean amounts of these variables are evident. In addition, variability in amounts of many of these habitat attributes (coefficient of variation) declined with increasing habitat suitability, further indicating that they are often important to NSOs in the province. These results suggest that timber harvesting that reduces availability of these structural attributes would generally reduce the probability of NSOs occurring in a given area within the Redwood Province. Changes in availability of these structural attributes can occur with a variety of silvicultural approaches and are not solely caused by even-age harvesting.

Effects of Uneven-Age Harvesting and Thinning

Comment [UFS8]: There is a recent pub (GTR) that has a section on this. See Wilson and Forsman. 2013. Thinning Effects on Spotted Owl Prey and Other Forest-Dwelling Small Mammals, in:

Anderson, Paul D.; Ronnenberg, Kathryn L., eds. 2013. Density Management in the 21st Century: West Side Story. Gen. Tech. Rep. PNW-GTR-880. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 249 p.

Some private timberlands in northern California currently emphasize uneven-age regeneration, which typically causes less visually dramatic changes to forests than does even-age harvesting. This form of harvesting nonetheless has the potential to cause substantial changes to forest structure or composition. For example, intensive selective logging of Douglas-fir (*Pseudotsuga mensiesii*) has resulted in extensive conversion of mixed-evergreen forest to hardwood-dominated forest in parts of the Redwood Province (Sawyer 2006). Relatively little harvesting

has occurred on federal lands within the NSO's range since adoption of the Northwest Forest Plan (Davis and Dugger 2011, Moeur et al. 2011, Kennedy et al. 2012; see below). However, federal agencies have recently expressed support for widespread thinning to reduce wildfire risk in interior forests in the Plan area (USFWS 2011a, 2012a).

Effects of contemporary uneven-age harvesting and thinning on NSOs are difficult to evaluate due to the paucity of rigorous research on the topic. Most of the available information about NSO responses to these silvicultural systems is based on the behavior of very small numbers of telemetered owls and was gathered in an opportunistic fashion during studies of other topics (reviewed in Hansen and Mazurek 2010, USFWS 2011a; see below). Evaluation of this topic is further complicated by poor descriptions of harvest methods, locations and intensities and, perhaps more importantly, post-harvest habitat conditions. The terms uneven-age harvesting and thinning encompass a tremendous variety of harvest types, objectives, and effects (Smith 1986). Harvesting described in relation to NSO telemetry consisted of a variety of commercial thinning or partial harvesting (leaving residual trees) prescriptions, including understory thinning of various intensities, removal of most trees up to a relatively large diameter class, and shelterwood harvests prior to or without removal of residual trees (see Hansen and Mazurek 2010).

In a synthesis prepared for the 2011 revised recovery plan for the NSO (USFWS 2011a), Hansen and Mazurek (2010) provided detailed summaries of data concerning responses of both NSOs and California spotted owls (CSOs) to uneven-age harvesting, partial harvesting, and thinning. This information was gleaned from both peer-reviewed and gray literature and was based on small sample sizes. The authors therefore, opted to review each data source as a "case study" so

that relatively detailed descriptions of harvesting and post-harvest conditions could be provided and so that the methodological strengths and weaknesses of studies could be evaluated. We summarize their review below, with the addition of one subsequent citation (Gallagher 2010).

Each of the 12 studies that we reviewed documented at least some use by NSOs or CSOs of areas harvested with uneven-age harvesting, partial harvesting, or thinning. At least four of the studies found owls nesting in harvest areas (Forsman et al. 1984, Zabel et al. 1992, King 1993, and Buchanan et al. 1995) and at least five recorded roosting in them (Solis 1983, Sisco 1990, King 1993, Hicks et al. 1999, and Meiman et al. 2003). It is important to note, however, that older forest structural attributes had been retained or regenerated in most of the harvest areas used for nesting or roosting. Three of the four studies that documented nesting in harvest areas described the nest stands as mature or old forest or an equivalent classification (USFS Region 5 "suitable habitat"; "understory reinitiation phase…of stand development"). The other study did not describe the harvest area used for nesting (King 1993). Harvest areas used for roosting in three studies likewise were either classified as mature or old forest (Solis 1983) or contained some older-forest structural characteristics, such as relatively high basal area or dense canopy cover (King 1993, Meiman et al. 2003). Two studies observed roosting in harvested stands that appeared to differ from this pattern; but one of the authors thought that the deaths of three birds that roosted in them were due to higher predation risk in the more open stands (Sisco 1990, Hicks et al. 1999).

Most of the reviewed studies found that spotted owls foraged to some degree in uneven-age harvested, partially harvested, or thinned areas. Irwin et al. (2005, 2008) stated that some NSOs

in their study areas selectively used certain harvest units but not others. However, they did not provide quantitative comparisons of prescriptions, post-harvest conditions, or proximities of harvest units to activity centers. Two other studies found that spotted owls generally avoided foraging in areas that recently experienced moderate to intensive partial harvesting or thinning, whereas use of lightly harvested areas varied among individuals (Anthony and Wagner 1999, Gallagher 2010). Anthony and Wagner (1999) found that NSOs (n = 15) in southern Oregon foraged in heavy and moderate partial-cuts less than expected (old stands with ≥30-40% of the original basal area removed and ≥"moderate" canopy cover reduction). Light partial-cuts (old forest with ≤20% of the original basal area removed and "small" reductions of "crown cover" [not described]) were used more than expected by two owls, as often as expected by five, and less than expected by eight. In the northern Sierra Nevada, Gallagher (2010) found that CSOs (n = 9) used heavily thinned "defensible fuel profile zones" (canopy cover reduced to 40%, removal of trees <30 in DBH, reduction of tree density and ladder and surface fuels) less than expected based on availability. She also reported a near-significant tendency ($p = 0.08$, n = 5) for avoidance of areas recently treated with understory thinning. Use and availability of harvest areas varied among individuals. Most individuals exhibited avoidance of defensible fuel profile zones and understory thins but one male showed strong selection for thinned areas (primarily understory thins). It is possible that thinning improved prey availability or otherwise benefited this male. However, Gallagher (2010) noted that thinning treatments were located unusually close to this male's activity center, which potentially increased his likelihood of using them due to central place foraging. She also noted that an unusually large proportion of understory thin units in the male's home range were also treated with prescribed fire, which could have temporarily increased abundances of deer mice (*Peromyscus* spp.) or other prey.

The limited available information suggests that thinning and uneven-age harvesting causes some spotted owls to increase their home range sizes, which could impose energetic costs on individuals (Meiman et al. 2003, Gallagher 2010). Meiman et al. (2003) reported that a male NSO's breeding season home range in the Oregon Coast Range was slightly larger before commercial thinning than afterward but that its nonbreeding season home range was 2.3 times larger. The individual appeared to shift its breeding season core area to include less of the thinned area and its nonbreeding season core area was more than twice as large following thinning as it was prior to thinning. In the northern Sierra Nevada, Gallagher (2010) found that the home range sizes of CSOs (n = 9) significantly increased with greater total area of fuels treatments (defensible fuel profile zones and understory thinning). She also reported near-significant trends of increasing home range size with greater area of defensible fuel profile zone ($p = 0.08$) and group selection harvesting ($p = 0.06$).

Four studies reported that thinning or partial harvesting near nests or roosts displaced spotted owls from those areas (Forsman et al. 1984, King 1993, Hicks et al. 1999, Meiman et al. 2003; also J. Reid, pers. comm.). The only study to describe this effect for more than two NSOs suggested that pairs' responses to harvesting near their nests depended on the intensity of the harvest, whether or not habitat in the nest area was excluded from harvesting, and whether or not suitable alternative habitat was available within the home range (Forsman et al. 1984).

The US Fish and Wildlife Service has expressed support for widespread thinning to reduce the risk of severe wildfire in dry forests within the NSO's range (USFWS 2011a, 2012a). Our

review suggests that spotted owls are often resilient to wildfire (and may benefit from low severity or patchy fire in southern forests) but that extensive severe fire can negatively affect the species by reducing amounts and contiguity of nesting and roosting habitat (see *Threats: Wildfire*). This conclusion might appear to support widespread thinning to reduce the risk of large severe fires. However, preliminary findings of negative effects of thinning on the species and the overall lack of reliable information on the topic suggest that more research is needed before thinning is employed at broad scales within the NSO's range. If widespread thinning is applied prior to rigorous study of its effects, our review suggests that it should be conducted well away from NSO activity centers and focused in young, homogeneous stands that are less suitable for NSOs and where thinning might increase habitat heterogeneity or accelerate development of complex, older-forest structure for prey (Carey 2006; but see below regarding effects of thinning on primary prey species). Planning of treatments should also integrate regional or local information about relationships between wildfires and topography (see *Threats: Wildfire*), the composition of NSO diets or prey communities, and other ecological factors that could influence how thinning affects wildfires and NSOs.

Timber Harvest Effects on Prey

The primary prey for NSOs in California are dusky-footed woodrats (*Neotoma fuscipes*), northern flying squirrels (*Glaucomys sabrinus*), and tree voles (*Arborimus* spp.) (Zabel et al. 1995, White 1996, Ward et al. 1998, Farber and Whitaker 2005, Diller et al. 2010, Klamath National Forest, unpubl. data). Other important prey in the state (either in terms of frequency or biomass contributions to diets) include other voles (*Myodes californicus*, *Phenacomys* spp., and

Microtus spp.), deer mice (*Peromyscus* spp.), pocket gophers (*Thomomys* spp.), broad-footed moles (*Scapanus latimanus*), and juvenile brush rabbits (*Sylvilagus bachmani*) and snowshoe hares (*Lepus americanus*). These species have a broad array of habitat associations and thus, respond quite differently to timber harvesting and other forest disturbances (Zeiner et al. 1990). Below we focus solely on timber harvest effects on the three primary prey species for NSOs in California. It is important to acknowledge, however, that NSOs typically have broad diets (see diet studies cited above) and that other prey species may also influence spotted owl demographic rates (Ward and Block 1995, Rosenberg et al. 2003).

Dusky-footed woodrats can occur in relatively high abundances in old forest, particularly in riparian areas and other locations with a well developed understory or brush layer (Carey et al. 1992, 1999). However, they generally reach their highest abundances in stands of brushy pole-timber that develop following severe disturbances (Carey et al. 1992, 1999, Sakai and Noon 1993, Anthony et al. 2003, Hamm et al. 2007). Thus, intensive harvesting of intermediate-age stands can result in temporary increases in abundance of dusky-footed woodrats. There is little information regarding effects of less intensive harvesting on dusky-footed woodrats. Hamm and Diller (2009) rarely found dusky-footed woodrats in thinned stands on private timberlands in the Redwood Region. They suggested that thinning without prescribed burning was insufficient for promoting growth of the disturbance-adapted shrubs locally favored by the species (see *Threats: Wildfire* regarding short-term effects of fire on prey).

Densities and demographic rates of northern flying squirrels are positively associated with habitat elements found in forests (e.g., arboreal lichens, truffles, and snags: Rosenberg and

Anthony 1992, Carey 1995, Waters and Zabel 1995, Gomez et al. 2005, Meyer et al. 2005, Lehmkuhl et al. 2006). Thus, they are likely to respond negatively to intensive forms of timber harvesting (e.g., Waters and Zabel 1995). Northern flying squirrels are also generally sensitive to habitat fragmentation caused by intensive harvesting (Smith 2007). For example, Rosenberg and Raphael (1986) found that densities of northern flying squirrels in the California Klamath Province were substantially lower in the smallest and most insular habitat patches (due to surrounding clearcut harvesting) than in the largest and best connected patches.

Research concerning the effects of thinning and other lower-intensity forms of harvesting on northern flying squirrels has generated inconsistent results (e.g., Carey 2000, Ransome and Sullivan 2002, Ransome et al. 2004, Gomez et al. 2005, Manning et al. 2012). Some of the inconsistency appears to be due to whether treated young stands are compared with structurally simple young stands (e.g., Gomez et al. 2005), structurally complex young stands (e.g., Carey 2000), or stands that have not recently experienced harvesting (Holloway and Smith 2011). The available research suggests that treated stands are more likely to contain relatively low abundances of northern flying squirrels when compared with structurally complex or mature and old stands, whereas they may exhibit similar or even higher abundances when compared with structurally simple young stands. Harvest intensity and levels of retention appear to be another major determinant of thinning effects on northern flying squirrels, with higher intensity thinning (lower retention levels) having stronger negative effects (Meyer et al. 2007, Holloway and Smith 2011, Manning et al. 2012; but see Ransome et al. 2004). Whether thinning is patchy or uniform (in terms of location and intensity) might also be important. For example, thinning can reduce the availability of truffles, the northern flying squirrel's primary food, for more than 10-20 years;

but variable-density thinning appears to be less harmful than commercial thinning (Waters et al. 1994, Colgan et al. 1999, Luoma et al. 2003, Meyer et al. 2005).

Tree voles generally occur at higher densities in old forests than in young forests (reviewed in Sztukowski and Courtney 2004, USFWS 2011b) and selectively use forests containing higher concentrations of habitat elements typically found in older stands (e.g., older stand age, larger diameter downed wood, greater basal area: Dunk and Hawley 2009). Tree voles are thought to be highly vulnerable to logging and other disturbances that reduce the extent and contiguity of old forests (Carey 1991, Huff et al. 1992, Hayes 1996, Adam and Hayes 1998, USFWS 2011b). Some tree vole populations occur in intensively managed landscapes with little or no old forest (e.g., Thompson and Diller 2002). However, the US Fish and Wildlife Service (2011b) noted that "the limited evidence available suggests that tree vole occupation of younger forest stands may be relatively short-lived (Diller 2010, pers. comm.) or intermittent (Hopkins 2010, pers. comm.)." Based on the natural histories of these species, reducing or fragmenting older forest could negatively affect them; but retention of older Douglas-fir (*Pseudotsuga menziesii*) trees and patches of well-connected canopy might ameliorate those impacts (Hayes 1996, Adam and Hayes 1998, USFWS 20011b). Clear-cutting and other severe disturbances should have the strongest effects on tree voles, due to the species' diet, nesting habitat associations, arboreal mode of travel, and apparently poor mobility (USFWS 2011b).

Habitat Lost to Past Timber Harvesting (1800s to 1994)

Rigorous research has shown that the fitness of NSOs in the southern part of their range is highest in landscapes with large concentrations of suitable breeding habitat (reviewed above). Herein we review information showing that the current availability of suitable breeding habitat was strongly affected by past timber harvesting, which removed or modified the majority of old forest that existed historically.

We are unaware of any estimates of the amount of suitable NSO habitat that existed at the time of Euro-American settlement (early to mid-1800s). Nesting-roosting habitat for NSOs generally occurs in relatively old, structurally complex conifer forest (Blakesley 2004). It is therefore, reasonable to evaluate historical trends in old conifer forest as a rough proxy for changes in amounts of suitable NSO habitat (USFWS 1990). Estimates reviewed for the NSO's federal listing determination indicated that approximately 18-24 million acres of old forest existed in western Oregon and Washington and northwestern California during the early to mid-1800s (USFWS 1990). These estimates did not include all regions or potentially suitable forest types within the subspecies' range. After including all regions and conifer forests, Strittholt et al. (2006) estimated that about 40 million acres of old conifer forest (>150 yrs) existed at the time of Euro-American settlement (Table 2). This is a crude approximation, as it is based on incomplete historical information and an assumption that nearly all pre-settlement conifer forest was old (i.e., had not experienced severe disturbance within the previous 150 years). However, Strittholt et al. (2006) noted that their regional estimates closely matched previous estimates for similar

regions and forest types, suggesting that they provide a reasonable baseline for comparison with contemporary forest conditions.

Using satellite imagery, Strittholt et al. (2006) estimated that 11.5 million acres of old conifer forest existed in 2000 (Table 2). Thus, approximately 72% of old conifer forest was lost in the Pacific Northwest during the 19th and 20th centuries (Table 2). This estimated post-settlement loss of old conifer forest is similar to earlier estimates of 60-88% reviewed in the NSO's federal listing determination (USFWS 1990). Strittholt et al. (2006) did not provide estimates of old forest declines by political boundaries so we cannot report their estimates for California alone. Old conifer forests declined by 62% in the Klamath provinces ("Klamath-Siskiyou Forests") and 79% in the eastern Cascades provinces ("Eastern Cascades Forests"), both of which substantially overlap with the NSO's range in northern California. Other than in two small regions surrounding major population centers in Washington and Oregon, declines in old conifer forest were primarily caused by widespread intensive logging (Strittholt et al. 2006). Mountainous terrain in the Klamath and eastern Cascades limited timber harvesting compared with more accessible areas but major losses of old conifer forest nonetheless occurred in those areas (Strittholt et al. 2006). Strittholt et al. (2006) did not evaluate trends in amounts of old forest for the Redwood Province but other sources estimated that 85-96% of old redwood forest was lost to intensive timber harvesting during the post-settlement period (USFWS 1992).

Table 2: Area (ha) of Pacific Northwest ecoregions and estimated historical (early to mid-1800s) and contemporary (2000) extents of old (>150 yrs) and mature (50-150 yrs) conifer forest within them (from Strittholt et al. 2006).

	Cascade Mountain Leeward Forests	*North Cascades Forests*	*Puget Lowland Forests*	*Central Pacific Coastal Forests*	*Central & Southern Cascades Forests*	*Eastern Cascades Forests*	*Klamath-Siskiyou Forests*	*Willamette Valley Forests*
Ecoregion area	1,600,444	1,278,056	1,719,726	4,267,988	4,481,279	5,398,139	5,033,181	1,487,769
Historical old conifer area	960,279	766,844	1,289,794	3,627,790	3,361,005	3,238,883	2,516,625	371,942
Percentage of ecoregion	60	60	75	85	75	60	50	25
Current old conifer area	420,394	511,396	67,353	668,281	1,328,796	687,836	946,394	34,993
Percentage of historical old conifer	44	67	5	18	39	18	38	9
Percent change	−56	−33	−95	−82	−61	−79	−62	−91
Mature conifer area	285,441	203,994	229,634	683,098	899,266	947,215	1,239,586	270,362
Percentage of historical old conifer	30	27	18	19	27	25	49	73
Combined area	705,835	715,391	296,987	1,351,379	2,228,063	1,635,051	2,185,980	305,355
Percentage of historical old conifer	74	93	23	37	66	43	87	82

Strittholt et al. (2006) reported that the majority of old (78%) and mature (50%) conifer forest in 2000 existed on public lands. Nearly all of the remaining old redwood forest likewise occurs on public lands (cite *[http://www.nps.gov/redw/faqs.htm]*). Much of the current difference among ownerships in amounts of older forest and suitable breeding habitat is due to past timber harvest rates. For example, loss of forest to harvesting during the 1970s through early 1990s occurred at substantially higher rates on private timberlands than on federal lands (e.g., >2 times faster in western Oregon) (Cohen et al. 2002, Staus et al. 2002, Healey et al. 2008). Nonetheless, an estimated 32% of suitable breeding habitat for NSOs occurred on non-federal lands at the time of the Northwest Forest Plan's implementation (1994), so conservation efforts for NSOs on non-federal lands remain important.

Although timber harvesting was substantially curtailed on federal lands following implementation of the Northwest Forest Plan (Healey et al. 2008, Kennedy et al. 2012; reviewed below), biologists noted the possibility that NSOs would continue to decline for many years due to lag effects of past harvesting (Courtney et al. 2004). The NSO has a relatively low

reproductive rate and might therefore be unable to immediately recover following removal or reduction of threats (Noon and Biles 1990). Furthermore, substantial recruitment of old forest and suitable nesting-roosting habitat could take multiple decades in areas that formerly experienced widespread intensive harvesting (Moeur et al. 2011; see below). Past harvesting could therefore be among the causes of continuing poor demographic performance of some NSO populations (Courtney et al. 2004). Forsman et al. (2011) noted, however, that some populations are declining on lands not previously subjected to widespread intensive timber harvesting (e.g., some National Parks). Based on this observation, they concluded that lag effects of past timber harvesting poorly explain continuing population declines. Yet, it is possible that lag effects of past timber harvesting do contribute to some population declines but that these effects are obscured by those of other stressors, such as competition with barred owls or large severe wildfires. Lag effects from past harvesting might be similarly obscured on private timberlands by impacts from barred owls and continuing timber harvesting. Timber harvesting continues to occur at high rates on private lands and is still the primary source of habitat loss for NSOs in those areas (Davis and Dugger 2011, Moeur et al. 2011, Kennedy et al. 2012).

Comment [UFS9]: Define "high" rate

Habitat Lost to Contemporary Timber Harvesting (1994-2007)

Davis and Dugger (2011) estimated NSO habitat trends following implementation of the Northwest Forest Plan. Their analyses were mostly limited to federal lands within the Plan area but they also estimated habitat trends on non-federal lands, as reported in the current NSO recovery plan (USFWS 2011a). In addition to these analyses, we review results presented by Moeur et al. (2011) because they provide some additional insight into recent habitat trends for

NSOs on non-federal lands. We do not review habitat trend estimates based on federal ESA Section 7 consultation records (Bigley and Franklin 2004, USFWS 2012b). These records provide a less consistent and complete data source than those used by Davis and Dugger (2011) (see Bigley and Franklin 2004). They may also overestimate habitat changes since they evaluate effects of planned projects, which may be greater than what is actually implemented (Bigley and Franklin 2004).

Davis and Dugger (2011) used remotely sensed (satellite imagery) vegetation data to model changes in habitat suitability for NSOs during the first 15 years of the Northwest Forest Plan (1994-2007 in California and 1996-2006 in Oregon and Washington). They modeled habitat suitability based on habitat attributes surrounding thousands of NSO pair locations. Suitable breeding habitat was defined as having both a probability of owl presence greater than expected based on random chance and environmental conditions typical of those found around nesting and roosting pairs. Habitat loss was defined as a change in suitability rank from suitable or highly suitable to marginal or unsuitable due to vegetation changes caused by forest disturbances. Davis and Dugger (2011) did not estimate recruitment of, or net changes, in breeding habitat. They felt that their remotely sensed data poorly captured the kinds of slow and subtle habitat changes that occur during development of intermediate-aged and older stands. However, Moeur et al. (2011) estimated trends in mature and old forests during the same time period, which could provide insight into net changes in breeding habitat for NSOs.

Comment [UFS10]: And forest inventory plot data

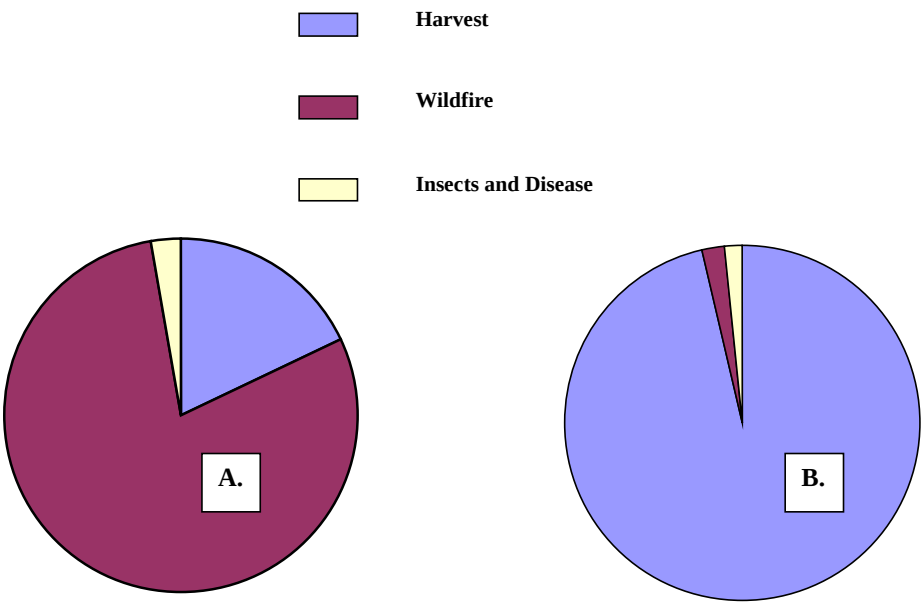
Table 3 shows estimated gross losses of suitable NSO breeding habitat to timber harvesting on federal and non-federal lands during the first 15 years of the Northwest Forest Plan (Davis and

Dugger 2011, USFW 2011a). Timber harvesting was responsible for a gross loss of about 54,000 acres (0.6%) of suitable breeding habitat on federal lands. This loss likely had little rangewide effect on NSOs but could have impacted the subspecies at local or regional scales. For example, harvesting resulted in a 3% gross loss of suitable breeding habitat on federal lands in the California Cascades, where habitat was already relatively limited. Approximately 92% of total suitable breeding habitat lost to timber harvesting occurred on non-federal lands. In contrast with federal lands, nearly all estimated gross habitat loss on non-federal lands was due to timber harvesting rather than natural disturbances (Figure 1; see *Threats: Wildfires*). In just 11-13 years, timber harvesting caused an estimated rangewide gross loss of 625,600 acres (15%) of suitable breeding habitat on non-federal lands. The largest losses on non-federal lands occurred in Oregon (301,200 ac, 22%) and Washington (234,200 ac, 19%). Non-federal lands in California experienced lower gross losses of suitable breeding habitat to harvesting (90,200 acres, 6%). Nonetheless, losses in all three states were substantial given the short time frame during which they occurred and the likelihood that little of the loss was offset by recruitment of suitable breeding habitat during that period (see below).

Table 3: Estimated gross losses of suitable NSO breeding habitat on federal and non-federal lands due to timber harvesting during 1994-2007 in California and 1996-2006 in Oregon and Washington (adapted from Davis and Dugger 2011, USFWS 2011a).

State	Ownership	Province	1994/1996 Ac	Harvest Ac	Harvest %
California	**Federal**	CA Cascades	213,200	6,500	3.0%
		CA Klamath	1,489,800	4,400	0.3%
		CA Coast	145,400	300	0.2%
		CA Federal Total	**1,848,400**	**11,200**	**0.6%**
	Non-Federal		**1,556,700**	**90,200**	**5.8%**
	Combined		**3,405,100**	**101,400**	**3.0%**
Oregon	**Federal**	OR Coast Range	611,200	3,300	0.5%
		Western OR Cascades	2,258,700	13,900	0.6%
		Eastern OR Cascades	402,900	5,800	1.4%
		Willamette Valley	3,400	100	2.9%
		OR Klamath	985,000	6,800	0.7%
		OR Federal Total	**4,261,200**	**29,900**	**0.7%**
	Non-Federal		**1,382,400**	**301,200**	**21.8%**
	Combined		**5,643,600**	**331,100**	**5.9%**
Washington	**Federal**	Olympic Peninsula	763,100	500	0.1%
		Eastern WA Cascades	673,600	8,100	1.2%
		Western WA Cascades	1,283,000	3,700	0.3%
		Western WA Lowlands	24,700	400	1.6%
		WA Federal Total	**2,744,400**	**12,700**	**0.5%**
	Non-Federal		**1,258,900**	**234,200**	**18.6%**
	Combined		**4,003,300**	**246,900**	**6.2%**
Rangewide	**Federal**		**8,853,800**	**53,800**	**0.6%**
	Non-Federal		**4,198,000**	**625,600**	**14.9%**
	Combined		**13,051,800**	**679,400**	**5.2%**

Figure 1: Proportions of suitable breeding habitat loss attributed to harvesting, wildfire, and insects and diseases on (A) federal lands and (B) non-federal lands during 1994-2007 (adapted from Davis and Dugger 2011 and USFWS 2011a).



The USFWS (2011a) and Davis and Dugger (2011) did not describe regional habitat trends for non-federal lands. However, insight into regional habitat trends on non-federal lands can be obtained from trends in mature and old forest during the same time period. Moeur et al. (2011) reported substantial gross losses of mature and old forest (mean DBH ≥20 in) on non-federal lands during the first 15 years of the Northwest Forest Plan. The largest gross losses, in terms of acreage, occurred in the Western Washington Lowlands (387,200 ac, 49%), Oregon Coast Range (362,500 ac, 50%), and California Coast Range (259,000 ac, 35%). All provinces and states within the NSO's range experienced large proportional losses, ranging from 31% in the Eastern Washington Cascades to 48% and 52% in the Klamath and Eastern Cascades of Oregon. Confirming the results of Davis and Dugger (2011; Figure 1), Moeur et al. (2011) found that gross losses of mature and old forest on non-federal lands were almost entirely due to timber harvesting (also see Kennedy et al. 2012).

Moeur et al. (2011) reported that gross loss of mature and old forest was substantially offset by recruitment into that habitat class. They noted, however, that given the short length of the monitoring period (10-14 yrs), recruitment was "likely due to incremental stand growth over the 20-in diameter threshold, or from understory disturbances that removed smaller diameter trees and raised the average stand diameter above the threshold, rather than from an increase in forests of much larger and older trees." Thus, it is unlikely that there was substantial recruitment of suitable and highly suitable breeding habitat for NSOs during this time period. This conclusion is supported by Davis and Dugger (2011), who found that most of the detectable habitat recruitment during their monitoring period occurred in the marginal suitability class, which more closely resembled their definition for dispersal habitat than for breeding habitat. Even if all

mature and old forest recruited during the first 15 years of the Plan provided suitable breeding habitat for NSOs, non-federal lands in California still experienced a net decline in area of mature and old forest during that period, and those in Washington and Oregon fared substantially worse (Moeur et al. 2011).

Future Harvesting in California

It is impossible to provide reliable projections of future timber harvesting or its effects on NSOs in California. Federal agencies have expressed support for widespread thinning to address wildfire risk on public lands in the state but we are unaware of any projections for harvest volume or effects on NSOs from these activities (USFWS 2011a, 2012a). Documents associated with Habitat Conservation Plans for private timberlands in California project substantial impacts of harvesting on some ownerships and relatively low impacts on others (see *Legal and Regulatory Framework* and *Threats: Inadequacy of Regulatory Mechanisms*). However, many landowners, in the state, including some large industrial timber companies, conduct timber harvesting outside of Habitat Conservation Plans. The state requires evaluation of potential environmental impacts of all Timber Harvest Plans but both landowners and responsible agencies have used inconsistent methods for conducting these evaluations. For example, some entities have strictly adhered to the state's Forest Practice Rules (CAL FIRE 2013), others have relied on poorly described and vetted variants of those rules (e.g., option "g+"), and still others have opted to follow US Fish and Wildlife Service (2009) recommendations. Based on an in-depth review of research concerning the NSO's habitat and spatial relationships, the US Fish and Wildlife Service (2009) recommended sweeping changes to NSO habitat retention guidelines in

the Forest Practice Rules for California's northern interior (CAL FIRE 2013). These recommendations are more scientifically supportable than are habitat retention guidelines in the Forest Practice Rules (CAL FIRE 2013), as they incorporate the large body of research of NSO-habitat relationships conducted since 1992 when guidelines in the Forest Practice Rules were created. In addition they were designed to enable CAL FIRE personnel lacking expertise with NSO-habitat relationships to properly determine if take would occur. However, the state has not officially adopted these recommendations or any other changes that incorporate the tremendous body of information about NSO-habitat relationships produced since 1992 (USFW 2009; see *Threats: Inadequacy of Regulatory Mechanisms*). Furthermore, since 2008, when the US Fish and Wildlife Service largely ceased providing technical assistance with timber harvest reviews in northern California, relatively few Timber Harvest Plans have been reviewed by personnel with sufficient biological expertise to evaluate whether or not take will occur (see *Threats: Inadequacy of Regulatory Mechanisms*). Lacking reliable harvest and take projections, and barring a major change in the legal or regulatory framework protecting NSOs, there is currently no reason to conclude that timber harvest effects on NSOs in California will substantially decline in the near future.

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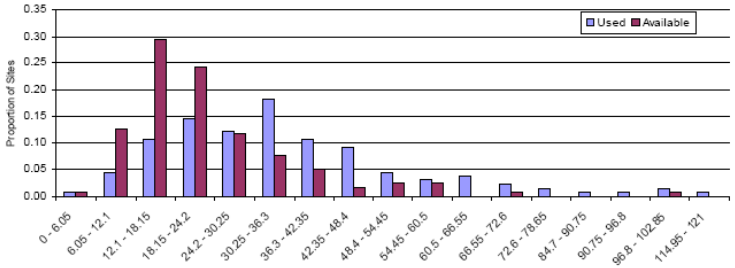
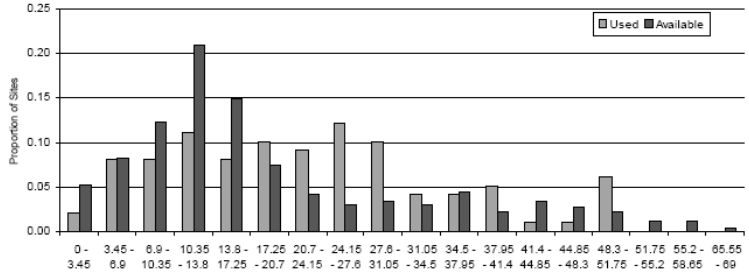
Appendix 1

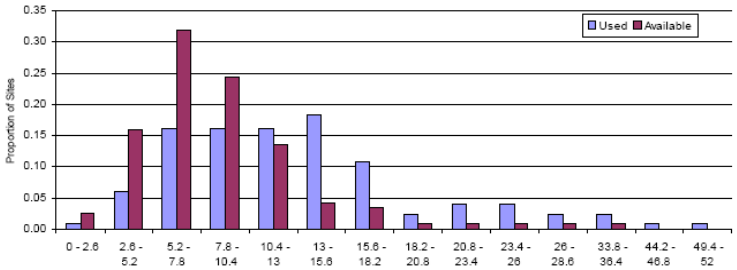
USFWS GNN (see USFWS 2011) histograms showing use by NSOs versus availability of select habitat attributes at a landscape-scale (200 ha, 494 ac) on Mendocino Redwood Co. (left column) and Green Diamond Resource Co. lands (right column).

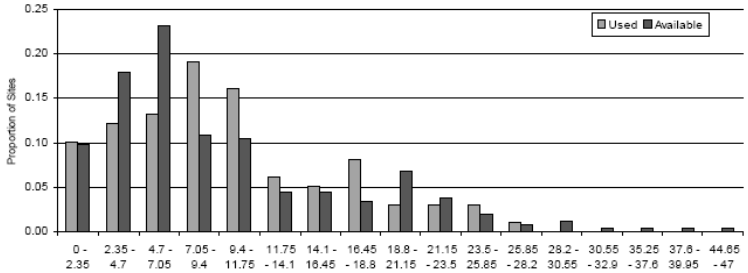
Live conifer trees per hectare ≥20 inches DBH:





Basal area of live conifers ≥20 inches DBH:

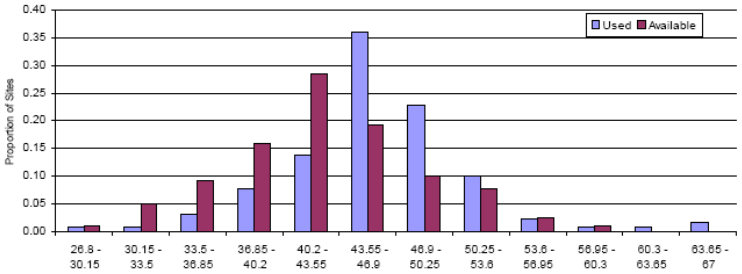


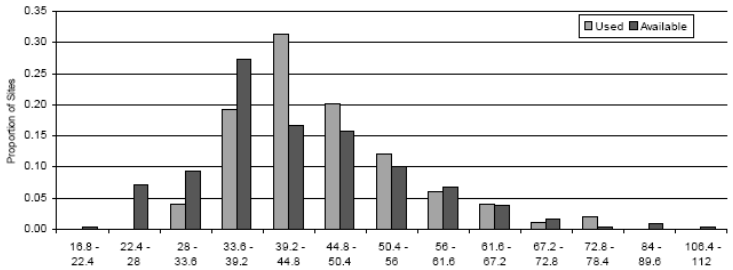


Appendix 1 (continued)

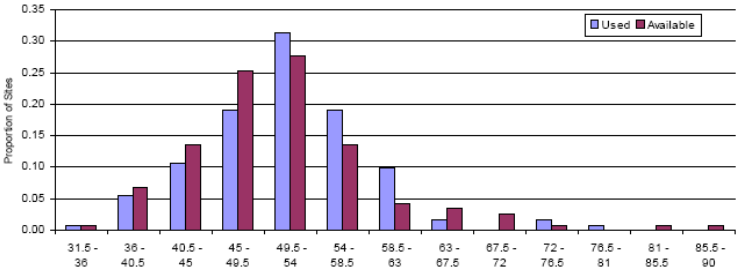
USFWS GNN (see USFWS 2011) histograms showing use by NSOs versus availability of select habitat attributes at a landscape-scale (200 ha, 494 ac) on Mendocino Redwood Co. (left column) and Green Diamond Resource Co. lands (right column).

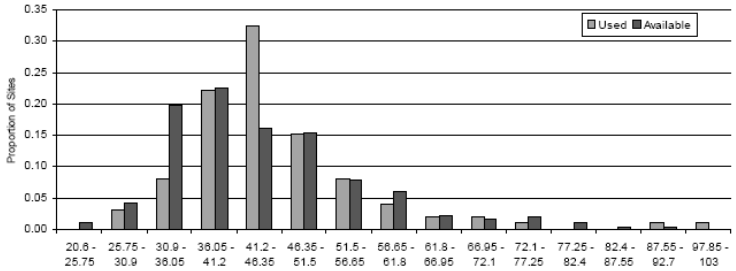
Basal area weighted mean diameter of all live conifers:





Basal area weighted stand age:

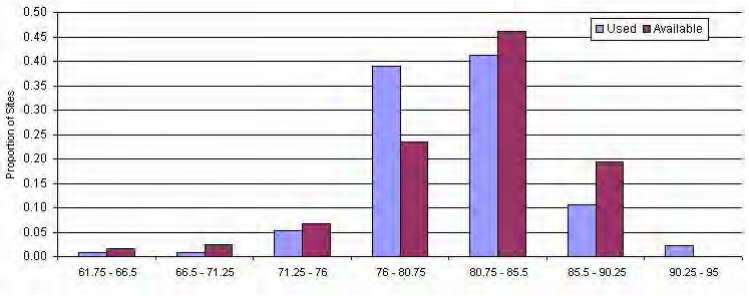


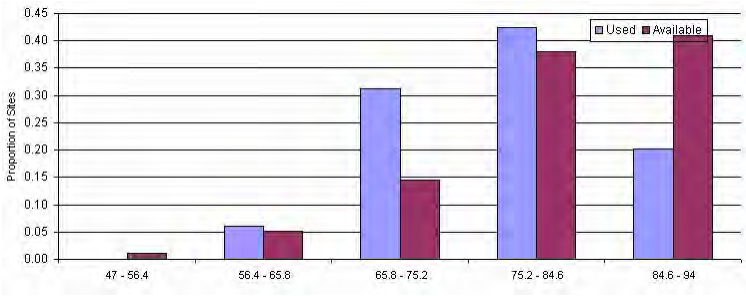


Appendix 1 (continued)

USFWS GNN (see USFWS 2011) histograms showing use by NSOs versus availability of select habitat attributes at a landscape-scale (200 ha, 494 ac) on Mendocino Redwood Co. (left column) and Green Diamond Resource Co. lands (right column).

Canopy cover:





Appendix 2

"Deconstructed" habitat suitability modeling (see text) for NSOs in the Redwood Province showing mean (SD, CV) values of select habitat structural attributes at the 200 ha (494 ac) scale by relative habitat suitability rank (USFWS 2011, unpubl. data).

Variable	Relative Habitat Suitability					
	Very Low	**Low**	**Med. Low**	**Med.**	**Med. High**	**High**
Strength of Selection*	-9.2	-2.9	-1.3	1.6	3.2	8.6
Percent of Region	16.3	24.5	26.2	22.4	9.7	0.9
Nesting-Roosting (ha)	57.9 (43.2, 75)	69.4 (40.8, 59)	79.9 (37.3, 47)	87.6 (33.6, 38)	94.3 (31.1, 33)	105.5 (30.8, 29)
Canopy Cover All Trees (%)	71.2 (23.2, 33)	75.2 (20.7, 28)	78.9 (18.1, 23)	81.0 (16.2, 20)	82.1 (15.5, 19)	82.9 (15.7, 19)
Canopy Cover Conifer (%)	43.9 (31.8, 72)	48.8 (30.0, 61)	53.4 (28.3, 53)	57.4 (27.2, 47)	61.4 (26.5, 43)	64.6 (26.4, 41)
BA Conifers ≥50 cm (m^2/ha)	10.6 (20.7, 195)	12.5 (23.0, 184)	14.1 (24.8, 176)	15.2 (25.6, 168)	17.6 (30.1, 171)	25.2 (45.9, 182)
BA Live Trees ≥75cm (m^2/ha)	7.3 (17.6, 241)	8.5 (20.1, 236)	9.3 (21.8, 234)	9.3 (22.4, 241)	10.4 (27.1, 261)	17.0 (44.0, 259)
Density Trees ≥50 cm (no./ha)	32.3 (37.3, 115)	36.1 (38.4, 106)	39.8 (40.0, 101)	42.5 (42.1, 99)	45.4 (44.5, 98)	50.0 (46.1, 92)
Density Trees ≥75 cm (no./ha)	8.2 (14.8, 180)	9.2 (15.6, 170)	9.9 (16.0, 162)	10.0 (15.5, 155)	10.4 (15.3, 147)	12.8 (16.8, 131)
Density Conifers ≥50 cm (no./ha)	22.1 (34.7, 157)	25.5 (36.4, 143)	28.9 (38.3, 133)	32.6 (40.7, 125)	37.3 (43.6, 117)	43.1 (45.6, 106)
Density Conifers ≥ 75 cm (no./ha)	6.6 (14.5, 220)	7.6 (15.4, 203)	8.4 (15.7, 187)	8.7 (15.2, 175)	9.4 (15.1, 161)	12.0 (16.7, 139)
Density Conifers ≥100 cm (no./ha)	2.5 (7.7, 308)	2.9 (8.4, 290)	3.2 (8.8, 275)	3.1 (8.3, 268)	3.2 (8.5, 266)	4.7 (10.4, 221)
Mean DBH Conifers by BA (cm)	42.8 (34.5, 81)	48.5 (35.5, 73)	51.7 (35.4, 68)	52.1 (34.0, 65)	52.9 (36.1, 68)	60.8 (51.1, 84)
QMD Dominant/Codominant Conifers (cm)	35.7 (29.1, 82)	40.2 (29.9, 74)	42.7 (29.7, 70)	42.6 (28.3, 66)	42.7 (29.7, 70)	48.1 (41.5, 86)

*Strength of selection calculated as the proportion of activity centers in a habitat suitability class divided by the proportion of the modeling region in that class.

September 5, 2014

Ken Hoffman's Peer Review of Timber Harvesting threat section:

Pg. 2

Non-federal lands contain the majority of the remaining breeding pairs of NSO. Not just the breeding habitat. There are more NSO in the Redwood zone on private land in Cali9fornia than the rest of the species range combined. Redwood NSOs are the last source population.

Pg. 7

"Most of the published research" or "a large amount of research" should replace "most of what is known"

'Diller et, al. 2010' is an unpublished document. Non-peer reviewed annual report.

Pg. 8

"Small patch clear-cutting"? WTF?

"Harvesting of suitable habitat (i.e. take)" should say "occupied" habitat.

Pg. 9

"Less is known"? A great deal is known. Less is published.

Pg. 10

Private timberland is divided almost equally between industrial and non-industrial. Most non-industrial timberland is uneven-aged managed – not uneven-aged regenerated.

Pg. 10-14

Thinning on National Forests occurs in even-aged stands surrounded by a sea of suitable habitat. Thinning on private land occurs either in long-term NTMPs or on industrial timberland which is a sea of unsuitable habitat.

Pg. 27

Market conditions drive harvest on non-industrial timberland. Industrial timberland is harvested on a schedule to keep mills in material.

-Thinning on Public land is insignificant for two reasons:

#1 Most NSO are on private land is in the Redwood zone

#2 Most Forest Service thinning occurs in a sea of suitable habitat.

HCPs all result in substantial impacts to NSO habitat and individuals through permitted take.

No mention of the USFWS guidance for the coast?

USFWS Technical Assistance almost immediately increased NSO habitat protections starting in 1999. Coastal guidance also far exceeds FPRs.

-Technical Assistance continued through 2008.

-Paper fails to recognize difference between industrial and non-industrial timber management.

Three Major Points

1. Redwood zone NSO is the last source population.
2. Redwood zone timberland is almost 50/50 industrial/non-industrial.
3. Inadequate regulatory mechanism and process for private land has been obvious since at least 1999.

Wildfire and Salvage Logging

Introduction

Recent status reviews have identified wildfire as a primary threat to the recovery of the northern spotted owl (NSO) (Courtney et al. 2004, USFWS 2011). Much of this concern was based on recent loss of suitable breeding habitat to wildfires and to the risk of extensive severe fires occurring in the future (Davis and Dugger 2011, USFWS 2011). Other researchers and stakeholders have questioned the scientific basis of claims that wildfires pose a threat to NSOs and have expressed distrust of agency recommendations for widespread use of forest thinning to reduce fire risk (e.g., Hanson et al. 2009, Heiken 2010, DellaSala et al. 2013).

There is currently limited information with which to evaluate responses of spotted owls to wildfires and post-fire salvage logging. This research suggests that wildfires have variable and complex effects on the species (Table 1). This is unsurprising given differences in wildfires, research methods, study areas, and spotted owl subspecies and populations. Nonetheless, patterns are evident in the literature concerning spotted owl responses to wildfires and salvage logging and these can be evaluated in light of the species' habitat and prey relationships. Currently available research suggests that low-to-moderate or mixed-severity wildfires have limited effects on spotted owls (Table 1). In fact, such fires could benefit NSOs in southern forests by contributing to landscape-level habitat heterogeneity associated with high fitness (Franklin et al. 2000). In contrast, large-scale severe (stand-replacing) fire can have strong negative effects on spotted owls (Table 1). This likely occurs when fires excessively modify,

reduce, or fragment concentrations of suitable nesting and roosting habitat needed for reproduction and survival (Franklin et al. 2000, Dugger et al. 2005, Schilling et al. 2013). Negative effects of extensive severe wildfires appear to be exacerbated by post-fire salvage logging, which structurally simplifies burned areas, removes important habitat legacies for prey, and creates high contrast habitat edges that educe spotted owls' use of burned areas (Clark 2007, Lee et al. 2012, 2013, Clark et al. 2013, Comfort 2013).

Regardless of scientific uncertainty regarding spotted owl responses to wildfire, it is clear that recent large wildfires have caused tremendous loss, degradation, and fragmentation of suitable habitat for NSOs on federal lands (Davis and Dugger 2011, USFWS 2011; also see Healey et al. 2008, Moeur et al. 2011). This is cause for concern since recovery of the subspecies largely relies on habitat protection on federal lands (USFWS 2011). Furthermore, much of the climate change research indicates that wildfires will continue to be a source of large-scale habitat change during coming decades (Westerling et al. 2006, Lenihan et al. 2008, Westerling and Bryant 2008, Littell et al. 2009). These concerns have prompted ecologists and federal agencies to advocate widespread forest thinning to reduce wildfire risk within the range of the NSO (USFWS 2008, 2011, 2012a, Franklin and Johnson 2012). However, the limited information currently available suggests that spotted owls often respond negatively to forest thinning (reviewed in Hansen and Mazurek 2010, USFWS 2011; see *Threats: Timber Harvesting*). Further research is needed to determine whether and how widespread thinning should be used in forests occupied by NSOs. Currently available information suggests that spotted owls tolerate, and possibly benefit from, low severity or patchy fire (Bond et al. 2002, 2009, Roberts 2008, Roberts et al. 2011, Keane et al. 2011, 2012, Lee et al. 2012, 2013, Comfort 2013). Thus, the current body of research

Comment [UFS1]: Not just continue, but become an increasing source…See Moritz et al. 2012, Dennison et al. 2014, Stavros et al. 2014 as additional references.

Comment [UFS2]: Perhaps couch NSO effects in terms of duration/time (e.g., short-term vs long-term). Much of the problem you write about here will be on how to balance the two.

Comment [UFS3]: Timber harvesting, which has mostly shifted from regeneration to thinning, was and is planned to occur under the NWFP (owl's range). Thinning is not always proposed by the land management agencies to reduce risks of large wildfires and future fire loss of habitat. It is also designed to accelerate development of old forest structure and species composition. Also, it is important to remember that it is also proposed to provide economic inputs to the local economies, another NWFP objective.

So, this statement should read that **research is needed to help land managers understand the effects of thinning on NSO**. Not to determine whether the agencies should thin. The NWFP calls for it.

supports use of prescribed fire and allowing wildfires to burn under prescribed conditions in dry forests within the NSO's range, provided sufficient concentrations of suitable habitat are retained.

Comment [UFS4]: This conclusion seems out of place. You have not made the argument yet.

Wildfire Effects on Spotted Owls

Indirect Evidence

Research of associations between landscape-scale habitat attributes and the demography and presence of NSOs has consistently found that the subspecies benefits from some form of habitat heterogeneity in the southern portion of its range (e.g., ecotones or edges between different vegetation classes) (Franklin et al. 2000, Zabel et al. 2003, Olson et al. 2004, Dugger et al. 2005, Carroll and Johnson 2008, Diller et al. 2010, Schilling et al. 2013; reviewed in *Threats: Timber Harvesting*). Yet, these same studies have also strongly demonstrated the importance of large concentrations of suitable breeding habitat around activity centers (reviewed in *Threats: Timber Harvesting*). Based on this research, wildfires likely have positive effects on NSOs in California when they contribute to beneficial forms of habitat heterogeneity and negative effects when they substantially reduce or degrade suitable habitat around activity centers. Extensive severe wildfires have the potential to remove or fragment core concentrations of suitable breeding habitat across multiple NSO territories. These fires, therefore, have the greatest likelihood of substantially impacting NSO populations. ~~Other~~ Smaller, less severe wildfires may impact fewer territories and have weaker negative effects on populations, burn in a manner that contributes to

Comment [UFS5]: I think it is more "fire-prone" portions rather than southern. The east side of the Cascades in Washington as example.

Comment [UFS6]: Delete?

Comment [UFS7]: Might want to define what you mean by "severe". Studies have used different definitions, which sometimes causes confusion.

Comment [UFS8]: Be careful on use of the term "habitat", should also define this too… nesting/roosting?

beneficial forms of habitat heterogeneity in some territories, or have a combination of these effects.

Direct Evidence

Several studies have investigated responses of NSOs to wildfires (Table 1). These studies provide crucial information for evaluating ~~fire~~ wildfire as a potential threat to the subspecies. However, their inferences are limited due to small sample sizes in all cases, the confounding effects of post-fire salvage logging in one case, and pooling of data from all three spotted owl subspecies in another case (Table 1; see below). In order to supplement these studies, we also reviewed research of fire effects on California spotted owls (*S. o. occidentalis*; CSOs) and Mexican spotted owls (*S. o. lucida*; MSOs) (Table 1). Because inferences from these studies are also limited, and given differences among fires, spotted owl populations, and research methods, we reviewed each project as a "case study". Relatively thorough descriptions of these studies allow identification of patterns in the literature, which could provide insights into general effects of wildfires on the species.

Table 1: Apparent effects of wildfires on spotted owls. See text for additional descriptions of study methods and findings.

Response Metric	Study†	Subspecies	Location*	Apparent Effect**	Notes
Survival	*Bond et al. 2002*	NSO, CSO, MSO	CA, AZ, NM	0	Only one post-fire survey season
	Clark et al. 2011	NSO	OR KLA	-	Likely cumulative effect of timber harvesting, severe fire, and salvage logging
Productivity	Gaines et al. 1997	NSO	E WA CAS	0 (-?)	Apparently no decline but possibly obscured by low reproduction year across population; Possibly lower total reproduction in burned landscapes due to lower pair occupancy; Only one post-fire season
	Bond et al. 2002	NSO, CSO, MSO	CA, AZ, NM	0 (+?)	Slightly higher than in other studies; Only one post-fire season
	Clark 2007	NSO	OR KLA	0 (-?)	Apparently no decline but low statistical power; Possibly lower total reproduction in burned landscapes due to lower pair occupancy
	Roberts 2008	CSO	CA SIERRA		
Site Fidelity	*Bond et al. 2002*	NSO, CSO, MSO	CA, AZ, NM	0	Site fidelity similar to other studies
Occupancy	Elliot 1985	CSO	CA COAST	-	Apparent abandonment by two pairs
	Gaines et al. 1997	NSO	E WA CAS	-	Post-fire occupancy was lowest found during five-year study; Only one post-fire season
	Jenness et al. 2004	MSO	AZ, NM	-	Statistically insignificant effect; Pooled all fire types and severities
	Keane et al. 2011, 2012	CSO	CA SIERRA/CAS	-/0	Extensive high severity fire apparently had a strong negative effect; Extensive low severity fire apparently had a neutral or weak negative effect; Possibly influenced by salvage logging
	Roberts et al. 2011	CSO	CA SIERRA	-	Authors concluded weak effect but pooled all fire types and severities
	Lee et al. 2012	CSO	CA SIERRA	0 (-?)	Similar occupancy at burned vs. unburned; Possibly lower occupancy at severely burned vs. other burned
	Lee et al. 2013	CSO	SO CA	-/0	Similar occupancy at burned vs. unburned; Significant reduction with extensive high severity fire in core area
	Clark et al. 2013	NSO	OR KLA	-	Cumulative effect of timber harvesting, severe fire, and salvage logging
Home Range	Clark 2007	NSO	OR KLA	-	Larger home ranges post-fire
	Bond et al. 2013	CSO	CA SIERRA	0(?)	Similar home range sizes to unburned areas
Roosting	King et al. 1997	NSO	E WA CAS	-	Apparent avoidance of moderate and severe burns
	Bond et al. 2009	NSO	CA SIERRA	-	Significant avoidance of moderate and severe burns during breeding season
Foraging	Clark 2007	NSO	OR KLA	+(?)	Apparent weak selection of moderately burned suitable habitat; Possible weak selection for severely burned suitable habitat; Very low use and availability of both moderately and severely burned suitable habitat
	Bond et al. 2009	NSO	CA SIERRA	+	Significant selection of severe burns
	Eyes 2014	CSO	CA SIERRA		
Roosting and Foraging	Comfort 2013	NSO	OR KLA	-/+ (?)	Preference for small patches of severely burned/salvage logged and avoidance of larger patches; Weak preference for low contrast edges (ecotones) created by fire

†Peer-reviewed publications shown in italics. * Locations: California Klamath (CA KLA); Eastern Washington Cascades (E WA CAS); Oregon Klamath (OR KLA); California, Arizona and New Mexico (CA, AZ, NM); California Central Coast Range (CA COAST); California at margin of northern Sierra Nevada and southern Cascades (CA SIERRA/CAS); California Sierra Nevada (CA SIERRA); southern California San Bernardino and San Jacinto Mountains (SO CA). **Apparent Effect: negative (-), positive (+), neutral (0), varied with fire severity and/or scale (/)—see Notes column and text for further explanations.

Comment [UFS9]: Not statistically, I'd keep the "0" here and delete the "+"

Survival

Wildfires may influence spotted owl survival in both the short- and long-term. For example, spotted owls, like other wildlife, could be injured or killed by smoke during fires (Singer and Schullery 1989, Smith 2000). Due to their poor mobility, young spotted owls with undeveloped flight feathers may be at particular risk of mortality during wildfires (Smith 2000). In addition to potential immediate effects, extensive moderate or severe wildfire might influence spotted owl survival over the longer-term by modifying habitat for roosting, foraging, or prey (see below).

Only two studies are currently available for evaluating effects of wildfires on spotted owl survival rates (Bond et al. 2002, Clark et al. 2011; Table 1). Bond et al. (2002) reported that 18 of 21 (86%) marked spotted owls were resighted one year after wildfires occurred in California, Arizona, and New Mexico. This minimum survival rate was similar to survival estimates found by long-term studies of the three spotted owl subspecies in unburned landscapes (Seamans et al. 1999, Franklin et al. 2000, W.S. LaHaye unpubl. data). Extensive severe fire (36-88%) occurred in four of the eight territories for which fire severity was mapped and the other half primarily burned at low to moderate severity. Thus, even extensive severe fire did not appear to have a large effect on spotted owl survival one year post-fire.

Clark et al. (2011) found evidence of a negative effect of wildfires and/or salvage logging on survival of 23 NSOs in the Oregon Klamath Province. Severe fire and/or post-fire salvage logging occurred in 30% and 41% of suitable NSO habitat in the two study areas. Estimated mean annual survival rates for NSOs located inside fire perimeters (0.69) and apparently

Comment [UFS10]: You should include "in press" results from Tempel et al.

High severity fire had negative effect on survival.

Their results suggest that reductions in the area of high-canopy forest (>70%) resulting from either logging or high-severity wildfire could reduce the viability of California spotted owl populations and may be contributing to ongoing declines in abundance and territory occupancy.

They recommended fuels Rx in dense stands while trying to avoid decreasing canopy too much.

This is good one for short vs long term effects.

Comment [UFS11]: Page 1026 of the paper states this, "Most (6 of 8) territories burned >50% at low to moderate severity."

So, two of the four that had 36-80% were <50%.

Comment [UFS12]: I disagree with this conclusion. Extensive, yes… severe, no.

They concluded that "spotted owls may have the ability to withstand the immediate, short-term (1-year) effects of fire **occurring at primarily low to moderate severities** within their territory.

displaced by fires and post-fire salvage logging (0.66) were lower than in areas just outside the fire perimeters (0.85) and in an unburned reference study area in the neighboring southern Cascades (0.85: Anthony et al. 2006). The degree to which post-fire salvage logging in the study areas influenced NSO survival rates is unknown. The study's occupancy analyses indicated that pre-fire timber harvesting, high severity wildfire~~s~~, and post-fire salvage logging cumulatively impacted NSOs through reductions of suitable nesting/roosting habitat (Clark et al. 2013; see below).

Apparently contradictory findings by Bond et al. (2002) and Clark et al. (2011) may be due to several factors. The most obvious difference between the studies is that the areas studied by Clark et al. (2011) experienced post-fire salvage logging while those studied by Bond et al. (2002) did not. The limited information currently available indicates that salvage logging negatively affects spotted owls (reviewed below). Additionally, the populations studied by Clark et al. (2011) may have been particularly sensitive to habitat loss to wildfires due to intensive pre-fire timber harvesting across a checkerboard ownership. It should also be noted that Bond et al. (2002) only examined wildfire effects one year post-fire. Fire injuries and post-fire outbreaks of insects and pathogens can continue to result in tree mortality for up to several years after a wildfire (Ryan and Amman 1996, Gaines et al. 1997, Hood et al. 2007).

Reproduction

The spotted owl is a relatively long-lived species that exhibits a bet-hedging life history strategy (Noon and Biles 1990, Franklin et al. 2000). This means that individuals often forego breeding

Comment [UFS13]: Based on this, their recommendation was to:
1) Increase protection of older forest in dry forest ecosystems to prevent future habitat loss to timber harvest and
2) Mitigate potential losses of older forest to stand-replacing fire and subsequent salvage logging

I assume that recommendation #1 refers to "nesting/roosting" habitat (a.k.a. older forest)

Comment [UFS14]: I hear and read this a lot. Upon careful reading of Bond et al. (2002), these two papers actually don't contradict each other. Bond et al. (2002) make no conclusion on high-severity wildfire. They only summarized effect (or lack thereof) on low-moderate severity wildfire.

In fact, Clark and Bond actually corroborate on low-moderate wildfire.

Please end this misconception here!

Comment [UFS15]: This is very misleading. I suggest deleting this sentence.

Clark et al. clearly present that high severity wildfire is 1 of 3 causes of loss of NSO N/R habitat.

Bond et al. show no effect from low-mod severity fire.

Comment [UFS16]: One reason why mitigation to reduce future wildfire losses is more important now.

If we had landscapes similar to what they were historically, prior to extensive harvesting, then large wildfires would not be so worrisome.

Comment [UFS17]: Good point. Another potential effect (from anecdotal observations in some of the demographic study areas) could be that sometimes a pair will stick around for a year or two after a wildfire removes extensive amounts of nesting/roosting habitat in their territory. Then eventually, the move on or disappear. We have observed this in a few cases. But again, that was due to high severity, not low-moderate.

Comment [UFS18]: Maybe put years here? It might give some needed context to "short-term" vs "long-term" effects.

during poor environmental conditions in order to maximize their chance of surviving and reproducing in the future. Given the species' life history strategy, spotted owl reproductive rates are likely sensitive to environmental changes, including those brought about by wildfires. However, annual fluctuations in spotted owl reproduction caused by variation in weather, prey populations, or breeding condition could obscure effects of wildfires or other factors on reproduction (e.g., Franklin et al. 2000).

We are aware of four studies that examined potential effects of wildfires on spotted owl reproduction (Gaines et al. 1997, Clark 2007, Bond et al. 2002, Roberts 2008; Table 1). None of these studies found substantive evidence of a wildfire-induced decline in reproduction by the species and one indicated a potentially positive effect. In the eastern Washington Cascades, Gaines et al. (1997) found little difference in productivity (number of young per pair) between burned (0.2; n = 5 or 6/ yr) and unburned sites (0.3; n = 13-17/yr) one year after a predominantly moderate to severe wildfire. However, the post-fire survey season clearly occurred during a poor reproduction year, potentially making it difficult to detect a difference between burned and unburned sites. Clark (2007) found no significant differences in productivity in burned areas in the Oregon Klamath Province (n = 31 territories) and an unburned study area in the neighboring southern Cascades (Anthony et al. 2006). He noted, however, that his study likely lacked the statistical power to detect a difference if one occurred. Bond et al. (2002) found that seven pairs of spotted owls produced an average of 1.0 offspring during a single breeding season following wildfires in California, Arizona, and New Mexico. This was higher than productivity rates found in unburned areas during long-term studies of the three spotted owl subspecies (Seamans et al. 1999, Franklin et al. 2000, W.S. LaHaye unpubl. data). *Add discussion of Roberts (2008)…*

Comment [UFS19]: Not significantly higher, and they cautioned against drawing conclusions from this given high annual variation in reproduction as you state above.

You need to clarify this as it implies that burned areas resulted in higher reproduction. Or delete it and stick to findings that have some statistical backing, otherwise you chance confusing the readers.

Currently available studies suggest that wildfires generally have minimal short-term effects on spotted owl reproduction (Gaines et al. 1997, Clark 2007, Bond et al. 2002) and that primarily low-to-moderate severity fire could positively affect reproduction (Roberts 2008). However, it might be difficult to capture fire effects on spotted owl reproduction (whether positive or negative) during short-term studies, particularly with only a single year of post-fire data (Franklin et al. 2000). In addition, it is possible that solely comparing productivity (e.g., offspring per pair) in burned and unburned areas could obscure a change in total reproduction in burned areas. Studies in Washington and Oregon reported post-fire declines in occupancy by pairs, suggesting that extensive severe fire can reduce reproductive opportunities for spotted owls (Gaines et al. 1997, Clark 2007; see below).

Comment [UFS20]: Apparently no effect.

Comment [UFS21]: Repetitious, already stated

The limited research investigating spotted owl-prey relationships has found positive associations between spotted owl reproduction and abundances or consumption of dusky-footed woodrats (*Neotoma fuscipes*) (White 1996), deer mice (*Peromyscus* spp.) (Ward 2001 cited in Ward and Block 1995, Rosenberg et al. 2003), or a suite of prey with diverse habitat associations (Ward and Block 1995). Abundances of deer mice, pocket gophers (*Thomomys* spp.), and other "pioneer" or "early-successional" prey often increase following fires (Ream 1981, Zwolak and Foresman 2007, Zwolak 2009, Bond et al. 2013). Dusky-footed woodrats appear to initially respond negatively to severe fires (Schwilk and Keeley 1998, Smith 2000) but not to patchy low severity fire, although loss of nest houses might have a brief negative effect on reproduction (Lee and Tietje 2005). However, it is possible that severe fire benefits dusky-footed woodrats over longer time periods (e.g., ≥5-20 yrs) through creation of brushy habitat. Crown fires should

Comment [UFS22]: There's a new paper by Ganey et al. 2014. Relative abundance of small mammals in nest core Areas and burned wintering areas of Mexican spotted Owls in the Sacramento Mountains New Mexico

Species richness and relative abundance of small mammals were greater in the burned wintering areas than in the associated unburned nest core areas

Comment [UFS23]: You jump straight from reproduction to prey… might want to add new section or make connection to reproduction as it also affects other demographic parameters.

negatively affect abundances of prey associated with well-canopied forest, such as northern flying squirrels (*Glaucomys sabrinus*) and tree voles (*Arborimus* spp.). These, along with dusky-footed woodrats, are the primary prey for NSOs in California (reviewed in *Threats: Timber Harvesting*). Low severity fires could also negatively affect northern flying squirrels and other prey associated with closed canopy forests by reducing dead woody materials, fire-intolerant understory plants, and truffles (Lehmkuhl et al. 2006, Meyer et al. 2007). Thus, wildfires likely have complex effects on NSO prey communities, depending on local or regional differences in prey community composition; wildfire size, severity, and configuration; and the length of time vegetation has had to regenerate following fire.

Occupancy

Potential wildfire effects on NSO population rates are most directly evaluated with measures of survival and reproduction. However, occupancy data are often more logistically and economically feasible to collect than are demographic data and could provide an early indication of population trends (MacKenzie 2005, Olson et al. 2005). Spotted owl occupancy is sensitive to environmental factors (Blakesley et al. 2005, Olson et al. 2005) so it is a potentially valuable measure of wildfire effects on the species. Nonetheless, occupancy data must be interpreted carefully since they can be strongly influenced by survey effort, analytical methods, and the presence of barred owls (Olson et al. 2005).

We evaluated nine studies of wildfire effects on spotted owl occupancy (Table 1). As described below and in Table 1, seven of these provided evidence of a negative effect of either severe fire or fire in general.

Two studies indicated potentially negative effects of wildfires on spotted owl occupancy but included few territories (Elliot 1985, Gaines et al. 1997). In Monterey County, California, informal yearly surveys suggested that two pairs of CSOs abandoned their territories for at least four years following a wildfire (Elliot 1985). The author did not describe the fire other than noting that it was extensive and caused substantial damage to understories and oaks in the previously occupied areas. In the eastern Washington Cascades, Gaines et al. (1997) found that two of six NSO sites were occupied one year after a predominantly moderate to severe wildfire. This was the lowest occupancy rate found during the five-year study period.

Two studies found statistically weak evidence of a negative effect of fire on spotted owl occupancy, but their methods may have precluded detection of stronger effects (Jenness et al. 2004, Roberts et al. 2011). Jenness et al. (2004) found a statistically insignificant tendency (p = 0.11) for higher occupancy rank (in ascending order: no owls, singles, pairs, reproductive pairs) in unburned sites than in paired burned sites in Arizona and New Mexico (paired sites were close to each other and had similar habitat and topography). Of the 29 paired-site comparisons, 14 (48%) had a higher occupancy rank in unburned sites, 6 (21%) had a higher rank in burned sites, and 9 (31%) were tied. In the Sierra Nevada of California, Roberts et al. (2011) found lower occupancy rates for CSOs in burned areas than in unburned areas, but the difference was not statistically analyzed (unmodeled occupancy = 0.50 in burned and 0.69 in unburned; modeled

occupancy = 0.46 in burned and 0.72 in unburned). Modeling by both studies indicated that spotted owl occupancy was more strongly influenced by habitat composition or structure than by whether or not fire had recently occurred in territories. However, both studies may have underestimated the impacts of severe fire due to pooling of diverse fire types and severities for analysis (including prescribed fires, wildfires, and wildfires allowed to burn under prescribed conditions).

Two studies found evidence of strong declines in occupancy in areas recently burned by extensive severe wildfire but both may have been confounded by post-fire salvage logging (Keane et al. 2011, 2012, Clark et al. 2013). In southwestern Oregon, Clark et al. (2013) examined how extensive wildfires and subsequent salvage logging affected occupancy dynamics of NSO pairs. In their first analysis, the authors compared pre- and post-fire occupancy dynamics in a burned study area in the Oregon Klamath Province (n = 22) to those in an unburned area in the nearby southern Cascades (Anthony et al. 2006). Combined, high severity fire and salvage logging removed or modified 26% of suitable nesting/roosting habitat in landscapes surrounding NSO activity centers in this area. The burned and salvage-logged study area experienced a 64% reduction in site occupancy during the post-fire period, compared with a 25% reduction in the unburned study area (difference not statistically analyzed). In the second analysis, the authors examined possible effects of severe fire and salvage logging on occupancy dynamics in 40 territories located in three burned study areas in the Oregon Klamath Province. In these areas, 19-26% of suitable habitat was burned at high severity and/or salvage logged. During the study's three-year post-fire period, site extinction probabilities were as high as 72% in two combined study areas and 92% in the third area. Site extinction probabilities in the

Comment [UFS24]: Always state what kind of habitat. Nesting/roosting, foraging, or dispersal?

burned study areas were best explained by a model that included extents of high severity fire, salvage logging, and early seral forest. Models that included these variables separately were not competitive with the model containing all three variables, suggesting that NSO occupancy declined due to cumulative habitat loss from severe fire and pre- and post-fire timber harvesting (see Clark et al. 2013: Table 6). The relative influence of these factors on occupancy is unknown, but the role of severe fire cannot be dismissed. For example, the highest extinction probability (92%) occurred in a study area with little salvage logging (<2%) of previously suitable habitat.

Keane et al. (2011, 2012) estimated occupancy of CSOs in two recently burned study areas near the margin of the Sierra Nevada and southern Cascades of California. One wildfire complex, and an unreported amount of post-fire salvage logging, resulted in an almost complete loss of potentially suitable CSO habitat in the area (70% of the area pre-fire vs. 6% post-fire consisted of mean canopy cover ≥40% and mean DBH ≥11 in). Pre-fire occupancy in this study area was unknown but the Forest Service identified 23 CSO activity centers in the area prior to the fires. Rigorous landscape survey coverage by Keane et al. (2011, 2012) confirmed occupancy in only one territory within the fire perimeter during each of two post-fire years, whereas approximately seven to nine territories were found post-fire in a surrounding one-mile survey buffer. The other area studied by Keane et al. (2011, 2012) primarily burned at low severity (ca. 60% of the area). Pre-fire occupancy was likewise unknown in this area but Forest Service pre-project surveys indicated the presence of about 10 territories. Surveyors confirmed occupancy of six territories in this area during the first and second years post-fire. While the study's findings are

preliminary and may have been influenced by post-fire salvage logging, they suggest that effects of large wildfires on CSOs are dependent on the extent of high severity fire.

Another study provided further evidence that effects of wildfires on spotted owl occupancy depend on the extent and location of high severity fire. Lee et al. (2013) compared occupancy dynamics of CSOs in 71 recently burned sites and 97 unburned sites in the San Bernardino Mountains and San Jacinto Mountains of southern California. An average of 23% of forest within burned "core areas" (500 ac around activity centers) experienced high severity fire (this percent is based on an assumption that the amount of pre-fire forest in burned core areas was the same as that reported for burned and unburned core areas combined). Mean annual probability of occupancy was 0.48 in unburned sites and 0.31 in burned sites. This difference was not statistically significant. However, Lee et al. (2013) did detect a statistically significant negative effect on occupancy when high severity fire burned more than 125 acres of forest within estimated core areas.

Two studies found that wildfires had neutral or positive effects on spotted owl occupancy (Bond et al. 2002, Lee et al. 2012). Bond et al. (2002) calculated site fidelity for spotted owls in 11 territories burned by wildfires in California, Arizona, and New Mexico. The fires burned most of the area within each estimated territory (territory size = ½ the nearest neighbor distance in each study area, based on previous studies). Half of the eight territories for which fire severity was mapped primarily burned at low to moderate severity and the other half experienced extensive severe fire (36-88%). Of 21 color-banded owls in the study, 18 (86%) were resighted the year after the fires and 16 (89%) of these were located in their pre-fire territory. Site fidelity

in this study was comparable to that in long-term studies of the three subspecies in unburned areas (Seamans et al. 1999, Franklin et al. 2000, W.S. LaHaye unpubl. data). In the Sierra Nevada, Lee et al. (2012) compared post-fire occupancy in 41 recently burned and 145 unburned historical CSO territories. An average of 32% of forest in burned territories experienced high severity fire. The authors found no significant association between CSO occupancy and whether or not territories had recently experienced wildfire within a 494-acre circle around activity centers (mean occupancy was 0.76 at unburned sites and 0.80 at burned sites).

The studies reviewed above are not directly comparable due to differences in methods, spotted owl subspecies and populations, fire extents and severities, and the presence or absence of post-fire salvage logging. The preponderance of evidence suggests that spotted owls in fire-prone forests are generally resilient to wildfires (Bond et al. 2002, Jenness et al. 2004, Keane et al. 2011, 2012, Roberts et al. 2011, Lee et al. 2012, 2013). However, wildfires that severely burn large areas of suitable habitat can substantially impact spotted owl occupancy, particularly when it occurs in breeding-season core areas (Elliot 1985, Gaines et al. 1997, Clark et al. 2013, Keane et al. 2011, 2012, Lee et al. 2013). Post-fire salvage logging appears to increase the negative effects of extensive severe fire on spotted owl occupancy; most likely by reducing suitability of burned areas for prey and foraging (Lee et al. 2012, 2013, Clark et al. 2013; reviewed below).

Home Range Size and Habitat Use

Changes in the behavior of individual spotted owls may provide insight into the mechanisms by which wildfires affect populations. For example, post-fire changes in home range size may

reflect fire effects on spotted owl energy budgets through changes in travel distances and prey availability. Changes in energy intake and output could, in turn, influence survival, reproduction, and occupancy of spotted owls. Patterns of habitat use may also be informative. For example, selection or avoidance of burned areas may reflect changes in availability of prey or roosting habitat, which could, in turn, influence occupancy, reproduction, or survival of spotted owls.

To our knowledge, only two studies have evaluated spotted owl home range sizes in relation to wildfires (Clark 2007, Bond et al. 2013; Table 1). Clark (2007) found that annual home range sizes of NSOs inside two fire perimeters in the Oregon Klamath Province were larger after wildfires than before them (n = 14 owls pre-fire and 20 post-fire). He attributed this difference to owls expanding their home ranges in response to habitat fragmentation caused by severe fire and post-fire salvage logging. This hypothesis was supported by other research in the region, which found that NSOs had larger home ranges in fragmented forests than in areas with larger, more intact patches of habitat (Carey et al. 1992, Schilling et al. 2013). Another study in the region suggested that the energetic cost of increased travel in fragmented forest was greater than the energetic benefit of increased access to prey associated with early-successional habitats (Carey and Peeler 1995).

Bond et al. (2013) compared the breeding season home ranges of seven CSOs (from four territories) during a single post-fire year in the Sierra Nevada of California with those in other studies during the same year in other parts of the subspecies range (D. Call, T. Munton, and G. Zimmerman unpubl. data). An average of 23% of forest burned at moderate severity and 9% at

high severity within a 1.2 mile radius of the four nests. Pre-fire home range sizes were unknown but CSOs in the four territories did not appear to have unusually large home ranges following predominantly low to moderate severity wildfire.

Five studies have described patterns of habitat use by spotted owls in burned areas (King et al. 1997, Clark 2007, Bond et al. 2009, Comfort 2013, Eyes 2014; Table 1). King et al. (1997; also Bevis et al. 1997) described initial effects of wildfires on NSOs in two territories in the eastern Washington Cascades. One territory primarily experienced low to moderate severity fire and the other mostly burned at high severity. Both territories experienced an unreported amount of salvage logging in unsuitable or severely burned habitat. Most NSO locations (84% and 89%) in the two territories were daytime roosts. In the territory primarily burned at low to moderate severity, 80% of the pair's post-fire locations were in unburned habitat, 16% were in low severity burns, and 4% were in moderate severity burns. The pair did not appear to roost in severely burned areas. The second territory studied by King et al. (1997) was occupied by a single male. After the fire, the male shifted his activity to an unburned area two to three miles away but continued to occasionally use areas near his former activity center. Of those locations, 74% were in unburned habitat, 17% were in low severity burns, 5% were in moderate severity burns, and 4% were in high severity burns. Maps of burn severity classes and NSO locations indicate that owls in these two territories strongly selected unburned areas for roosting.

Clark (2007) evaluated habitat selection by 12 NSOs (7 territories) inside a wildfire perimeter in the Oregon Klamath Province. NSO locations were primarily nocturnal and may therefore, have largely represented foraging activity. Individuals in this area used all habitat classes, including

moderate and severe burns and areas that had been salvage logged. However, when the data from individuals were pooled for analysis, the owls exhibited a strong preference for nesting-roosting habitat that was unburned or burned at low severity (unburned and low severity were combined into a single class). NSOs in the study also selectively used moderately burned, previously-suitable habitat; although both use and availability of this habitat class were low compared with unburned or lightly burned habitat. Owls' use of burned areas was concentrated closer to activity centers, which was expected, given that spotted owls are central place foragers during the breeding season (Rosenberg and McKelvey 1999).

In the Sierra Nevada, California, Bond et al. (2009) described the habitat associations of seven CSOs from four territories during a single post-fire season. Of the four nests found during the study, one was approximately 0.3 mile outside the fire perimeter, one was in forest burned at low severity, and two were in forest burned at moderate severity. One of the two nest trees found in a moderate severity burn was apparently killed by the fire and one produced the only fledgling detected during the study. It is unclear from the paper whether these events occurred at the same nest or different nests. The four pairs roosted in all burn severity classes but exhibited statistically significant selection of low severity burns and avoidance of moderate and high severity burns. Only one of 60 roost sites was located in a high severity burn. Burned roost sites generally resembled unburned roost sites (>60% canopy cover and large-diameter trees). Bond et al. (2009) also evaluated CSO selection of foraging habitat in the area. Probability of use for foraging was highest when sites were burned and within 0.6 mile of nests or roosts. Probability of use was also positively associated with presence of edge between burn severity classes. Five of the owls foraged in high severity burns within 0.9 mile of nests or roosts more often than in

other burn severity classes. Bond et al. (2009) suggested that CSOs in these four territories selectively foraged in high severity burns in order to access abundant prey in those areas. This hypothesis was supported by their finding that high severity burns had the highest herb and shrub cover and highest basal area of snags of any burn severity class, including unburned. These features are key resources for spotted owl prey communities (Carraway and Verts 1991, Carey et al. 1999, Holloway and Smith 2011).

Comfort (2013) evaluated habitat selection (roost and foraging locations combined) by 23 NSOs in a burned area in the Oregon Klamath Province. Her best performing model for explaining habitat selection included habitat suitability, disturbance severity, high contrast edge, and low contrast edge. Habitat selection varied with spatial scale but NSOs exhibited a strong preference for higher habitat suitability and avoidance of higher severity disturbance (high severity fire and/or salvage logging). NSOs showed a preference for high contrast edge at small spatial scales (2-8 ac) and avoidance at medium and large scales (32-2,049 ac). NSOs also exhibited a weak preference for low contrast edge. Comfort (2013) concluded that patchy, mixed severity fire (small patches of high severity fire within a matrix of unburned and low-to-moderate severity fire) created conditions favored by NSOs in her study, whereas large patches created by high severity fire and salvage logging were strongly avoided. Salvage logging apparently contributed to conditions avoided by NSOs by structurally homogenizing burned areas, which increased the sizes of high severity patches and amounts of high contrast edge. However, the relative influence of high severity fire and salvage logging on habitat selection by NSOs in this study is unknown.

Add discussion of Eyes (2014) (selection of low severity burned edges and proportional use of high severity burned edges)…

The limited available information concerning spotted owl habitat use following wildfires indicates that the species avoids roosting in moderate and high severity burns (King et al. 1997, Clark 2007, Bond et al. 2009). This finding is concordant with the spotted owl's close association with densely-canopied older forest for roosting (Blakesley 2004). Little is known about the effects of wildfire on selection of nest sites. Bond et al. (2009) found three CSO nests in forest recently burned at low and moderate severity, and young fledged from one nest in a moderate severity burn. Moderate severity fire killed one of the four CSO nest trees in their study. We are unaware of any reports of spotted owls nesting in severely burned areas. Based on the species' nesting habitat requirements (Blakesley 2004), long-term use of severely burned areas for nesting is likely uncommon. Two studies specifically examined selection of foraging habitat by spotted owls *(adding Eyes 2014 will make three studies)*. Both found use of all burn severity classes, but Clark (2007) found a preference for foraging in unburned to moderately burned older forest while Bond et al. (2009) found a preference for severe burns. It is unclear if this difference was due to differences in the studies' methods, spotted owl diets, or effects of fire and timber harvesting (including post-fire salvage logging) on vegetation. Comfort's (2013) research suggested that NSOs respond positively to the presence of severe burns when they occur in small patches within a matrix of unburned or low-to-moderate severity burns. However, she combined roost and foraging locations in her analysis, which might have obscured differences in NSO use of burn severity classes for different functions. Furthermore, hers and Clark's (2007) studies were confounded by post-fire salvage logging, which appears to negatively affect spotted

owls (reviewed below). *Discussion of use of fire-created edges in Comfort 2013 and Eyes 2014…*

Salvage Logging

While salvage logging might be judiciously used to meet certain conservation objectives (e.g., generating downed wood to minimize erosion or create wildlife habitat), it is generally conducted to meet financial goals or remove hazard trees (Peterson et al. 2009). Intensive or poorly planned salvage logging can have a variety of negative effects on ecosystems, such as soil compaction, increased erosion, and impacts on insectivorous and cavity-nesting and -denning animals (reviewed in McIver and Starr 2000, Noss et al. 2006, Peterson et al. 2009).

Comment [UFS25]: Economic?

We know of three studies that have directly evaluated effects of post-fire salvage logging on spotted owls (Clark 2007 and Clark et al. 2013, Lee et al. 2012, 2013). Clark (2007) conducted a radio-telemetry study in areas recently burned by wildfires in the Oregon Klamath Province. He recorded limited use of salvage logged areas; presumably for foraging since locations were primarily nocturnal. Use of salvage logged areas was slightly lower than expected based on its abundance in territories (not statistically analyzed), indicating weak avoidance of salvage logged areas by NSOs. However, avoidance might have been stronger since some of the study's telemetry locations were potentially recorded prior to the occurrence of salvage logging. Most (60%) NSO locations in salvage logged areas occurred in riparian buffers, thinned areas, and patches of wildlife leave trees, rather than intensively salvaged areas. During the same study, Clark et al. (2013) found that post-wildfire declines in NSO occupancy were best explained by a

model that included extents of pre-fire timber harvesting, severe fire, and post-fire salvage logging. Models that included these factors separately were not competitive with this model, indicating that severe fire and pre- and post-fire harvesting collectively contributed to declines in NSO occupancy; most likely through cumulative habitat loss or degradation.

In the Sierra Nevada, Lee et al. (2012) recorded occupancy for eight CSO territories that experienced wildfire and post-fire salvage logging. Seven of the territories were occupied during the two-year period between the occurrence of wildfire and salvage logging, whereas none of the territories were occupied following salvage logging.

Lee et al. (2013) evaluated effects of salvage logging on CSOs in the San Bernardino and San Jacinto Mountains of Southern California. They noted that salvage logging in their study area was modest compared with commercial salvage logging typically employed in the Pacific Northwest and Sierra Nevada (salvage logging in their study area mostly consisted of firewood cutting on private in-holdings and hazard tree removal along Forest Service roads). Lee et al. (2013) did not find a statistically significant effect of post-fire salvage logging on CSO occupancy dynamics. However, site extinction probability was slightly higher, and mean annual probability of occupancy was slightly lower, in salvage logged areas than in other burned areas. Weak negative effects of light salvage logging were evident during all eight post-fire study years.

The limited available evidence suggests that salvage logging decreases the probability that spotted owls will use burned areas (Comfort 2013) and increases the probability that they will

abandon their territories following wildfires (Clark 2007, Lee et al. 2012, 2013, Clark et al. 2013). This likely occurs because salvage logging reduces suitability of burned areas for foraging spotted owls and their prey. Stands recently burned by moderate or severe fire often contain high biodiversity due to the presence of both early-successional conditions and key biological legacies in the form of snags, logs, and live trees (Noss et al. 2006). Due to fire suppression and salvage logging, stands with these conditions are currently rare in many fire-prone forests within the spotted owl's range (Noss et al. 2006). Selective use of moderate or high severity burns for foraging is likely due to spotted owls exploiting short-term increases in prey associated with both early-successional vegetation (e.g., shrubs) and legacy habitat elements (e.g., large diameter snags, logs, and live trees) (Ream 1981, Zwolak 2009, Bond et al. 2013). Salvage logging removes legacy elements, while associated use of herbicides reduces shrubs and grasses important to many prey species (Bond et al. 2013, Comfort 2013). In the longer-term, spotted owls can continue to benefit from the contributions of legacy habitat elements to regenerating stands. For example, large legacy snags, trees, and logs can provide valuable habitat elements for northern flying squirrels and other prey (Holloway and Smith 2011). Removal of these elements through salvage logging could therefore reduce the value of subsequent regenerating stands as prey habitat. Harvesting of legacy snags and live trees could also directly affect spotted owls by reducing availability of foraging perches in the short-term and suitable nest trees during later successional stages. Large-scale salvage logging could also reduce NSOs' use of burned areas by extensively replacing low contrast (diffuse) edges with less favorable high contrast (hard) edges (Comfort 2013).

Summary

Inferences from studies of direct effects of wildfires and salvage logging on spotted owls are limited due to inclusion of only a small number of spotted owls or territories. Nonetheless, more information is available concerning this topic than is generally acknowledged. The preponderance of currently available evidence indicates that spotted owls are often resilient to wildfires but can be strongly impacted by extensive severe fire. Following wildfire, many spotted owls may remain in their territories, exploit short-term increases in prey in burned areas, and continue to reproduce at reasonably high rates. However, wildfires that result in substantial loss or fragmentation of suitable habitat, particularly within breeding core areas, can cause spotted owls to increase their home range sizes, abandon their territories, and possibly, emigrate from burned landscapes or die of starvation or disease. Negative effects of severe fire appear to be greatest when suitable habitat is already limited (e.g., due to widespread intensive timber harvesting) and when post-fire salvage logging reduces suitability of burned areas for foraging and prey.

Comment [UFS26]: Seems to contradict previous sentence. Is the unacknowledged info in this paper? Suggest deleting this sentence.

Wildfire Effects on Recent Habitat Trends

Past and continuing habitat loss was a primary reason for listing the NSO under the federal Endangered Species Act (USFWS 1990). At the time of listing, the Fish and Wildlife Service estimated that 60-88% of the subspecies' habitat had already been lost (USFWS 1990; also see *Threats: Timber Harvesting*). They attributed most of this loss to widespread intensive timber harvesting. Since listing of the NSO and subsequent adoption of the Northwest Forest Plan,

timber harvesting has declined and wildfire has been identified as the primary source of forest disturbance and habitat loss on federal lands (Courtney et al. 2004, Healey et al. 2008, USFWS 2011, Kennedy et al. 2012). Nonetheless, timber harvesting continues to be the primary source of habitat loss on non-federal lands (Healey et al. 2008, Davis and Dugger 2011, Moeur et al. 2011, Kennedy et al. 2012).

Comment [UFS27]: This and Kennedy focused on LSOG. Not all late-successional/old-growth forest is NSO habitat (e.g., ponderosa pine, subalpine forests, etc.)

You should put in Lint 2005 and Davis et al. 2011 as they focused on NSO habitat status and trends.

Comment [UFS28]: Or include "older forests and" before "habitat loss".

Estimates of recent trends in amounts of NSO habitat, and of older forest in general, have been produced as part of monitoring efforts for the Northwest Forest Plan; and are therefore, largely restricted to the Plan's area and time span (Davis and Lint 2005, Moeur et al. 2005, 2011, Healey et al. 2008, Davis and Dugger 2011). We focus on estimates by Davis and Dugger (2011) because they replaced those of Davis and Lint (2005) and are more specific to NSO habitat than those of Moeur et al. (2005, 2011) and Healey et al. (2008). We do not review habitat trend estimates based on federal ESA Section 7 consultation records (Bigley and Franklin 2004, USFWS 2012) due to greater scientific uncertainty and methodological bias associated with those data (see Bigley and Franklin 2004). Trends described by Bigley and Franklin (2004), Moeur et al. (2005, 2011), Healey et al. (2008), and the US Fish and Wildlife Service (2012) quantitatively differ from those of Davis and Dugger (2011) but similarly indicate that wildfires have been the primary source of recent habitat loss on federal lands.

Comment [UFS29]: Like this is stated

Comment [UFS30]: Good! Finally, this is clarified. Thank you.

Davis and Dugger (2011) used remotely sensed (satellite imagery) vegetation data to model changes in habitat suitability across the NSO's range during the first 15 years of the Northwest Forest Plan (1994-2007 in California and 1996-2006 in Oregon and Washington). Habitat suitability was based on characteristics surrounding thousands of NSO pair locations across the

Plan area. Suitable breeding habitat was defined as having both a probability of owl presence greater than expected based on random chance and environmental conditions typical of those found around nesting and roosting pairs. Estimated habitat trends included gross loss of both suitable breeding habitat and "core" suitable breeding habitat (>330 ft from edge). Davis and Dugger (2011) considered habitat loss to have occurred when an area classified as suitable at the beginning of Northwest Forest Plan was later downgraded to a lower suitability rank (unsuitable or marginal) due to vegetation changes caused by forest disturbances. Davis and Dugger (2011) did not estimate recruitment of, or net changes in, breeding habitat because their remotely sensed data was incapable of accurately capturing relatively slow and subtle habitat changes during development of intermediate-aged and older stands. They did, however, estimate net trends in NSO dispersal habitat, which they defined as forest with a mean ~~canopy~~conifer cover of at least 40% and a mean conifer DBH of at least 11 inches. Recruitment of dispersal habitat was more detectable than that of breeding habitat due to more rapid and measurable growth in younger forest (some recruitment also occurred due to degradation of suitable breeding habitat by forest disturbances).

Comment [UFS31]: Nesting/roosting

Estimated gross losses of suitable breeding habitat on federal and non-federal lands are presented in Tables 2 and 3, respectively. During the first 15 years of the Northwest Forest Plan, wildfires were responsible for an estimated gross loss of 236,700 acres (2.7%) of suitable breeding habitat on federal lands rangewide and 13,100 acres (0.3%) on non-federal lands (1.9% combined). In California, wildfires removed an estimated 75,500 acres (4.1%) of suitable breeding habitat on federal lands and 5,600 acres (0.4%) on non-federal lands (2.4% combined). Approximately 70% of habitat loss to wildfire on federal lands occurred within the Oregon and California

Klamath Provinces (Table 2). Most of this habitat loss was caused by the 1999 Megram Fire and 2002 Biscuit Fire (Table 4). Fires in the Eastern Cascades Provinces of Washington, Oregon, and California contributed less to total habitat loss than did fires in the Klamath, but were often more destructive in terms of proportion of suitable habitat lost within individual fire perimeters. In contrast with federal lands, wildfires were responsible for very little habitat loss on non-federal lands; rather, timber harvesting accounted for most losses in these areas (Figure 1).

Table 2: Estimated gross losses of suitable NSO breeding habitat on federal lands due to wildfires during 1994-2007 in California and 1996-2006 in Oregon and Washington (adapted from Davis and Dugger 2011, USFWS 2011).

State	Province	Initial Acres	Acres Lost	Percent Lost
California	CA Cascades	213,200	1,800	0.8%
	CA Klamath	1,489,800	71,600	4.8%
	CA Coast	145,400	2,100	1.4%
Oregon	OR Coast Range	611,200	0	0.0%
	Western OR Cascades	2,258,700	28,900	1.3%
	Eastern OR Cascades	402,900	17,800	4.4%
	Willamette Valley	3,400	0	0.0%
	OR Klamath	985,000	93,600	9.5%
Washington	Olympic Peninsula	763,100	200	0.0%
	Eastern WA Cascades	673,600	20,000	3.0%
	Western WA Cascades	1,283,000	700	0.1%
	Western WA Lowlands	24,700	0	0.0%
Rangewide Total		8,854,000	236,700	2.7%

Comment [UFS32]: Initial assumption at implementation of the NWFP was that about 2.5% per decade would be lost to wildfire. We are seeing this exceeded in some provinces, but the reserve network was designed to be large enough to function with losses from large wildfires.

There was not "trigger" to review this in the NWFP but the large amounts lost in some areas is concerning. Most if this loss is also occurring in the reserved land use allocations. This may be a focus of future review after the 20yr monitoring reports are finished (2015).

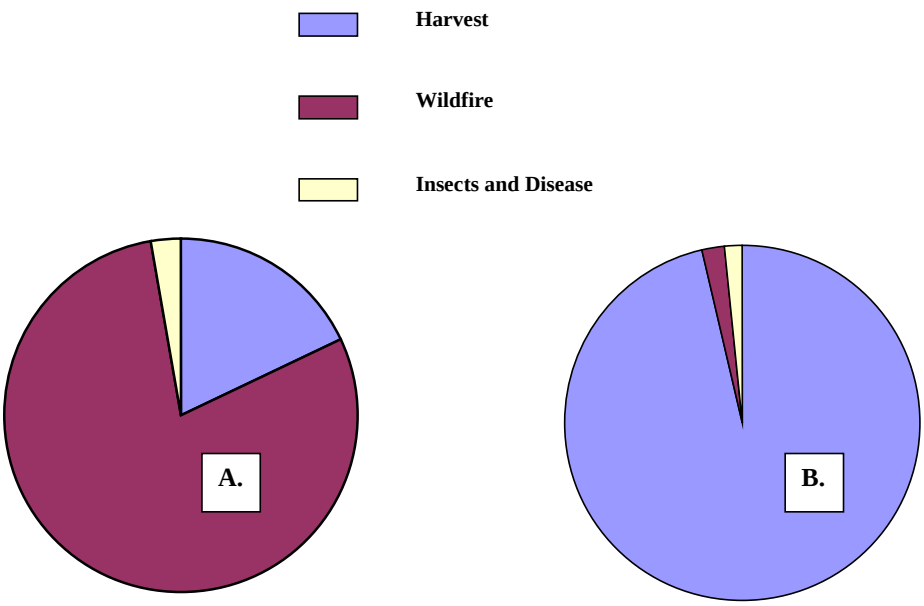
Table 3: Estimated gross losses of suitable NSO breeding habitat on non-federal lands due to wildfires during 1994-2007 in California and 1996-2006 in Oregon and Washington (adapted from Davis and Dugger 2011, USFWS 2011).

State	Initial Acres	Acres Lost	Percent Lost
California	1,556,700	5,600	0.4%
Oregon	1,382,400	5,100	0.4%
Washington	1,258,900	2,400	0.2%
Total	4,198,000	13,100	0.3%

Table 4: Estimated gross losses of suitable NSO breeding habitat to individual wildfires during 1994-2007 (note: "habitat degraded" describes areas downgraded from highly suitable to suitable; from Davis and Dugger 2011).

Fire name	Year	Broad physiographic province	Habitat in wildfire perimeter	Habitat lost		Habitat degraded	
			Acres	*Acres*	*%*	*Acres*	*%*
Biscuit Fire	2002	Klamath Mountains	226,230	93,730	41	12,019	5
Megram Fire	1999	Klamath Mountains	76,337	27,520	36	4,589	6
B&B Complex	2003	East Cascades	26,269	16,403	62	907	3
Bake-oven Fire	2006	Klamath Mountains	23,946	8,873	37	581	2
Boulder Fire	2002	West Cascades	34,059	8,460	25	2,074	6
Davis Fire	2003	East Cascades	8,050	6,943	86	5	0
Pigeon Fire	2006	Klamath Mountains	13,896	5,634	41	327	2
Rex Complex	2001	East Cascades	8,548	4,750	56	278	3
Timbered Rock	2002	West Cascades	10,216	4,539	44	569	6
Spring Fire	1996	West Cascades	13,504	3,931	29	858	6
Deep Harbor Fire	2004	East Cascades	5,761	3,930	68	64	1
Hancock Fire	2006	Klamath Mountains	12,712	3,132	25	336	3
Apple Fire 2	2002	West Cascades	12,227	2,810	23	928	8
Fischer Fire	2004	East Cascades	4,479	2,340	52	34	1
Fork Fire	1996	Klamath Mountains	2,962	2,113	71	14	0
Needles Fire	2003	East Cascades	1,946	874	45	1	0
Trough Fire	2001	Klamath Mountains	1,851	798	43	4	0
Hunter Fire	2006	Klamath Mountains	2,236	789	35	40	2
Deer Point Fire	2002	East Cascades	505	380	75	0	0
Tatoosh Complex	2006	East Cascades	666	378	57	0	0

Figure 1: Proportions of suitable breeding habitat loss attributed to harvesting, wildfire, and insects and diseases on (A) federal lands and (B) non-federal lands during 1994-2007 (adapted from Davis and Dugger 2011 and USFWS 2011).

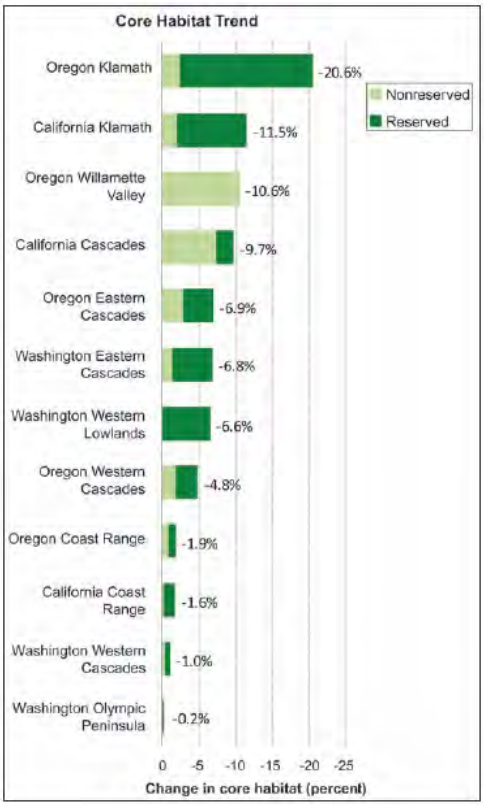


Davis and Dugger (2011) reported substantial losses of core breeding habitat on federal lands during the first 15 years of the Northwest Forest Plan (Figure 2). These losses primarily occurred in reserved areas. Changes in ratios of core and edge habitat classes indicated that increased fragmentation of suitable breeding habitat on federal lands was greatest in the Oregon and California Klamath Provinces and California Cascades Province (see Table 3-3 in Davis and Dugger 2011). Increased fragmentation in these regions was primarily due to wildfires.

Comment [UFS33]: Should define this as there are numerous uses of the term "core" in the literature.

Describe how it differs from the other habitat (e.g., nesting./roosting). Make it clear that the previous numbers above relate to N/R and not "core".

Figure 2: Gross losses of "core" suitable breeding habitat on reserved and non-reserved federal lands during 1994-2007 in California and 1996-2006 in Oregon and Washington (from Davis and Dugger 2011).



Davis and Dugger (2011) estimated a 5.2% net gain in NSO dispersal habitat. Much of this gain was due to succession in young forests in non-reserved lands at the margins of federal forests. However, accounting for forest connectivity and NSO dispersal distances, Davis and Dugger (2011) reported a 1% net loss of "dispersal-capable landscape". Much of the loss of dispersal-capable landscape in the Klamath and Eastern Cascades Provinces was due to large wildfires, whereas timber harvesting on non-federal lands was responsible for much of the loss in other regions.

Loss and fragmentation of breeding habitat to wildfires was likely at least partially offset by recruitment of new habitat through succession of mature and old forest. However, Davis and Dugger (2011) found that detectable recruitment of breeding habitat primarily occurred in the marginal suitability class. This finding was supported by Moeur et al. (2005), who found that about 90% of recruitment of older forest (mature and old-growth combined) during the first 10 years of the Northwest Forest Plan was at the lower end of the class' diameter range (i.e., mean DBH 20-30 in). In fact, Moeur et al. (2011) noted that given the short length of the monitoring period (10-14 yrs), recruitment was "likely due to incremental stand growth over the 20-in diameter threshold, or from understory disturbances that removed smaller diameter trees and raised the average stand diameter above the threshold, rather than from an increase in forests of much larger and older trees." It is likely that some newly recruited mature forest provides suitable habitat for NSOs but much if it could lack the canopy layering, large diameter snags and logs, and other structural attributes typical of nesting and roosting habitat (Blakesley et al. 2004).

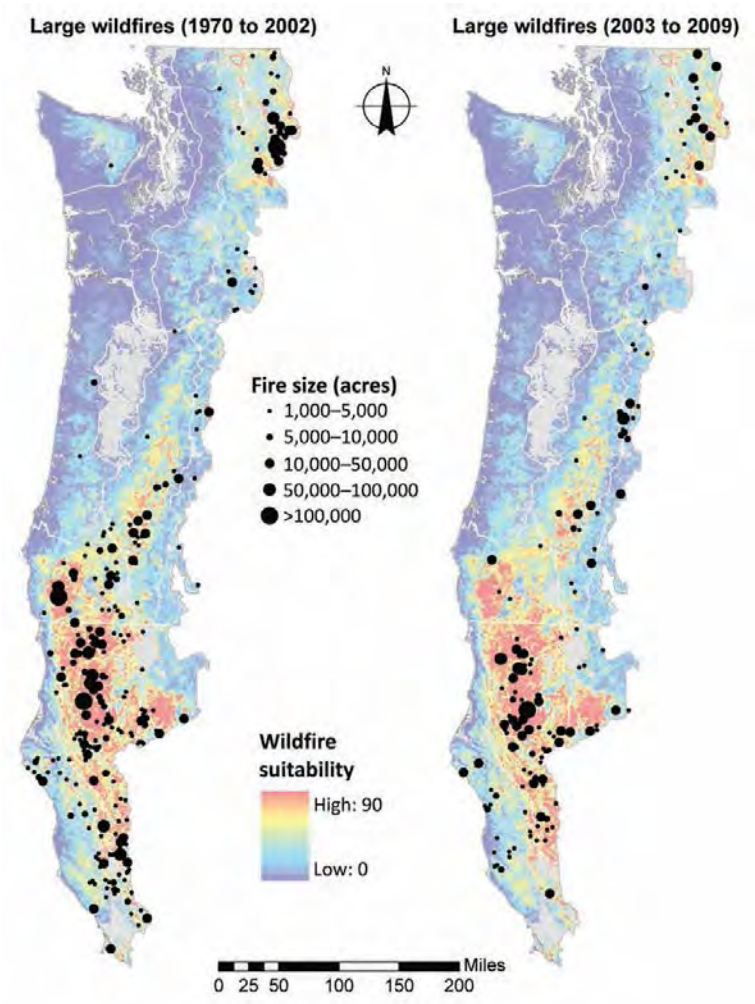
Loss and fragmentation of suitable breeding habitat does not necessarily equate to negative impacts on NSOs (Franklin and Gutiérrez 2002; e.g., Bond et al. 2002, 2009, Lee et al. 2012). Studies in southern Oregon and northern California found that the presence and fitness of NSOs are generally highest in landscapes with a mix of both large amounts of suitable breeding habitat and other habitat classes, such as foraging habitat or "non-habitat" (Franklin et al. 2000, Zabel et al. 2003, Olson et al. 2004, Dugger et al. 2005; reviewed above and in *Threats: Timber Harvesting*). Fitness is also generally highest when suitable breeding habitat occurs in large or clustered patches with large amounts of ecotone or edge between vegetation classes (Franklin et al. 2000, Dugger et al. 2005). This combination of conditions is important because it provides NSOs with a balance of resources needed for both survival and reproduction (Franklin et al. 2000). Active fire regimes in dry forests within the NSO's range in California (e.g., mixed-conifer and interior mixed-evergreen) historically contributed to these conditions by generally sparing older forest and maintaining some form of habitat heterogeneity at both stand and landscape scales (Sugihara et al. 2006). Some contemporary wildfires may still burn in this manner and thereby continue to perform an important ecosystem function in these forests. However, large severe wildfires have contributed, along with fire suppression and timber harvesting, to homogenization of some forests in interior northern California (Skinner et al. 2006). Thus, large severe fires may impact NSOs in California through loss of habitat heterogeneity, as well as reduced amounts and connectivity of suitable breeding habitat.

Fire Risk in California

Prior to Euro-American settlement, dry forests in the western U.S. generally experienced relatively frequent, low-to-moderate or mixed severity fire regimes (Agee 1993, Sugihara et al. 2006, Van de Water and Safford 2011). Mean pre-settlement fire return intervals in California were 11 years in yellow pine forests (e.g., *Pinus ponderosa*, *P. jeffreyi*), 11-16 years in mixed-conifer forests, and 29 years in mixed-evergreen forests (Van de Water and Safford 2011). Mean fire return intervals in redwood forests south of Del Norte County were also relatively frequent (6-44 yrs: Stuart and Stephens 2006). Frequent fire during the pre-settlement period generally maintained forests with less dense and more clumped tree distributions, higher proportions of fire-resistant trees (i.e., larger size classes and more fire-tolerant species), and lighter and less continuous fuel beds than occur today (Sugihara et al. 2006). In northern California, this characteristic fine-scale structural heterogeneity was often overlaid with coarser variability created by effects of elevation, terrain, soils, and other physiographic factors on fire and vegetation patterns (Skinner and Taylor 2006, Skinner et al. 2006, Sawyer 2007). For example, in areas of deeply incised terrain in the Klamath Mountains and southern Cascades of California, upper slopes and south and west facing aspects typically experienced more frequent and severe fire than did other areas (Skinner and Taylor 2006, Skinner et al. 2006). Due to fire suppression, early-successional vegetation communities formerly maintained by frequent, small-scale severe fire have greatly declined in some areas of California (Skinner 1995, Nagel and Taylor 2005). Overall, research indicates that fire suppression and other human activities have led to decreased forest heterogeneity at both stand and landscape scales and have contributed to substantial changes in fire regimes in California's dry forests (Sugihara et al. 2006).

Due to fire suppression, fire-free periods have dramatically increased in California's interior forests (Sugihara et al. 2006). For example, fire rotation near Hayfork in the Klamath Mountains increased more than 10-fold (from 19 to 238 yrs) during the post-settlement period (Taylor and Skinner 2003). Abnormally long fire-free periods have facilitated increased accumulation and continuity of fuels in dry, fire-prone forests (Sugihara et al. 2006). When wildfires do occur there is often an increased risk of them becoming very large and for suppression forces to be overwhelmed by their size and number (e.g., CAL FIRE 2008). As in other dry forests across the western U.S., the mean and maximum sizes of wildfires, and the total annual area burned, significantly increased in California's dry montane forests during the 20th and early 21st Centuries (Miller et al. 2009, 2012). CAL FIRE (2008) noted that more than half of the 26 largest fires recorded in California during 1932-2008 occurred during the last eight years of that period. Based on recent (1970-2002) fire behavior, most of northern California's interior can be classified as highly prone to large (>1,000 ac) wildfires (Davis et al. 2011; Figure 3).

Figure 3: Relative probability of large (>1,000 ac) wildfires ("wildfire suitability") across the NSO's range (from Davis et al. 2011). Modeling was based on landscape and climatic characteristics of locations at which large wildfires occurred during 1970-2002 (left) and was compared with subsequent (2003-2009) locations (right).



Studies of recent trends in extents of high severity fire in California have found conflicting results. For example, Miller et al. (2009) and Miller and Safford (2012) reported a substantial increase in the extent of high severity fire in the Sierra Nevada and southern Cascades of California during 1984-2010; while Hanson and Odion (2014) did not find an increase in the Sierra Nevada during the same period. Similarly conflicting results have been found for the California Klamath Province. Hanson et al. (2009) found a significant increase in high severity fire in the California and Oregon Klamath Provinces during 1984-2005; whereas Miller et al. (2012) did not find an increase in the California Klamath Province during a similar period (1987-2008). Scientific debate ensued regarding the appropriateness of methods used in various studies to determine trends in high severity fire (e.g., Hanson et al. 2009, 2010 vs. Spies et al. 2010).

Differences in findings regarding trends in high severity fire are related to variation in studies' temporal and spatial scales of analysis, as well as in methods for determining fire severity (Courtney et al. 2008, Miller et al. 2012, Hanson and Odion 2014). For example, Miller et al. (2012) noted that both their own study and those of Odion et al. (2004, 2010) may have underestimated trends in high severity fire in the California Klamath Province due to inclusion of unusual fire years. Studies by Odion et al. (2004, 2010) were based on fire effects during a single year (1987), which Miller et al. (2012) described as unusual. Large areas burned at below-average severity during 1987 due to abnormally strong inversions, and the fact that some of the fires burned well into fall (when conditions often favor lower severity fire). Miller et al. (2012) also noted that their own ability to detect a trend in fire severity could have been compromised by inclusion of both this year and 2008, which likewise experienced unusually large, low severity fires. Differences in the area analyzed could also affect evaluations of trends

in high severity fire. For example, the Biscuit Fire, which was predominantly located in Oregon, included extensive areas of high severity fire and therefore could have influenced results of trends analyses for the Oregon and California Klamath Provinces combined versus the California Klamath alone (Miller et al. 2012).

Regardless of whether or not the extent of high severity fire increased in California during the last two decades, large severe fires have recently occurred in these areas, and they were responsible for most loss, degradation, and fragmentation of suitable breeding habitat for NSOs on federal lands (Davis and Dugger 2011, Davis et al. 2011; see above). These data cannot be used to project how fires in the future will affect NSOs since they do not necessarily represent past or future fire conditions or effects. However, it is highly unlikely that wildfires will cease to be a major source of habitat loss for NSOs in the future. Rather, climate change research has generally projected a continued increase in the number and sizes of wildfires and the annual area burned during coming decades (Westerling et al. 2006, Lenihan et al. 2008, Westerling and Bryant 2008, Littell et al. 2009). There is scientific uncertainty regarding recent and future trends in the extent of high severity fire in California. Nonetheless, large severe fires will at least occasionally occur in the future and will continue to be a source of habitat loss and modification for NSOs in the state.

Increases in the number and sizes of wildfires, and effects of fires on NSO habitat, have led to calls for widespread use of thinning and other forms of active management in dry, fire-prone forests (USFWS 2008, 2011, 2012a, Franklin and Johnson 2012). Some researchers and stakeholders, however, have expressed doubts regarding estimates of fire risk and effects on

Comment [UFS34]: The trend in large wildfires has increased, and seems to be continuing (Happy Camp, July Complex…etc). With increased area burned, you get increased area burned in high severity.

Comment [UFS35]: Moritz et al. 2012, Stavros et al. 2014, Dennison et al. 2013

Comment [UFS36]: Perhaps it would be informative to include what was originally planned in the NWFP? The way this reads, and in general, the perception is that this is something newly proposed in response to recent large wildfires.

The NWFP (1994) actually called for widespread thinning in the fire prone portions of the owl's range to reduce risks of stand-replacing wildfires. And this was not just for NSO, it also focused on other late-successional species.

In fact, the agencies developed a specific Land Use Allocation called the "Managed Late Successional Area". Managed Late-Successional Areas are similar to Late- Successional Reserves (LSR) but were identified for certain owl locations in the drier provinces where regular and frequent fire is a natural part of the ecosystem. Certain silvicultural 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.

Even in regular LSRs in the Eastern Cascades or Klamath Provinces, silviculture aimed at reducing the risk of stand-replacing fires may be appropriate. Treatments may include thinning and underburning. Such activities in older stands in westside provinces may be warranted when levels of fire risk are high. (Record of Decision, B-7 to B-8).

Many of these treatments may reduce the quality of habitat for late-successional organisms. Thus, managers need to seek a balanced approach that reduces risk of fire while protecting large areas of fire-prone late-successional forest (B-8).

NSOs, concerns about potential effects of thinning on NSOs, and distrust of federal agency intentions (Hanson et al. 2009, Heiken 2010, DellaSala et al. 2013). As discussed in *Threats: Timber Harvesting* (also Hansen and Mazurek 2010, USFWS 2011), there is currently little known about the effects of forest thinning on spotted owls but the preponderance of evidence indicates that commercial thinning can have negative short-term effects on the species. Federal agencies should carefully consider this information when formulating land management policies and prescriptions aimed at reducing wildfire risk. Land managers should also consider greater use of prescribed fire and allowing wildfires to burn under favorable conditions; particularly at lower elevations in the California Klamath Province, where summertime inversions often minimize fire severity (Miller et al. 2012).

Comment [UFS37]: But how is this balanced with potential long-term beneficial effects? This is what needs to be determined in my opinion.

Again, from NWFP ROD - Many of these treatments may reduce the quality of habitat for late-successional organisms. Thus, managers need to seek a balanced approach that reduces risk of fire while protecting large areas of fire-prone late-successional forest (B-8).

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Wildfire and Salvage Logging

Comment [M1]: The entire document is written within a framework that assumes fire is bad. This biased treatment is unfortunate. I assume you've made fire a threat to the species as reason to list, but this synthesis of fire and owls is biased and poorly done. I stopped reading closely on page 15 because I was tired of correcting the errors and biased statements.

Recent status reviews have identified wildfire as a primary threat to the recovery of the northern spotted owl (NSO) (Courtney et al. 2004, USFWS 2011). Much of this concern is based on recent loss of suitable breeding habitat to wildfires and to the risk of extensive severe fires occurring in the future. Other researchers and stakeholders have questioned the scientific basis of claims that wildfires pose a threat to NSOs and have expressed distrust of agency recommendations for widespread use of forest thinning to reduce fire risk (Hanson et al. 2009, Heiken 2010, DellaSala et al. 2013). Surprisingly, existing reviews supporting both sides of this debate have only considered a portion of the available information concerning spotted owl responses to wildfires, and mostly in regard to their limitations and inconsistent findings. Our review confirms these limitations and suggests that wildfires have variable and complex effects on spotted owls. Fire is a crucial ecosystem process in dry forests within the species' range, and some spotted owl populations are known to benefit from a mix of habitat conditions resembling those historically maintained by active fire regimes (e.g., Franklin et al. 2000). However, the preponderance of currently available evidence indicates that large severe wildfires can have strong negative effects on spotted owls. Wildfires may also negatively affect spotted owls through cumulative or interactive effects with other environmental stressors, such as timber harvesting, salvage logging, and competition with barred owls (see *Potential Threats: Cumulative and Interactive Effects*).

Comment [M2]: unclear

Comment [M3]: wording ?

Comment [M4]: hmmmm.

Wildfire Effects on Spotted Owls

Several studies have investigated responses of NSOs to wildfires (Table A). These studies provide crucial information for evaluating fire as a potential threat to the subspecies. However, their inferences are limited due to small sample sizes in all cases, the potentially confounding effects of post-fire salvage logging in one case, and pooling of data from all three spotted owl subspecies in another case (Table A; see below). In order to supplement these studies, we also reviewed research of fire effects on California spotted owls (CSOs) and Mexican spotted owls (MSOs) (Table A). Because inferences from these studies are also limited, and given differences among fires, spotted owl populations, and research methods, we review each project as a "case study". Relatively thorough descriptions of these studies allow identification of patterns in the literature, which could provide insights into general effects of wildfires on the species.

Comment [M5]: ??

Table A: Apparent effects of wildfires on spotted owls. See text for additional descriptions of study methods and findings.

Response Metric	Study	Subspecies	Location*	Apparent Effect**	Notes
Mortalities	~~Paton et al. 1991~~	~~NSO~~	~~CA KLA~~	~~(?)~~	~~Likely due to heavy radio tags~~
	King et al. 1997	NSO	E WA CAS	-(?)	Only one individual; Possibly due to wildfire also logging
	Clark 2007	NSO	OR KLA	-(?)	Possibly due to wildfire and logging (unpublished grey lit.; analysis has problems)
Survival	Bond et al. 2002	NSO, CSO, MSO	CA, AZ, NM	0	Only one post-fire survey season
	Clark et al. 2011	NSO	OR KLA	-	~~Possible cumulative~~ Cumulative effect of timber harvesting, severe fire, and salvage logging
Productivity	~~Paton et al. 1991~~	~~NSO~~	~~CA KLA~~	~~(?)~~	~~Possible decline; Likely due to heavy radio tags~~
	Gaines et al. 1997	NSO	E WA CAS	0	Apparently no decline but possibly obscured by low reproduction year across population; Possibly lower total reproduction in burned landscapes due to lower pair occupancy; Only one post-fire season Anecdotal, no statistical power!
	Bond et al. 2002	NSO, CSO, MSO	CA, AZ, NM	0 (+?)	Slightly higher than in other studies; Only one post-fire season
	Clark 2007	NSO	OR KLA	0 ?	Apparently no decline but low statistical power; Possibly lower total reproduction in burned and logged landscapes due to lower pair occupancy
	Roberts 2008	CSO	CA SIERRA	+	Repro higher in burned.
Site Fidelity	Bond et al. 2002	NSO, CSO, MSO	CA, AZ, NM	0	Site fidelity similar to other studies
Occupancy	Elliot 1985	CSO	CA COAST	-?	Apparent abandonment by two pairs (this is anecdotal)
	Gaines et al. 1997	NSO	E WA CAS	-?	Post-fire occupancy was lowest found during five-year study; Only one post-fire season (anecdotal, no stats)
	Jenness et al. 2004	MSO	AZ, NM	0	Statistically ~~weak but pooled all fire types and severities~~no difference
	Keane et al. 2011, 2012	CSO	CA SIERRA/CAS	-?	Extensive high severity fire apparently had a strong negative effect; Extensive low severity fire apparently had a neutral or weak negative effect; Result influenced by extensive salvage logging
	Roberts et al. 2011	CSO	CA SIERRA	0	~~Authors concluded weak effect but pooled all fire types and severities~~No difference between burned and unburned
	Lee et al. 2012	CSO	CA SIERRA	0 (+?)	Similar occupancy at burned vs. unburned; Possibly ~~lower~~ higher occupancy at ~~severely~~ burned vs. ~~other~~ unburned
	Lee et al. 2013	CSO	SO CA	0/-	Similar occupancy at burned vs. unburned; Significant reduction with extensive high severity fire in core area
	Clark et al. 2013	NSO	OR KLA	-?	Cumulative effects of timber harvesting, severe fire, and salvage logging
Home Range	Clark 2007	NSO	OR KLA	-?	Larger home ranges post-fire and salvage logging
	Bond et al. 2013	CSO	CA SIERRA	0	Similar home range sizes to unburned areas
Roosting	King et al. 1997	NSO	E WA CAS	-	Apparent avoidance of moderate and severe burns
	Bond et al. 2009	NSO	CA SIERRA	-	Significant avoidance of moderate and severe burns
Foraging	Clark 2007	NSO	OR KLA	+(?)	Apparent weak selection of moderately burned suitable habitat; Possible weak selection for severely burned suitable habitat; Very low use and availability of both moderately and severely burned suitable habitat

Comment [M6]: This study says nothing about fire effects, should be omitted.

Comment [M7]: Always confounded fire and salvage logging. Don't assume or report that the effects were from fire!

Comment [M8]: This study says nothing about fire effects, should be omitted.

Comment [M9]: Always confounded fire and salvage logging. Don't assume or report that the effects were from fire!

Comment [M10]: Leave this to occupancy

Comment [M11]: Always confounded fire and salvage logging. Don't assume or report that the effects were from fire!

Comment [M12]: Always confounded fire and salvage logging. Don't assume or report that the effects were from fire!

	Bond et al. 2009	NSO	CA SIERRA	+	Significant selection of severe burns

* Locations: California Klamath (CA KLA); Eastern Washington Cascades (E WA CAS); Oregon Klamath (OR KLA); California, Arizona and New Mexico (CA, AZ, NM); California Central Coast Range (CA COAST); California at margin of northern Sierra Nevada and southern Cascades (CA SIERRA/CAS); California Sierra Nevada (CA SIERRA); southern California San Bernardino and San Jacinto Mountains (SO CA). **Apparent Effect: negative (-), positive (+), neutral (0), varied with fire severity (/)—see Notes column and text for further explanations.

Survival

Although adult spotted owls are capable of rapid and sustained flight, it is possible that they are occasionally killed by large or fast moving fires. Young owls with undeveloped flight feathers may be at particular risk of mortality during wildfires due to poor mobility (Smith 2000). Even in unburned areas, spotted owls could be injured or killed by smoke (Singer and Schullery 1989, Smith 2000). In addition to these potential immediate effects, extensive moderate or severe wildfire could influence spotted owl survival over the longer-term by ~~removing or~~ modifying habitat for roosting, foraging, or prey (see below).

Comment [M13]: Data-free statement, recommend deletion

Comment [M14]: Could be positive or negative modification, author should avoid judgmental language when speculating.

Only two studies are currently available for evaluating effects of wildfires on spotted owl survival rates (Table A). Bond et al. (2002) reported that 18 of 21 (86%) marked spotted owls were resighted one year after wildfires occurred in California, Arizona, and New Mexico. This minimum survival rate was similar to survival estimates in unburned areas found by other, longer-term studies of the three spotted owl subspecies (Seamans et al. 1999, Franklin et al. 2000, W.S. LaHaye unpubl. data). Extensive severe fire (36-88%) occurred in four of the eight territories for which fire severity was mapped and the other half primarily burned at low to moderate severity. Thus, even extensive severe fire did not appear to have a large effect on spotted owl survival one year post-fire. ~~In contrast,~~ Clark et al. (2011) found evidence of a negative effect of combined wildfires and salvage logging on survival of 23 NSOs in the Oregon Klamath Province. Severe fire and salvage logging occurred in 30% and 41% of suitable NSO habitat in the two study areas. Estimated mean annual survival rates for NSOs located inside fire perimeters (0.69) and apparently displaced by fires and post-fire salvage logging (0.66) were

lower than in areas just outside the fire perimeters (0.85) and in an unburned reference study area in the neighboring southern Cascades (0.85: Anthony et al. 2006). The degree to which post-fire salvage logging in the study areas influenced NSO survival rates is unknown, but we know salvage logging has a documented negative effect on occupancy (Lee et al. 2013).~~.~~ The study's occupancy analyses indicated that pre-fire timber harvesting, wildfires, and post-fire salvage logging cumulatively impacted NSOs through reductions of suitable habitat (Clark et al. 2013; see below).

Apparently contradictory findings by Bond et al. (2002) and Clark et al. (2011) may be due to several factors. The most obvious difference between the studies is that the areas studied by Clark et al. (2011) experienced post-fire salvage logging while those studied by Bond et al. (2002) did not. Additionally, the populations studied by Clark et al. (2011) may have been particularly sensitive to habitat loss to wildfires due to intensive pre-fire timber harvesting across a checkerboard ownership. ~~It is also possible that Bond et al. (2002) failed to detect a negative effect of wildfires on spotted owls due to their reliance on data collected one year after fires occurred.~~It should be noted that Bond et al (2002) only examined effects 1 year post fire. Fire injuries and post-fire outbreaks of insects and pathogens can continue to result in tree mortality for up to several years after a wildfire (Ryan and Amman 1996, Gaines et al. 1997, Hood et al. 2007).

Comment [M15]: Bad language

Comment [M16]: Why assume tree death can only negatively affect SPOW? What about small mammal prey increases post fire?

There is relatively little information about the causes of spotted owl mortalities in recently burned areas. Not all spotted owl projects include radio-telemetry, which enables researchers to

recover dead birds. Even with radio-telemetry, only a portion of owl carcasses are recovered before they are too scavenged or decomposed to conduct a necropsy.

We reviewed three studies that described the condition of dead spotted owls found in areas recently burned by wildfire (Table A). In the Western Klamath Region of California, Paton et al. (1991) reported that one telemetered NSO died during a wildfire and that four more died within seven weeks. There was no evidence that any of the birds died from smoke inhalation or burns; rather, survival in the study area appeared to have declined due to the energetic costs of radio packs that were quite heavy by current standards. However, the authors noted that the telemetered owls in their study were exposed to high levels of carbon monoxide and total suspended particulates when an inversion trapped a dense layer of smoke near the ground for more than three weeks. In the eastern Washington Cascades, King et al. (1997; also Bevis et al. 1997) described a female NSO's behavior and death following a wildfire. The female and her fledgling survived when a low to moderate severity fire burned through the nest grove and produced thick smoke. Shortly after her offspring dispersed, the female moved to a new location outside the burned area and then died less than a month later. Her carcass was emaciated, indicating that she died from starvation or illness. King et al. (1997) speculated that this spotted owl died due to a post-fire decline in prey availability, but no prey data were presented. Clark (2007) reported that a total of eight NSOs died during his telemetry study in the Oregon Klamath Province. Six of the owls were recovered, all of which were emaciated. He likewise suggested that the deaths were related to a ~~post-fire~~ decline in prey availability due to combined effects of fire and salvage logging, but no prey data were presented. ~~This hypothesis was indirectly supported by the study's finding that NSOs' annual home ranges increased after wildfires~~

Comment [M17]: Without presenting examples direct mortality detected in telemetry studies of unburned areas, these anecdotes are biased and misleading.

Comment [M18]: Delete, this paper does not provide any data to judge fire effects on SPOW

Comment [M19]: Data-free anecdotes are dangerous.

Comment [M20]: But like King he had no data to support this speculation.

~~occurred (see below).~~ It is also possible that a factor other than fire caused a decline in prey availability or that the wildfires affected NSO survival in other ways. For example, loss or degradation of suitable roosting habitat could stress NSOs by limiting their ability to thermoregulate (Barrows 1981, Ganey et al. 1993, Ting 1998, Weathers et al. 2001).

Reproduction

The spotted owl is a relatively long-lived species that exhibits a bet-hedging life history strategy (Noon and Biles 1990, Franklin et al. 2000). This means that individuals often forego breeding during poor environmental conditions in order to maximize their chance of surviving and reproducing in the future. Given the species' life history strategy, spotted owl reproductive rates are likely sensitive to environmental changes, including those brought about by wildfires. However, annual fluctuations in spotted owl reproduction caused by variation in weather, prey populations, or breeding condition could obscure effects of wildfires on reproduction (e.g., Franklin et al. 2000).

We are aware of four studies that examined potential effects of wildfires on spotted owl reproduction (Table A). None of these studies found substantive evidence of a wildfire-induced decline in reproduction by the species. In the Western Klamath Region of California, ~~Paton et al. (1991) noted a possible difference in reproduction by NSOs in two areas burned by the same wildfire. Reproduction and fire effects were poorly described for burned versus unburned areas (e.g., number of eggs vs. number of fledglings; inversion-trapped smoke vs. understory burning in different areas of the fire), but demographic rates in the study appeared to be influenced by whether or not owls were fitted with heavy radio tags, rather than by variation in fire effects~~. In

the eastern Washington Cascades, Gaines et al. (1997) found little difference in productivity (number of young per pair) between burned (0.2; n = 5 or 6/ yr) and unburned sites (0.3; n = 13-17/yr) one year after a predominantly moderate to severe wildfire. However, it is possible that coincidentally low reproduction across the population during the post-fire year made it difficult to detect a difference between burned and unburned sites; particularly with such a small sample size. Clark (2007) found no significant differences in productivity in burned areas in the Oregon Klamath Province (n = 31 territories) and an unburned study area in the neighboring southern Cascades (Anthony et al. 2006). He noted, however, that his study likely lacked the statistical power to detect a difference if one occurred. Bond et al. (2002) found that seven pairs of spotted owls produced an average of 1.0 offspring during a single breeding season following wildfires in California, Arizona, and New Mexico. This was higher than productivity rates ~~found~~ found in unburned areas during long~~er~~-term studies of the three spotted owl subspecies (Seamans et al. 1999, Franklin et al. 2000, W.S. LaHaye unpubl. data).

Comment [M21]: No statistics were presented.

Comment [M22]: Why speculate that a difference ought to be there?

Currently available studies suggest that wildfires generally have little or no short-term effects on spotted owl reproduction. However, it might be difficult to capture fire effects on spotted owl reproduction during short-term studies, particularly those with only a single year of post-fire data. In addition, it is possible that solely comparing productivity (e.g., offspring per pair) in burned and unburned areas could obscure a decline in total reproduction in burned areas. Studies in Washington and Oregon reported post-fire declines in occupancy by pairs, suggesting that wildfires may reduce reproductive opportunities for spotted owls (Gaines et al. 1997, ~~Clark 2007;~~ see below). Alternatively, it is possible that wildfires sometimes contribute to higher reproduction by spotted owls. For example some pairs or populations may experience higher

reproduction following wildfires due to short-term increases in availability of deer mice (*Peromyscus* spp.), pocket gophers (*Thomomys* spp.), and other prey (Ream 1981, Zwolak 2009, Bond et al. 2013).

Comment [M23]: Finally, the potential positive effects are mentioned.

Occupancy

Potential wildfire effects on NSO population rates are most directly evaluated with measures of survival and reproduction. However, occupancy data are often more logistically and economically feasible to collect than are demographic data and could provide an early indication of population trends (MacKenzie 2005, Olson et al. 2005). Spotted owl occupancy is sensitive to environmental factors (Blakesley et al. 2005, Olson et al. 2005) so it is a potentially valuable measure of wildfire effects on the species. Nonetheless, occupancy data must be interpreted carefully since they can be strongly influenced by survey effort, analytical methods, and the presence of barred owls (Olson et al. 2005).

We evaluated nine studies of wildfire effects on spotted owl occupancy (Table A). As described below and in Table A, all but one of these provided at least weak evidence of a negative effect of either severe fire or fire in general.

Two studies indicated potentially ~~strong declines~~ negative effects in spotted owl occupancy but included very few territories (Elliot 1985, Gaines et al. 1997). In Monterey County, California, informal yearly surveys suggested that two pairs of CSOs abandoned their territories for at least four years following a wildfire (Elliot 1985). The author did not describe the fire other than

noting substantial damage to understories and oaks in the previously occupied areas. In the eastern Washington Cascades, Gaines et al. (1997) found that ~~only~~ two of six NSO sites were occupied one year after a predominantly moderate to severe wildfire. This was the lowest occupancy rate found during the five-year study period.

Two studies found ~~only weak~~no evidence of ~~a negative~~any effect of fire on spotted owl occupancy, but their methods may have precluded detection of stronger effects (Jenness et al. 2004, Roberts et al. 2011). Jenness et al. (2004) found a statistically insignificant tendency for higher occupancy rank (no owls, singles, pairs, reproductive pairs) in unburned sites than in paired burned sites in Arizona and New Mexico (paired sites were close to each other and had similar habitat and topography). Of the 29 paired-site comparisons, 14 (48%) had a higher rank in unburned sites, 6 (21%) had a higher occupancy rank in burned sites, and 9 (31%) were tied. In the Sierra Nevada of California, Roberts et al. (2011) found ~~lower occupancy estimates for CSOs in burned areas (0.46) than in unburned areas (0.72); but the difference was not statistically analyzed~~no difference in occupancy between burned and unburned sites. Modeling by both studies indicated that spotted owl occupancy was more strongly influenced by habitat composition or structure than by whether or not fire had recently occurred in territories. However, both studies may have underestimated the impacts of severe fire due to pooling of diverse fire types and severities for analysis (including prescribed fires, wildfires, and wildfires allowed to burn under prescribed conditions). Roberts et al. (2011) may also have underestimated shorter-term effects of wildfires due to inclusion of data collected up to 15 years post-fire.

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Comment [M24]: Exactly corrrect

Comment [M25]: Why are you reaching for reasons that bad fire effects were absent rather than presenting the data in an unbiased voice?

Two studies found evidence of strong declines in occupancy in areas recently burned by extensive severe wildfire but both ~~may have been~~were seriously confounded by post-fire salvage logging (Keane et al. 2011, 2012, Clark et al. 2013). In southwestern Oregon, Clark et al. (2013) examined how extensive wildfires and subsequent salvage logging affected occupancy dynamics of NSO pairs. In their first analysis, the authors compared pre- and post-fire occupancy dynamics in a burned study area in the Oregon Klamath Province (n = 22) to those in an unburned area in the nearby southern Cascades (Anthony et al. 2006). High severity fire and salvage logging removed or modified 26% of suitable habitat in landscapes surrounding NSO sites in this area. The burned and salvage logged study area experienced a 64% reduction in site occupancy during the post-fire period, compared with a 25% reduction in the unburned study area (difference not statistically analyzed). In the second analysis, the authors examined possible effects of severe fire and salvage logging on occupancy dynamics in 40 territories located in three burned study areas in the Oregon Klamath Province. In these areas, 19-26% of suitable habitat was burned at high severity and~~/or~~ salvage logged. During the study's three-year post-fire period, site extinction probabilities were as high as 72% in two combined study areas and 92% in the third area. Site extinction probabilities in the burned and logged study areas were best explained by a model that included extents of high severity fire, salvage logging, and early seral forest. Models that included these variables separately were not competitive with the model containing all three variables, suggesting that NSO occupancy declined due to cumulative habitat loss from severe fire and pre- and post-fire timber harvesting. ~~The relative influence of these factors on occupancy is unknown, but the role of severe fire cannot be dismissed. For example, the highest extinction probability (92%) occurred in a study area with little salvage logging (<2%) of previously suitable habitat.~~

Comment [M26]: Incorrect. Their model structures were not organized to differentiate among these effects.

Comment [M27]: Using anecdotal examples as refutation of statistics is wrong and should be avoided.

Keane et al. (2011, 2012) estimated occupancy of CSOs in two recently burned study areas near the margin of the Sierra Nevada and southern Cascades of California. One wildfire complex, and an unreported amount of post-fire salvage logging, resulted in an almost complete loss of potentially suitable CSO habitat in the area (70% of the area pre-fire vs. 6% post-fire consisted of mean canopy cover ≥40% and mean DBH ≥11 in). Pre-fire occupancy in this study area was unknown but the Forest Service identified 23 CSO activity centers in the area prior to the fires. Rigorous landscape survey coverage by Keane et al. (2011, 2012) confirmed occupancy in only one territory within the fire perimeter during each of two post-fire years, whereas approximately seven to nine territories were found post-fire in a surrounding one-mile survey buffer. The other area studied by Keane et al. (2011, 2012) primarily burned at low severity (ca. 60% of the area). Pre-fire occupancy was likewise unknown in this area but Forest Service pre-project surveys indicated the presence of about 10 territories. Surveyors confirmed occupancy of six territories in this area during the first and second years post-fire. While the study's findings are preliminary and may have been influenced by post-fire salvage logging, they suggest that effects of large wildfires on CSOs are strongly dependent on the extent of high severity fire.

Comment [M28]: This study is weak, unpublished, and uninterpretable due to the unquantified salvage logging. Use with care, or not at all.

~~Another study provided further~~ The only published study that accounted for effects of logging and fire separately documented evidence that effects of wildfires on spotted owl occupancy depend on the extent of high severity fire. Lee et al. (2013) compared occupancy dynamics of CSOs in 71 recently burned sites and 97 unburned sites in the San Bernardino Mountains and San Jacinto Mountains of southern California. An average of 23% of forest within burned "core areas" (500 ac around activity centers) experienced high severity fire (this percent is based on an

assumption that the amount of pre-fire forest in burned core areas was the same as that reported for burned and unburned core areas combined). Mean annual probability of occupancy was 0.48 in unburned sites and 0.31 in burned sites. This difference was not statistically significant. ~~However, probability of occupancy was consistently lower in burned sites during all eight post-fire years, suggesting that wildfire had a biologically meaningful effect on CSO occupancy. Furthermore, a~~A statistically significant negative effect on occupancy was detected~~, particularly for pairs,~~ when more than 125 acres of forest within core areas burned at high severity.

~~Finally, t~~Two studies found that wildfires had ~~little~~ positive or no effect on spotted owl occupancy (Bond et al. 2002, Lee et al. 2012). Bond et al. (2002) calculated site fidelity for spotted owls in 11 territories burned by wildfires in California, Arizona, and New Mexico. The fires burned most of the area within each estimated territory (territory size = ½ the nearest neighbor distance in each study area, based on previous studies). Half of the eight territories for which fire severity was mapped primarily burned at low to moderate severity and the other half experienced extensive severe fire (36-88%). Of 21 color-banded owls in the study, 18 (86%) were resighted the year after the fires and 16 (89%) of these were located in their pre-fire territory. Site fidelity in this study was comparable to that in other, longer-term studies of the three subspecies (Seamans et al. 1999, Franklin et al. 2000, W.S. LaHaye unpubl. data).

In the Sierra Nevada, Lee et al. (2012) compared post-fire occupancy in 41 recently burned and 145 unburned historical CSO territories. An average of 32% of forest in burned territories experienced high severity fire. The authors found no significant association between CSO occupancy and whether or not territories had recently experienced wildfire within a 494-acre

circle around activity centers (but mean occupancy was higher in burned sites: 0.76 at unburned sites and 0.80 at burned sites). ~~Of the nine sites in which at least 50% of forest was severely burned within larger 988-acre areas around activity centers, eight were surveyed post-fire and CSOs were detected in five of those (63%). This level of occupancy appears to have been lower than that of burned sites as a whole (not statistically analyzed), but it also indicates that CSOs can persist in areas with extensive severe fire.~~

The studies reviewed above are not directly comparable due to differences in methods, spotted owl subspecies and populations, fire extents and severities, and the presence or absence of post-fire salvage logging. ~~Nonetheless, the weight of currently available evidence indicates that, while spotted owls can persist in burned landscapes, wildfires may often reduce occupancy.~~Current data (weighted by sample sizes, statistical power, and confounding effects of salvage logging) indicate that wildfire does not significantly affect occupancy except rarely, in the most extreme situations, when most suitable habitat in the nest core area is severely burned. ~~The studies further suggest that the magnitude of wildfire effects on occupancy depends on the extent of severe fire. However, even mixed severity wildfires may substantially reduce occupancy when suitable habitat is already limited (e.g., due to intensive timber harvesting: Clark et al. 2013)~~. Post-fire salvage logging can increase the negative effects of extensive severe fire on spotted owl occupancy; most likely by reducing suitability of burned areas for prey and foraging (see below).

Home Range Size and Habitat Use

Changes in the behavior of individual spotted owls may provide insight into the mechanisms by which wildfires affect populations. For example, post-fire changes in home range size may reflect fire effects on spotted owl energy budgets through changes in travel distances and prey availability. Changes in energy intake and output could, in turn, influence survival, reproduction, and occupancy of spotted owls. Patterns of habitat use may also be informative. For example, selection or avoidance of burned areas may reflect changes to availabilities of prey or roosting habitat, which could, in turn, influence occupancy, reproduction, or survival of spotted owls.

To our knowledge, only two studies have evaluated spotted owl home range sizes in relation to wildfires (Clark 2007, Bond et al. 2013). Clark (2007) found that annual home range sizes of NSOs inside two fire perimeters in the Oregon Klamath Province were larger after the fires than before them (n = 14 owls pre-fire and 20 post-fire). He attributed this difference to owls expanding their home ranges in response to habitat fragmentation caused by severe fire and salvage logging. This hypothesis was supported by other research in the region, which found that NSOs had larger home ranges in fragmented forests than in areas with larger, more intact patches of habitat (Carey et al. 1992, Schilling et al. 2013). Another study in the region suggested that the energetic cost of increased travel in fragmented forest was greater than the energetic benefit of increased access to prey associated with early-successional habitats (Carey and Peeler 1995).

Comment [M29]: Whenever you mention this Clark 2007study you must call any affects due to"fire and salvage logging" because they did not discriminate between these thing, but lumped all together.

Bond et al. (2013) compared the breeding season home ranges of seven CSOs (from four territories) during a single post-fire year in the Sierra Nevada of California with those in other studies during the same year in other parts of the subspecies range (D. Call, T. Munton, and G. Zimmerman unpubl. data). An average of 23% of forest burned at moderate severity and 9% at high severity within a 1.2 mile radius of the four nests. Pre-fire home range sizes were unknown but CSOs in the four territories did not appear to have unusually large home ranges following predominantly low to moderate severity wildfire.

Three studies have described patterns of habitat use by spotted owls in burned areas (Table A). King et al. (1997; also Bevis et al. 1997) described initial effects of wildfires on NSOs in two territories in the eastern Washington Cascades. One territory primarily experienced low to moderate severity fire and the other mostly burned at high severity. Both territories experienced an unreported amount of salvage logging in unsuitable or severely burned habitat. Most NSO locations (84% and 89%) in the two territories were daytime roosts. In the territory primarily burned at low to moderate severity, 80% of the pair's post-fire locations were in unburned habitat, 16% were in low severity burns, and 4% were in moderate severity burns. The pair did not appear to use severely burned areas. The second territory studied by King et al. (1997) was occupied by a single male. After the fire, the male shifted his activity to an unburned area two to three miles away but continued to occasionally use areas near his former activity center. Of those locations, 74% were in unburned habitat, 17% were in low severity burns, 5% were in moderate severity burns, and 4% were in high severity burns. Maps of burn severity classes and NSO locations indicate that owls in these two territories strongly selected unburned areas for roosting.

Clark (2007) evaluated habitat selection by 12 NSOs (7 territories) inside a wildfire perimeter in the Oregon Klamath Province. NSO locations were primarily nocturnal and may therefore, have largely represented foraging activity. Individuals in this area used all habitat classes, including moderate and severe burns and areas that had been salvage logged. However, when the data from individuals were pooled for analysis, the owls exhibited a strong preference for nesting-roosting habitat that was unburned or burned at low severity (unburned and low severity were combined into a single class). NSOs in the study also selectively used moderately burned, previously-suitable habitat; although both use and availability of this habitat class were low compared with unburned or lightly burned habitat. Clark (2007) speculated that selection of moderately burned habitat was related to increased prey availability following fire in those areas. Owls' use of burned areas was concentrated closer to activity centers, which was expected, given that spotted owls are central place foragers during the breeding season (Rosenberg and McKelvey 1999).

In the Sierra Nevada, California, Bond et al. (2009) described the habitat associations of seven CSOs from four territories during a single post-fire season. Of the four nests found during the study, one was approximately 0.3 mile outside the fire perimeter, one was in forest burned at low severity, and two were in forest burned at moderate severity. One of the two nest trees found in a moderate severity burn was apparently killed by the fire and one produced the only fledgling detected during the study. It is unclear from the paper whether these events occurred at the same nest or different nests. The four pairs roosted in all burn severity classes but exhibited statistically significant selection of low severity burns and avoidance of moderate and high

severity burns. Only one of 60 roost sites was located in a high severity burn. Burned roost sites generally resembled unburned roost sites (>60% canopy cover and large-diameter trees). Bond et al. (2009) also evaluated CSO selection of foraging habitat in the area. Probability of use for foraging was highest when sites were burned and within 0.6 mile of nests or roosts. Probability of use was also positively associated with presence of edge between burn severity classes. Five of the owls foraged in high severity burns within 0.9 mile of nests or roosts more often than in other burn severity classes. Bond et al. (2009) suggested that CSOs in these four territories selectively foraged in high severity burns in order to access abundant prey in those areas. This hypothesis was supported by their finding that high severity burns had the highest herb and shrub cover and highest basal area of snags of any burn severity class, including unburned. These features are key resources for spotted owl prey communities (Carraway and Verts 1991, Carey et al. 1999, Holloway and Smith 2011).

The limited available information concerning spotted owl habitat use following wildfires indicates that the species ~~strongly~~ avoids roosting in moderate and high severity burns. This is unsurprising, given the spotted owl's close association with densely-canopied older forest for roosting (*section_xxx*). Little is known about the effects of wildfire on selection of nest sites. Bond et al. (2009) found three CSO nests in forest recently burned at low and moderate severity, and young fledged from one nest in a moderate severity burn. Moderate severity fire killed one of the four CSO nest trees in their study. We are unaware of any reports of spotted owls nesting in severely burned areas. Because of the species' nesting habitat requirements (*section_xxx*), it is likely uncommon. Two studies examined selection of foraging habitat by spotted owls. Both found use of all burn severity classes, but Clark (2007) found a preference for foraging in

Comment [M30]: Always confounded fire and salvage logging. Don't assume or report that the effects were from fire! Maybe move all mention of Clark 2007 to salvage logging section.

unburned to moderately burned older forest while Bond et al. (2009) found a preference for severe burns. It is unclear if this difference was due to differences in the studies' methods, spotted owl diets, or effects of fire and timber harvesting on vegetation.

Salvage Logging

Salvage logging further modifies recently burned forests and could exacerbate negative effects of severe fire on spotted owls. While salvage logging might be judiciously used to meet certain conservation objectives (e.g., generating downed wood to minimize erosion or create wildlife habitat), it is generally conducted to meet financial goals or remove hazard trees (Peterson et al. 2009). Intensive or poorly planned salvage logging can have a variety of negative effects on ecosystems, such as soil compaction, increased erosion, and impacts on insectivorous and cavity-nesting and -denning animals (reviewed in McIver and Starr 2000, Noss et al. 2006, Peterson et al. 2009).

We know of three studies that have directly evaluated effects of post-fire salvage logging on spotted owls (Clark 2007 and Clark et al. 2013, Lee et al. 2012, 2013). Clark (2007) conducted a radio-telemetry study in areas recently burned by wildfires in the Oregon Klamath Province. He recorded limited use of salvage logged areas; presumably for foraging since locations were primarily nocturnal. Use of salvage logged areas was slightly lower than expected based on its abundance in territories (not statistically analyzed), indicating weak avoidance of salvage logged areas by NSOs. However, avoidance might have been stronger since some of the study's telemetry locations were potentially recorded prior to the occurrence of salvage logging. Most

Comment [M31]: These papers confound fire and salvage.

(60%) NSO locations in salvage logged areas occurred in riparian buffers, thinned areas, and patches of wildlife leave trees, rather than intensively salvaged areas. During the same study, Clark et al. (2013) found that post-wildfire declines in NSO occupancy were best explained by a model that included extents of pre-fire timber harvesting, severe fire, and post-fire salvage logging. Models that included these factors separately were not competitive with this model, indicating that severe fire and pre- and post-fire harvesting collectively contributed to declines in NSO occupancy; most likely through cumulative habitat loss or degradation.

In the Sierra Nevada, Lee et al. (2012) recorded occupancy for eight CSO territories that experienced wildfire and post-fire salvage logging. Seven of the territories were occupied during the two-year period between the occurrence of wildfire and salvage logging, whereas none of the territories were occupied following salvage logging.

Lee et al. (2013) evaluated effects of salvage logging on CSOs in the San Bernardino and San Jacinto Mountains of Southern California. They noted that salvage logging in their study area was modest compared with commercial salvage logging typically employed in the Pacific Northwest and Sierra Nevada (salvage logging in their study area mostly consisted of firewood cutting on private in-holdings and hazard tree removal along Forest Service roads). Lee et al. (2013) did not find a statistically significant effect of post-fire salvage logging on CSO occupancy dynamics. However, site extinction probability was slightly higher, and mean annual probability of occupancy was slightly lower, in salvage logged areas than in other burned areas. Weak negative effects of light salvage logging were evident during all eight post-fire study years, suggesting that they were biologically, if not statistically, significant.

The limited available evidence suggests that salvage logging increases the probability that spotted owls will abandon their territories following wildfires. This likely occurs because salvage logging reduces suitability of burned areas for foraging spotted owls and their prey. Stands recently burned by moderate or severe fire often contain high biodiversity due to the presence of both early-successional conditions and key biological legacies in the form of snags, logs, and live trees (Noss et al. 2006). Due to fire suppression and salvage logging, stands with these conditions are currently rare in many fire-prone forests within the spotted owl's range (Noss et al. 2006). Selective use of moderate or high severity burns for foraging is likely due to spotted owls exploiting short-term increases in prey associated with both early-successional vegetation (e.g., shrubs) and legacy habitat elements (e.g., large diameter snags, logs, and live trees) (Ream 1981, Zwolak 2009, Bond et al. 2013). Salvage logging removes legacy elements, while associated use of herbicides reduces shrubs and grasses important to many prey species (Bond et al. 2013). In the longer-term, spotted owls can continue to benefit from the contributions of legacy habitat elements to regenerating stands. For example, large legacy snags, trees, and logs can provide valuable habitat elements for northern flying squirrels and other prey (Holloway and Smith 2011). Removal of these elements through salvage logging could therefore reduce the value of subsequent regenerating stands as prey habitat. Harvesting of legacy snags and live trees could also directly affect spotted owls by reducing availability of foraging perches in the short-term and suitable nest trees during later successional stages.

<u>Summary</u>

Research of direct effects of wildfires and salvage logging on spotted owls have been opportunistic and have therefore, lacked the ability to compare pre- and post-fire data. Most studies' inferences are also limited due to inclusion of only a small number of spotted owls or territories. Nonetheless, more information is available concerning this topic than is generally acknowledged. The preponderance of currently available evidence indicates that spotted owls are often resilient to wildfires but can be strongly impacted by extensive severe fire. Following wildfire, many spotted owls may remain in their territories, exploit short-term increases in prey in burned areas, and continue to reproduce at reasonably high rates. However, wildfires that result in substantial loss or fragmentation of habitat can cause spotted owls to increase their home range sizes, abandon their territories, and possibly, die of starvation or disease. Negative effects of severe fire appear to be greatest when suitable habitat is already limited (e.g., due to widespread intensive timber harvesting) and when post-fire salvage logging reduces suitability of burned areas for foraging and prey.

Comment [M32]: Lee et al 2012 and 2013 do look pre- and post-fire!

Wildfire Effects on Recent Habitat Trends

Past and continuing habitat loss was a primary reason for listing the NSO under the federal Endangered Species Act (USFWS 1990). At the time of listing, the Fish and Wildlife Service estimated that 60-88% of the subspecies' habitat had already been lost (USFWS 1990; also see *Potential Threats: Timber Harvesting*). They attributed most of this loss to timber harvesting and land conversion but also acknowledged the roles of wildfire and other natural disturbances. Since listing of the NSO and subsequent adoption of the Northwest Forest Plan, timber harvesting has declined and wildfire has been identified as the primary source of forest

Comment [M33]: How is habitat lost? Define how suitable habitat is defined, and how it is lost.

disturbance and habitat loss on federal lands (Courtney et al. 2004, USFWS 2011, Kennedy et al. 2012).

Estimates of recent trends in amounts of NSO habitat, and of older forest in general, have been produced as part of monitoring efforts for the Northwest Forest Plan; and are therefore, largely restricted to the Plan's area and time span (Davis and Lint 2005, Davis and Dugger 2011, Moeur et al. 2005, 2011). We focus on estimates by Davis and Dugger (2011) because they replaced those of Davis and Lint (2005) and are more specific to NSO habitat than those of Moeur et al. (2005, 2011). We do not review habitat trend estimates based on federal ESA Section 7 consultation records (Bigley and Franklin 2004, USFWS 2012) due to greater scientific uncertainty and methodological bias associated with those data (see Bigley and Franklin 2004). Trends described by Bigley and Franklin (2004), Moeur et al. (2005, 2011), and USFWS (2012) quantitatively differ from those of Davis and Dugger (2011) but similarly indicate that wildfires have been the primary source of recent habitat loss on federal lands (see below).

Comment [M34]: There is a problem of bias in how suitable habitat is defined, and the criteria for 'loss' or 'degraded'.

Davis and Dugger (2011) used remotely sensed (satellite imagery) vegetation data to model changes in habitat suitability across the NSO's range during the first 15 years of the Northwest Forest Plan (1994-2007 in California and 1996-2006 in Oregon and Washington). Habitat suitability was based on characteristics surrounding thousands of NSO pair locations across the Plan area. Suitable breeding habitat was defined as having both a probability of owl presence greater than expected based on random chance and environmental conditions typical of those found around nesting and roosting pairs. Estimated habitat trends included gross loss of both suitable breeding habitat and "core" suitable breeding habitat (>330 ft from edge). Davis and

Comment [M35]: But rarely include burned sites, so definition of 'suitable habitat' is biased against burned forest.

Dugger (2011) considered habitat loss to have occurred when an area classified as suitable at the beginning of Northwest Forest Plan was later downgraded to a lower suitability rank (unsuitable or marginal) due to vegetation changes caused by forest disturbances. Davis and Dugger (2011) did not estimate recruitment of, or net changes in, breeding habitat because their remotely sensed data was incapable of accurately capturing relatively slow and subtle habitat changes during development of intermediate-aged and older stands. They did, however, estimate net trends in NSO dispersal habitat, which they defined as forest with a mean canopy cover of at least 40% and a mean DBH of at least 11 inches. Recruitment of dispersal habitat was more detectable than that of breeding habitat due to more rapid and measurable growth in younger forest (some recruitment also occurred due to degradation of suitable breeding habitat brought about by forest disturbances).

Estimated gross losses of suitable breeding habitat on federal and non-federal lands are presented in Tables B and C, respectively. During the first 15 years of the Northwest Forest Plan, wildfires were responsible for an estimated gross loss of 236,700 acres (2.7%) of suitable breeding habitat on federal lands rangewide and 13,100 acres (0.3%) on non-federal lands (1.9% combined). In California, wildfires removed an estimated 75,500 acres (4.1%) of suitable breeding habitat on federal lands and 5,600 acres (0.4%) on non-federal lands (2.4% combined). Approximately 70% of habitat loss to wildfire on federal lands occurred within the Oregon and California Klamath Provinces (Table B). Most of this habitat loss was caused by the1999 Megram Fire and 2002 Biscuit Fire (Table D). Fires in the Eastern Cascades Provinces of Washington, Oregon, and California contributed less to total habitat loss than did fires in the Klamath, but were often more destructive in terms of proportion of suitable habitat lost within individual fire perimeters.

In contrast with federal lands, wildfires were responsible for very little habitat loss on non-federal lands; rather, timber harvesting accounted for most losses in these areas (Figure A).

Table B: Estimated gross losses of suitable NSO breeding habitat on federal lands due to wildfires during 1994-2007 in California and 1996-2006 in Oregon and Washington (adapted from Davis and Dugger 2011, USFWS 2011).

State	Province	Initial Acres	Acres Lost	Percent Lost
California	CA Cascades	213,200	1,800	0.8%
	CA Klamath	1,489,800	71,600	4.8%
	CA Coast	145,400	2,100	1.4%
Oregon	OR Coast Range	611,200	0	0.0%
	Western OR Cascades	2,258,700	28,900	1.3%
	Eastern OR Cascades	402,900	17,800	4.4%
	Willamette Valley	3,400	0	0.0%
	OR Klamath	985,000	93,600	9.5%
Washington	Olympic Peninsula	763,100	200	0.0%
	Eastern WA Cascades	673,600	20,000	3.0%
	Western WA Cascades	1,283,000	700	0.1%
	Western WA Lowlands	24,700	0	0.0%
Rangewide Total		8,854,000	236,700	2.7%

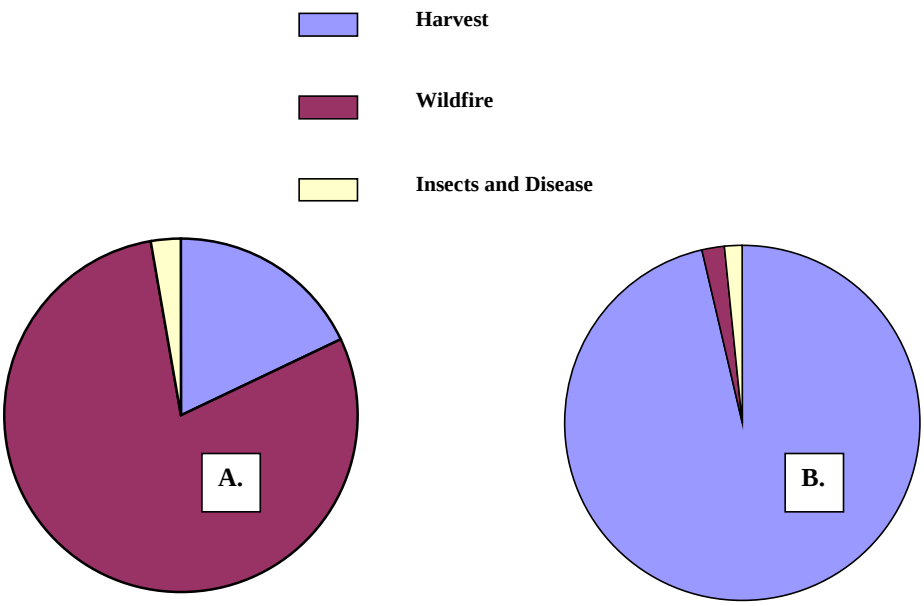
Table C: Estimated gross losses of suitable NSO breeding habitat on non-federal lands due to wildfires during 1994-2007 in California and 1996-2006 in Oregon and Washington (adapted from Davis and Dugger 2011, USFWS 2011).

State	Initial Acres	Acres Lost	Percent Lost
California	1,556,700	5,600	0.4%
Oregon	1,382,400	5,100	0.4%
Washington	1,258,900	2,400	0.2%
Total	4,198,000	13,100	0.3%

Table D: Estimated gross losses of suitable NSO breeding habitat to individual wildfires during 1994-2007 (note: "habitat degraded" describes areas downgraded from highly suitable to suitable; from Davis and Dugger 2011).

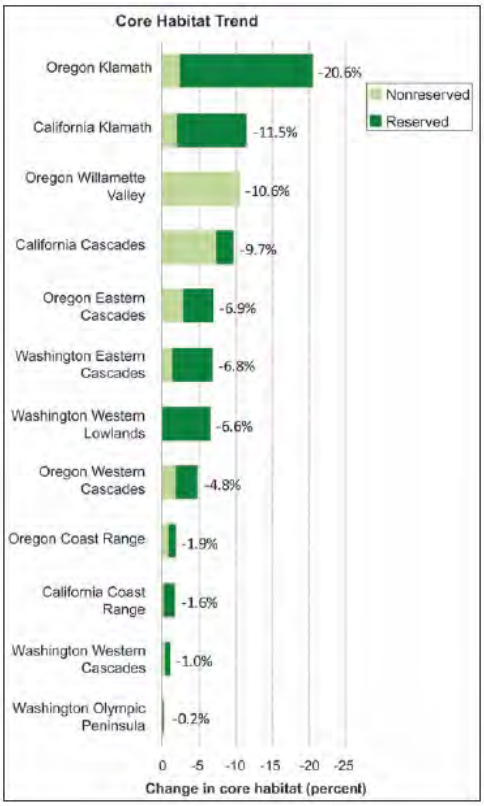
Fire name	Year	Broad physiographic province	Habitat in wildfire perimeter	Habitat lost		Habitat degraded	
			Acres	*Acres*	*%*	*Acres*	*%*
Biscuit Fire	2002	Klamath Mountains	226,230	93,730	41	12,019	5
Megram Fire	1999	Klamath Mountains	76,337	27,520	36	4,589	6
B&B Complex	2003	East Cascades	26,269	16,403	62	907	3
Bake-oven Fire	2006	Klamath Mountains	23,946	8,873	37	581	2
Boulder Fire	2002	West Cascades	34,059	8,460	25	2,074	6
Davis Fire	2003	East Cascades	8,050	6,943	86	5	0
Pigeon Fire	2006	Klamath Mountains	13,896	5,634	41	327	2
Rex Complex	2001	East Cascades	8,548	4,750	56	278	3
Timbered Rock	2002	West Cascades	10,216	4,539	44	569	6
Spring Fire	1996	West Cascades	13,504	3,931	29	858	6
Deep Harbor Fire	2004	East Cascades	5,761	3,930	68	64	1
Hancock Fire	2006	Klamath Mountains	12,712	3,132	25	336	3
Apple Fire 2	2002	West Cascades	12,227	2,810	23	928	8
Fischer Fire	2004	East Cascades	4,479	2,340	52	34	1
Fork Fire	1996	Klamath Mountains	2,962	2,113	71	14	0
Needles Fire	2003	East Cascades	1,946	874	45	1	0
Trough Fire	2001	Klamath Mountains	1,851	798	43	4	0
Hunter Fire	2006	Klamath Mountains	2,236	789	35	40	2
Deer Point Fire	2002	East Cascades	505	380	75	0	0
Tatoosh Complex	2006	East Cascades	666	378	57	0	0

Figure A: Proportions of suitable breeding habitat loss attributed to harvesting, wildfire, and insects and diseases on (A) federal lands and (B) non-federal lands during 1994-2007 (adapted from Davis and Dugger 2011, USFWS 2011).



Davis and Dugger (2011) reported substantial losses of core breeding habitat on federal lands during the first 15 years of the Northwest Forest Plan (Figure B). These losses primarily occurred in reserved areas. Changes in ratios of core and edge habitat classes indicated that increased fragmentation of suitable breeding habitat on federal lands was greatest in the Oregon and California Klamath Provinces and California Cascades Province (see Table 3-3 in Davis and Dugger 2011). Increased fragmentation in these regions was primarily due to wildfires.

Figure B: Gross losses of "core" suitable breeding habitat on reserved and non-reserved federal lands during 1994-2007 in California and 1996-2006 in Oregon and Washington (from Davis and Dugger 2011).



Davis and Dugger (2011) estimated a 5.2% net gain in NSO dispersal habitat. Much of this gain was due to succession in young forests in non-reserved lands at the margins of federal forests. However, accounting for forest connectivity and NSO dispersal distances, Davis and Dugger (2011) reported a 1% net loss of "dispersal-capable landscape". Much of the loss of dispersal-capable landscape in the Klamath and Eastern Cascades Provinces was due to wildfires, whereas timber harvesting on non-federal lands was responsible for much of the loss in other regions.

Loss and fragmentation of breeding habitat to wildfires was likely at least partially offset by recruitment of new habitat through succession of mature and old forest. However, Davis and Dugger (2011) found that detectable recruitment of breeding habitat primarily occurred in the marginal suitability class. This finding was supported by Moeur et al. (2005), who found that about 90% of recruitment of older forest (mature and old-growth combined) during the first 10 years of the Northwest Forest Plan was at the lower end of the class' diameter range (i.e., mean DBH 20-30 in). It is likely that some newly recruited mature forest provides suitable habitat for NSOs but much if it could lack the canopy layering, large diameter snags and logs, and other structural attributes typical of nesting and roosting habitat (*section_xxx*).

Loss and fragmentation of suitable breeding habitat does not necessarily equate to negative impacts on NSOs (Franklin and Gutiérrez 2002; e.g., Bond et al. 2002, 2009, Lee et al. 2012). Studies in southern Oregon and northern California found that the presence and fitness of NSOs are generally highest in landscapes with a mix of both large amounts of suitable breeding habitat and other habitat classes, such as foraging habitat or "non-habitat" (Franklin et al. 2000, Zabel et al. 2003, Olson et al. 2004, Dugger et al. 2005; reviewed in *section_xxx*). Fitness is also

generally highest when suitable breeding habitat occurs in large or clustered patches with large amounts of ecotone or edge (Franklin et al. 2000, Dugger et al. 2005). This combination of conditions is likely important because it provides NSOs with a balance of resources needed for survival and reproduction (Franklin et al. 2000). Active fire regimes in dry forests within the NSO's range in California historically contributed to these conditions by generally sparing older forest and maintaining some form of habitat heterogeneity at both stand and landscape scales (Sugihara et al. 2006). Some contemporary wildfires may still burn in this manner and thereby continue to perform an important ecosystem function in these forests. However, large severe wildfires have contributed, along with fire suppression and timber harvesting, to homogenization of some dry forests within the NSO's range (Skinner et al. 2006). Thus, large severe fires may impact NSOs through loss of habitat heterogeneity, as well as reduced amounts and connectivity of suitable breeding habitat.

Fire Risk in California

Prior to Euro-American settlement, dry forests in the western U.S. generally experienced relatively frequent, low-to-moderate or mixed severity fire regimes (Agee 1993, Sugihara et al. 2006, Van de Water and Safford 2011). Mean pre-settlement fire return intervals in California were 11 years in yellow pine forests (e.g., *Pinus ponderosa*, *P. jeffreyi*), 11-16 years in mixed-conifer forests, and 29 years in mixed-evergreen forests (Van de Water and Safford 2011). Mean fire return intervals in redwood forests south of Del Norte County were also relatively frequent (6-44 yrs: Stuart and Stephens 2006). Frequent fire during the pre-settlement period generally maintained forests with less dense and more clumped tree distributions, higher proportions of

fire-resistant trees (i.e., larger size classes and more fire-tolerant species), and lighter and less continuous fuel beds than occur today (Sugihara et al. 2006). This characteristic fine-scale structural heterogeneity was often overlaid with coarser variability created by effects of elevation, terrain, soils, and other physiographic factors on fire and vegetation patterns (Sawyer 2007). For example, in areas of deeply incised terrain in the Klamath Mountains and southern Cascades of California, upper slopes and south and west facing aspects typically experienced more frequent and severe fire than did other areas (reviewed in Skinner and Taylor 2006, Skinner et al. 2006). Due to fire suppression, early-successional vegetation communities formerly maintained by frequent, small-scale severe fire have greatly declined in some areas of California (Skinner 1995, Nagel and Taylor 2005). Overall, research indicates that fire suppression and other human activities have led to decreased forest heterogeneity at both stand and landscape scales and have contributed to substantial changes in fire regimes in California's dry forests (Sugihara et al. 2006).

Due to fire suppression, fire-free periods have dramatically increased in California's dry forests (Sugihara et al. 2006). For example, fire rotation near Hayfork in the Klamath Mountains increased more than 10-fold (from 19 to 238 yrs) during the post-settlement period (Taylor and Skinner 2003). Abnormally long fire-free periods have facilitated increased accumulation and continuity of fuels in dry forests (Sugihara et al. 2006). When wildfires do occur there is often an increased risk of them becoming very large and for suppression forces to be overwhelmed by their size and number (e.g., CAL FIRE 2008). As in other dry forests across the western U.S., the mean and maximum sizes of wildfires, and the total annual area burned, significantly increased in California's dry montane forests during the 20th and early 21st Centuries (Miller et

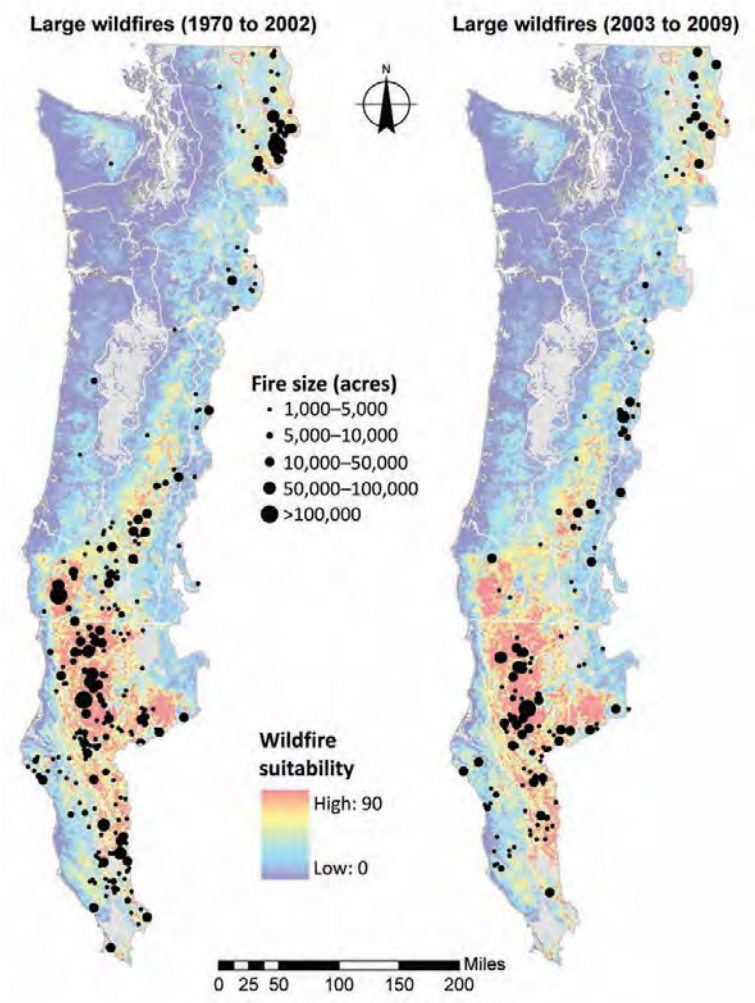
al. 2009, 2012). CAL FIRE (2008) noted that more than half of the 26 largest fires recorded in California during 1932-2008 occurred during the last eight years of that period. Based on recent (1970-2002) fire behavior, the majority of northern California's interior can be classified as highly prone to large (>1,000 ac) wildfires (Davis et al. 2011; Figure C).

Studies of recent trends in extents of high severity fire in California have found conflicting results. For example, Miller et al. (2009) reported a substantial increase in the extent of high severity fire in the Sierra Nevada and southern Cascades of California during 1984-2006; while Hanson and Odion (2014) did not find an increase in the Sierra Nevada during nearly the same period (1984-2010). Similarly conflicting results have been found for the California Klamath Province. Hanson et al. (2009) found a significant increase in high severity fire in the California and Oregon Klamath Provinces during 1984-2005; whereas Miller et al. (2012) did not find an increase in the California Klamath Province during a similar period (1987-2008). Scientific debate ensued regarding the appropriateness of methods used to determine fire severity (e.g., Hanson et al. 2009, 2010 vs. Spies et al. 2010).

Differences in findings regarding trends in high severity fire are related to variation in studies' temporal and spatial scales of analysis, as well as in methods for determining fire severity (Courtney et al. 2008, Miller et al. 2012, Hanson and Odion 2014). For example, Miller et al. (2012) noted that both their own study and those of Odion et al. (2004, 2010) may have underestimated trends in high severity fire in the California Klamath Province due to inclusion of unusual fire years. Studies by Odion et al. (2004, 2010) were based on fire effects during a single year (1987), which Miller et al. (2012) described as unusual. Large areas burned at

below-average severity during 1987 due to abnormally strong inversions, and the fact that some of the fires burned well into fall (when conditions often favor lower severity fire). Miller et al. (2012) also noted that their own ability to detect a trend in fire severity could have been compromised by inclusion of both this year and 2008, which likewise experienced unusually large, low severity fires. Differences in the area analyzed could also affect evaluations of trends in high severity fire. For example, the Biscuit Fire, which was predominantly located in Oregon, included extensive areas of high severity fire and therefore could have influenced results of trends analyses for the Oregon and California Klamath Provinces combined versus the California Klamath alone (Miller et al. 2012).

Figure C: Relative probability of large (>1,000 ac) wildfires ("wildfire suitability") across the NSO's range (from Davis et al. 2011). Modeling was based on landscape and climatic characteristics of locations at which large wildfires occurred during 1970-2002 (left) and was compared with subsequent (2003-2009) locations (right).



Regardless of whether or not the extent of high severity fire increased in California during the last two decades, large severe fires have recently occurred in these areas, and they were responsible for most loss, degradation, and fragmentation of suitable breeding habitat for NSOs on federal lands (Davis and Dugger 2011, Davis et al. 2011; see above). These data cannot be used to project how fires in the future will affect NSOs since they do not necessarily represent past or future fire conditions or effects. However, it is highly unlikely that wildfires will cease to be a major source of habitat loss for NSOs in the future. Rather, climate change research has generally projected a continued increase in the number and sizes of wildfires and the annual area burned during coming decades (see *Potential Threats: Climate Change*). There is scientific uncertainty regarding recent and future trends in the extent of high severity fire in California. Nonetheless, large severe fires will at least occasionally occur in the future and will therefore continue to be a source of habitat loss and modification for NSOs in the state.

Comment [M36]: These aren't peer reviewed. More accurately USFS biologists are responsible for loss and degradation when they redraw PACS and re-designate habitat post fire.

Increases in the number and sizes of wildfires, and effects of fires on NSO habitat, have led to calls for widespread use of thinning and other forms of active management in dry forests (USFWS 2008, 2011, 2012a, Franklin and Johnson 2012). Some researchers and stakeholders, however, have expressed doubts regarding estimates of fire risk and effects on NSOs; concerns about potential effects of thinning on NSOs; and distrust of federal agency intentions (Hanson et al. 2009, Heiken 2010, DellaSala et al. 2013). As discussed in *Potential Threats: Timber Harvesting* (also Hansen and Mazurek 2010, USFWS 2011), there is currently little known about the effects of forest thinning on spotted owls. The available information suggests that low intensity thinning and prescribed fire could be judiciously used to reduce fire risk or restore habitat for NSOs. In contrast, poorly planned thinning could have unintended consequences for

Comment [M37]: This is wrong and biased. Where's Seamans and Gutierrez 2007, Williams et al. 2011. Whre is your citation for how thinning reduced fire risk and 'restores' habitat?

the subspecies. If thinning is used in landscaped occupied by NSOs, it should generally be limited to strategic locations outside of owl core areas and its effects should be monitored within an adaptive management framework. Land managers should also consider allowing more wildfires to burn under prescribed conditions; particularly at lower elevations in the California Klamath Province, where summertime inversions often minimize fire severity (Miller et al. 2012).

Comment [M38]: Where is your evidence that thinning affects fire behavior? This is an enormous leap in logic

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From: [redacted]
To: FGC
Subject: Northern Spotted Owl
Date: Monday, May 02, 2016 2:56:16 PM
Attachments: NSOCommentletterdocx.docx
Evaluation Process for NSO Info to Determine Compliance 919.9(g) and 919.10.pdf
CAL_FIRE_919.9g_Additional_Info_Explanation_Aug09.pdf
Revised USFWS Attachement B NSO Take Avoidance Analysis-- Interior 2-27-08.pdf
USFWS_ NSO_TakeAvoidanceGuidelines_ScienceSupportDocument_121409.pdf
USFWS_Info-for_NSO_TechnicalAssistance_020108.pdf
Revised_USFWS_Attachement_A_NSO_Take_Avoidance_Analysis--_Coast Redwood_3-15-11.pdf
NSO_Disclosure-and-Imapcts_Analysis_Interior_12.13.11.pdf
NSOAttach1.pdf
NSOAttach2.pdf
NSOAttach3.pdf
NSOAttach4.pdf

Please find attached my comments and associated attachments and documents on the DFW staff report.

Bill Snyder

Bill Snyder
[redacted]

April 22, 2016

Mr. Eric Silcar, President
California Fish and Game Commission
P.O. Box 944209
Sacramento, CA,

Subject: Department of Fish and Wildlife Staff Report Findings Regarding the Potential for Take of NSO Attributable to Timber Harvesting on Non-federal Ownerships

Dear President Silcar,

I appeared before you at the April 14, 2016 Fish and Game Commission hearing in Santa Rosa to provide comments on my review of the Department of Fish and Wildlife's (DFW) status review of 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.

The DFW staff report concluded that the continued existence of NSO is threatened by listing factors associated with a present danger associated with modification or destruction of its habitat. Specifically, the DFW staff report concludes that operations under the current regulations which govern timber harvesting on non-federal timberlands on the state are not adequate to prevent the loss of habitat. The basis for this conclusion is that the existing rule language of 14CCR 919.9(g) and 939.9(g) in combination with definition of NSO habitat in 14CCR 895.1 are not adequate to prevent loss of habitat during implementation of a harvesting operation and that the current rules do not adequately address potential cumulative impacts associated with the loss of NSO habitat attributable to timber harvesting.

Time was too brief at the Commission hearing to provide my comments regarding the staff analysis and conclusions regarding habitat loss under the existing Forest Practice Regulations. As I stated at the Santa Rosa Commission hearing, I am offering the comments contained in this letter based on my knowledge of the Department of Forestry and Fire Protection's regulatory process and Timber Harvesting Plan Review having served as the Deputy Director of the Department of Forestry and Fire Protection with responsibilities for the Forest Practice program area. While at the Department, I oversaw the transition of a transfer of evaluation of potential impacts of timber harvesting from the United States Fish and Wildlife Service (USFWS) to Cal Fire. As part of that transfer, the USFWS provided Cal Fire staff with guidance on measures necessary to avoid take of NSO for inclusion in operational implementation of Timber Harvesting Plans and Nonindustrial Timber Management Plans. The USFWS also provided the scientific support documentation for the recommendations and, similar to the conclusion reached by DFW staff, advised Cal Fire that operations pursuant to 14CCR919.9(g) and 939(g) would not be adequate in all cases to avoid take of NSO. Copies of these documents are available on the Cal Fire website but are attached to this letter for your reference.

Based on the advice from the USFWS and supporting documentation regarding best available science supporting their recommendations for measures to avoid take of NSO, Cal Fire concluded that a fair

argument had been raised pursuant to CEQA regarding potential for take of NSO through use of 14CCR 919.9(g) or 939.9(g) where assessment of habitat impacts was based on the 14 CCR 895.1 definitions. Based on the fair argument raised by the USFWS regarding take avoidance using these rule sections and the reality that Cal Fire review staff did not have the same level of expertise in evaluating the potential for take of NSO, Cal Fire requested and the USFWS provided guidance for plan preparers and reviewers to utilize for incorporation into THPs and NTMPs to avoid take. These documents are also attached for your reference. Cal Fire supported this guidance and based on the requirements of Board of Forestry and Fire Protection rule section 14 CCR 896 and the need to ensure consistency with California Environmental Quality Act (CEQA) and the federal Endangered Species Act (ESA), recommended that plan preparers follow the advice provided by the USFWS and include information in THPS and NTMPs to avoid take. Take avoidance through this process was determined to be consistent with the provisions of 14 CCR 919.9(e) and 939.9(e). This option is commonly referred to in THPs and NTMPs as Option e or Alternative e. Plans that included this option and the required analysis were reviewed for consistency with the Technical Assistance letter provided to Cal Fire by the USFWS. The USFWS did agree to continue providing Technical Assistance for NTMPs which they had previously provided TA(s) and were available on a case by case basis to provide Technical Assistance at the request of Cal Fire on specific plan issues.

I do at this point want to make it clear that the following comments are not being made on behalf of anyone but myself and should not in any way be construed to represent Cal Fire's position regarding the DFW staff analysis or recommendations.

Potential for Habitat Loss Leading to Take

I want to commend DFW staff and the level of analysis of the THP and NTMP staff provided in the staff report regarding timber harvesting operations and the regulatory framework in place to avoid take of NSO. However, in reviewing the staff report I was disappointed to note that much of the support for the determination that timber harvesting on private ownerships conducted under plans approved by Cal Fire have the potential to result in loss of habitat that could result in take of NSO was based on a conclusion that THPs were still largely reliant on Option G of the Forest Practice Rules. This conclusion by DFW staff was based on evaluation of 2013 THPs as well as a group of NTMPs relative to Options (Alternatives) described in approved harvesting plans .

The extent to which DFW concluded Option g was being utilized was not consistent with my understanding of how RPFs and Cal Fire were responding to the arguments raised by the USFWS regarding use of Option g. While I am retired, I do have a continuing interest in forestry and resource management along with a commitment to ensuring that forest management is encouraged while at the same time assuring that other resource values are protected. DFW staff analysis indicated a level of use of Option g than I would have expected and also indicated that sequential harvesting of habitat in Activity Centers as leading to cumulative loss of NSO habitat.

To satisfy my need to understand what was going on with the process and specifically why DFW was identified so many THPs that used Option g, I requested and received from Cal Fire a list of 2013 THPs within the range of NSO as well as a listing of NTMPs. Utilizing this information, I summarized the following information for each of the 2013 THPs and all of the listed NTMPs for a period inclusive of 2011 through 2015:

1. THP/NTMP Landowner

2. Acreage
3. Silviculture
4. NSO Option utilized
5. Pre and Post-harvest Nesting and Roosting Habitat acres
6. Pre and Post-harvest Foraging acres
7. Pre and Post harvest non-habitat acres

If Option e was indicated or in those instances where Option g was utilized but the plan preparer indicated that the USFWS habitat definitions and retention standards would met, I also evaluated whether or not the habitat retention standards recommended by USFWS were being met in terms of total habitat retention post-harvest and whether limitation on removal of habitat in excess of the retention standard was less than the 1/3 removal level recommended. Analysis was further divided into small and large landowners based upon a criteria of ownership criteria of approximately 30,000 acres or greater for large ownerships.

There were a total of one hundred and thirteen 2013 Timber harvesting plans identified within the range of the NSO. Please refer to Attachment 1 for a list of the plans. Thirty plans were submitted for ownerships where take had been authorized under a federally approved Habitat Conservation Plan. For the remaining THPs a no take standard was applicable. THP take avoidance was demonstrated through compliance with the following Forest Practice Rule options

NSO Take Avoidance Option utilized	Number of 2013 Plans
Spotted Owl Management Plan	8
Spotted Owl Resource Management Plan	5
USFWS Technical Assistance-Option e	70*
Option g	1**
Habitat Conservation Plan	30

*Includes one THP with an Habitat Retention Agreement with USFWS
**One plan included in the list fell outside of the range of the NSO but was within 1.3 miles of the NSO range boundary

Data and information in the plans does not appear to support the conclusion reached in the DFW staff report relative to the use of Option g. It my observation that where Option g was cited in the discussion of NSO protection measures that USFWS habitat definitions were used and that plans and habitat analysis indicated retention of habitat and limitations on removal of suitable habitat in excess of USFWS recommendations.

Further analysis was conducted on all of the Option e plans to determine level of compliance with guidance provided by the USFWS for habitat retention. Each of the THPS or NTMPs was reviewed as they are posted in the Cal Fire THP Library. Since the DFW analysis focused primarily on habitat loss, information collected from each plan focused on habitat. It was noted that each of the plans appeared to contain detailed calling record information, database checks, operational limitations in terms of timing and distance from occupied activity centers consistent with the USFWS recommendations, but I did not summarize this information.

Given the limited time, I focused my review on analysis of whether the individual plans complied with the total habitat retention guidance recommended by USFWS. This included retention of 200 acres of

Nest/Roost habitat and 300 acres of foraging habitat within 0.7 miles surrounding the Activity Center for THPs/NTMPs in the coast and retention of 250 acres of Nest/Roost habitat and 1085 acres of foraging habitat within 1.3 miles of the Activity Center for the northern area. Coast and Northern District plans were categorized as being consistent with USFWS guidance if habitat retention exceeded the recommended habitat retention levels. Also, a plan was considered to be consistent with the guidance in those instances where habitat was deficit but no removal of existing habitat was proposed.

It is recognized that for the interior plans, habitat is further broken down into low quality and high quality habitat and High Quality N/R and N/R with minimum retention for habitat within 0.5 miles of the Activity Center and for the area between 0.5 miles of the Activity Center and 1.3 miles. Time did not permit me, given other obligations, to analyze compliance at this level. Instead the analysis focused on whether the total habitat retention indicated in the THP/NTMP were consistent with USFWS recommendations. Nest Roost Habitat represented a combination of High Quality Nest Roost/and Nest Roost represented within the 1.3 mile radius. Foraging habitat represented a combination of foraging and low quality foraging habitat.

Further, given DFW staff report concerns about operations reducing habitat to minimum recommended retention levels and the extent of disturbance to NSO habitat in the vicinity of the Activity Center, an analysis was also conducted to determine whether post-harvest retention levels met the recommendation that no more than 1/3 of the suitable habitat in excess of 500 acres within 0.7 miles of the Activity Center and 1335 acres within 1.3 miles for Northern District Plans be removed during the course of timber operations. THPS and NTMPs were considered to be consistent with the USFWS guidance if they met or exceeded the USFWS recommended standard.

Attachments 2, 3 and 4 provide summary data and results from information gathered for the THPs and NTMPs which utilized Option E with respect to compliance with USFWS guidance for total habitat retention within 0.7 miles for coast plans and 1.3 miles for northern plans.

A total of 28 NTMPs were included in the analysis. The included NTMPs are listed in Attachment 4. Eight of the 28 NTMPs did not include an include an analysis of NSO habitat because there were no NSO Activity Centers located within 0.7 miles (coast) or 1.3 miles (northern) of the NTMP boundary. Nineteen NTMPs did include habitat information associated with 45 NSO Activity Centers. In all instances approved NTMPs met or exceeded the USFWS habitat retention requirements and were consistent with recommended limitations on disturbance of suitable habitat in excess of the habitat retention recommended. Given current Cal Fire requirements for subsequent surveys and demonstration of ongoing conformance to the USFWS guidance, cumulative harvests under a series of Notice of Timber Operations, are not anticipated to reduce habitat in a manner which is inconsistent with USFWS guidance without further Technical Assistance. Cal Fire will continue to provide Notices of timber Operations to DFW staff.

For the small landowner Option e THP's included in Attachment 3, 30 plans were analyzed to summarize habitat data. Seventeen of these plans indicated there were no Activity Centers located within 0.7 miles (coast) or 1.3 miles (inland) of the plan area. Twenty-seven NSO Activity Centers were noted on 14 plans. It was noted that post-harvest retention of suitable habitat had been met for all plans included in the analysis. There was one noted deviation from the recommendations for limiting disturbance to suitable habitat in excess of the retention levels recommended by USFWS. In this instance, the information indicated that 40% of the habitat in excess of the minimum would be operated.

For the large landowner Option e plans included in Attachment 2, 31 plans were analyzed to summarize habitat data. Seven of the 31 plans indicated there were no NSO Activity Centers located within 0.7 miles (coast) or 1.3 miles (northern) of the plan area. Twenty-four plans summarized habitat information for 52 different Activity centers. At twelve of the Activity Centers, it was noted that NSO habitat was deficit prior to operations. The files for these plans indicated that no timber operations would be conducted in existing suitable habitat and Technical Assistance letters from the USFWS or Cal Fire were included for operations under the plans. One THP indicated harvest in excess of 1/3 of the habitat in excess of USFWS recommendations.

It is my conclusion based on analysis of the habitat data in these plans and NTMPs:

1. Approved plans which do not rely on HCP take authority, Spotted Owl Management Plans negotiated with the USFWS, or Spotted Owl Resource Plan are consistent with USFWS guidance regarding retention of NSO habitat and removal of habitat in excess through timber operations under Option (Alternative) e.
2. There has not been, nor is there likely to be the widespread use of Option g since 2008.
3. Given Cal Fire's current direction to plan preparers and to Review Team staff that THPs submitted in the future will be expected to demonstrate consistency with USFWS recommendations.
4. Habitat loss to timber harvesting on nonfederal lands is not likely to result in "take" of NSO except as authorized through a HCP.
5. Recommendations by DFW staff to modify BOF rules are not necessary at this time.

Cumulative Impacts

DFW expressed concern regarding the potential for cumulative impacts of harvesting operations on non-federal lands and developed data regarding cumulative timber operations within activity centers. It was not possible given the time available to evaluate the information to determine silviculture sequentially over time, and the extent to which suitable habitat was impacted by harvesting. It is likely, as the DFW staff report indicates, that some of the silviculture applied adjacent to these activities was selection where it should be expected, dependent on the cutting cycle length, that one or more harvest entries would have taken place over an approximately 25 year period. It is also likely that habitat quality for previously unsuitable habitat over this period would have changed as stands grow and individual stems increase in size. For these reasons the DFW staff analysis appears to be overly-simplistic and not accurate. While there are likely approaches that could be taken to do the type of habitat analysis that would be necessary to overlay changes in NSO habitat attributable to operations and forest growth, the complexities of this type of analysis should be recognized. A simpler approach would be to focus on the potential for cumulative impacts of individual timber harvesting plans moving forward under USFWS recommendations. An argument can be made that as long as the USFWS recommendations are followed, habitat will be retained adjacent to each Activity Center at each subsequent harvest entry. For the balance of the area available for harvest, habitat suitability will likely change over time, but under USFWS recommendations removal of suitable habitat would be limited to no more than 1/3 of the NSO habitat available in excess of the USFWS recommended retention. It is hard to visualize that cumulative impacts to suitable habitat would not be avoided at the Activity Center scale.

At a larger NSO range scale in California, It would also be worthwhile to evaluate change in vegetation over time within the range of NSO given the likelihood that growth will exceed harvests in the region on non-federal lands. Over time this should, in the absence of wildfire, lead to increasing tree sizes and higher levels of canopy density which will positively influence dispersal of owls and increase the overall

quantity of habitat. Sources of data to this analysis are available in FIA and from large companies within the region.

It is my conclusion based on a quick review of the 2013 THPs and the 2011-2015 NTMPs that:

1. Cumulative impacts under the current Option e are unlikely given the requirement that at each harvest entry, habitat retention requirements would need to be met.
2. Harvesting of suitable habitat in in excess of retention requirements is currently provided under the guidance provided by USFWS. However, harvesting is limited to no more than 1/3 of the suitable habitat. The analysis provided on page 95 of the staff report should focus on what is being retained but instead gives a false impression of the level of habitat removal by first assuming that all acres harvested are in suitable habitat, and that sequential harvesting over long periods of time has removed habitat to the extent that "take" would be likely. Neither conclusion can be supported by the information provided.
3. Additional analysis of vegetation types and projections of growth would likely indicate increasing trends in tree size and canopy cover over time.
4. Adequate information is provided in each approved plan to ensure that Timber Harvesting Plans will maintain existing habitat.

Analysis of NTMPs

The DFW staff report provides and evaluation of impacts of NTMPs without evaluating the ongoing role of the USFWS regarding providing Technical Assistance for NTMPs where Technical Assistance had been previously provided. In general this would apply to NTMPs approved prior to 2008. As noted previously, NTMPS approved sometime shortly after 2008 handoff to Cal Fire would be approved under BOF Rules. While this could have resulted in NTMPS being approved under Option g, the analysis of 2011-2015 NTMPs indicated this was not the case. For NTMPs approved prior there is a likelihood that the USFWS is continuing to provide Technical Assistance. To the extent that the DFW staff failed to recognize the USFWS role in providing ongoing Technical Assistance by DFW, the data and information report does not provide an accurate assessment of the potential for "take" associated with habitat modification or conduct of timber operations under NTOs submitted for approved NTMPs.

It is my conclusion after reading the DFW staff report that:

1. Adequate information is provided at approval of NTMPs to ensure that timber harvesting will meet USFWS habitat retention requirements, and subsequent Notices of Timber Operations (NTO) will need to demonstrate conformance with USFWS survey protocols and include sufficient information in the NTO to confirm that "take" will be avoided.
2. Contrary to the DFW staff report Cal Fire does provide copies of all NTOs to DFW and would be able to provide DFW copies of all support documentation of "take" avoidance/habitat retention analyses provided by the Registered Professional Forester.
3. The DFW staff report does not address the ongoing role of USFWS in providing ongoing Technical Assistance and in so doing, does not provide an accurate picture of "take" avoidance procedures related to NTOs.
4. The analyses of NTMPs should be revised to reflect the role of USFWS.
5. The analysis of the potential or habitat removal associated with NTMPs after 2008 should be revised to reflect habitat analyses under the appropriate BOF Option. Option selected for the 2011-2015 indicated that Option e or its equivalent was utilized in 100% of the NTMPs I reviewed.

Ongoing Role of USFWS

The USFWS has and continues to provide assistance in assisting Cal Fire with evaluating the potential for take of NSO. The initial guidance provided to Cal Fire in 2008 regarding the potential for take under Option g of the BOF rules, the take avoidance measures provided initially in 2008 and revised subsequently since, and the scientific basis for the habitat classification, retention standards, timing of timber operations, spatial limitation on timber harvesting operations during the breeding season, and other recommendations are important to the determination of whether operations approved by Cal Fire will result in "take" of NSO. Unfortunately, the DFW staff report does not discuss the efficacy of the guidance provided by the USFWS to avoid "take" under the state standard nor is an evaluation of the science supporting the USFWS recommendation offered. I would recommend that before a finding is made by the Fish and Game Commission that timber harvesting is modifying habitat and allowing disturbance of breeding NSO that would lead to take, that an analysis of the USFWS "take" avoidance recommendations and supporting science be conducted by DFW staff. Only then, with a based on a conclusion by DFW that the USFWS is in error, should a finding be made that timber harvesting on non-federal lands is a factor which threatens habitat or breeding o the extent that "take" is likely.

Conclusion

In reviewing the 2013 approved THPs and the 2011-2015 NYMPs within the range of the NSO, it is clear that THPs and NTMPs did not rely on Option g of the BOF. Given that a "fair argument' has been raised by the USFWS which found that Option g of the BOF rules would not in all cases avoid "take", it is expected that the use of Option g would be limited going forward as well. Without analysis and demonstration by DFW staff regarding the science used by USFWS to justify the recommendations for "take" avoidance in THPs and NTMPs, a finding by the FGC regarding the potential for timber harvesting on non-federal lands to cause "take" is not supported by fact. Hopefully, the FGC will request DFW staff to reexamine the analyses and evaluation of potential for "take" taking a prospective as opposed to retrospective approach. "Take" under the federal definition is intended to be avoided if USFWS guidance is followed. Based on the analyses of approved THPs and NTMPs included in Attachments 2, 3 and 4, this is the case, as THP and NTMP submitters are moving forward under the provisions of HCPs where take is allowed , SOMPs, SORPs or Alternative e. "Take" should not be occurring under approved plans.

Also, while I recognize that the DFW staff report is not required to consider economics, the costs associated with complying with the USFWS recommendations are significant, particularly to small landowners. For this reason I would encourage FGC to include in its findings a recommendation that DFW staff work with USFWS staff to develop an approach to a small landowner Safe Harbor Agreement approach that would be cost effective for the landowners and provide for protection of NSO habitat. The current Habitat Retention Area approach used by USFWS on some NTMPs should be a workable model. In addition it must be recognized that small landowners are impacted by the complexity of the THP/NTMP process in its current form. I would urge the FGC to request that DFW staff work as quickly as possible to make a "consistency determination" with the current USFWS guidance and supporting science. Making a consistency determination, if possible, will go a long way towards allaying the apprehension that many small landowners have regarding the state listing. Lastly, I would urge the FGC to include a finding to have DFW staff work with USFWS and private landowners to evaluate the existing database with the goal of inactivating NSO activity centers that no longer meet agreed upon criteria and can be considered either abandoned or inactive.

For your information in addition to Attachment 1 thru 4, I am attaching guidance documents from the USFWS along with their evaluation of the underlying science which was submitted to Cal Fire.

Sincerely,

Bill Snyder

M e m o r a n d u m

To: Unit Foresters
Forest Practice Inspectors
Regional Review Team Foresters

Date: July 7, 2008
R12

Telephone: (916) 653-4995

From: **Chris Browder, Deputy Chief, THP Administration**
California Department of Forestry and Fire Protection
(CAL FIRE)

Subject: Evaluation Process for Northern Spotted Owl Information to Determine Compliance with CCR § 919.9(g) [939.9(g)] and 919.10 [939.10]

Introduction

The following generally describes the information the California Department of Forestry and Fire Protection (CAL FIRE) will request from plan proponents, where that information should be put in the timber harvesting document (plan), and which CAL FIRE staff will be responsible for review of such information when making take avoidance determinations for the northern spotted owl (NSO) associated with timber operations.

First Review

The first review team is responsible for determining whether the submitted plan or amendment provides adequate information to evaluate compliance with 14 CCR §§ 919.9(g) [939.9(g)] and 919.10 [939.10]. In addition to ensuring that adequate information has been included in the plan, the first review team will ensure that all NSO activity centers (ACs) identified in the California Department of Fish and Game's NSO Database Management System (NSO database) Report # 2 have been addressed in the plan and that the pre- and post-harvest habitat analysis tables provided demonstrate retention of sufficient post-harvest suitable NSO habitat.

The seventeen items listed below under **Plan Contents** are similar to the information currently required by the U.S. Fish and Wildlife Service (USFWS) for NSO Technical Assistance (TA). CAL FIRE has determined that this same information may be needed to allow the Director to exercise discretion and make a determination based upon information that is sufficiently clear and detailed (14 CCR § 897(b)(3)). However, CAL FIRE recognizes that a Registered Professional Forester (RPF) may deviate from the specific plan contents outlined below and still provide sufficient information to

determine that the plan is in conformance with the rules, take of NSO has been avoided, and potential significant and cumulative impacts have been addressed.

Plan Contents relative to NSO take avoidance and § 919.9(g) [939.9(g)]:

Under Section II, the following should be provided--

1. Whether the plan is in the range of the NSO.
2. How the plan will comply with 14 CCR § 919.9(g) [939.9(g)].
3. Whether there are known NSOs on, or within 1.3 miles of, the plan.
4. How the plan will address and provide protection for a previously unknown NSO discovered after take avoidance determination.
5. Appropriate enforceable language stipulating no timber operations shall occur until such time as all surveys for the current, or immediately preceding, survey period are complete, the results have been provided to CAL FIRE, and the results of CAL FIRE's take avoidance determination have been incorporated into the plan, including any resultant changes in timber operations to avoid take, if necessary.
6. A description of habitat retention levels and operational protection measures for any known ACs within 500 feet, 1000 feet, 0.5-mile radius (interior only, USFWS-recommended measures), 0.7-mile radius, and 1.3-mile radius, including a description of such measures.

Under Section IV, the following should be provided--

7. Cumulative Impacts: Have cumulative effects to the NSO been adequately addressed?

Under Section V, the following should be provided--

8. A copy of the most recent NSO database inquiry and results, including the most current date and version utilized.
9. A map showing the NSO assessment area within 1.3 miles of the plan boundary.
10. A map showing nesting, roosting and foraging habitat out to 0.7 mile from the plan boundary or out to 0.25 mile for plans that will only operate in unsuitable habitat to verify placement of survey route.
11. Pre- and post-harvest habitat analysis maps for the 0.5 mile- (interior only--USFWS-recommended measures), 0.7 mile- and 1.3-mile radius circles around all known NSO ACs.
12. Tables indicating the acres of suitable pre- and post-harvest nesting, roosting and foraging habitat within the 0.5- (interior only, USFWS-recommended measures), 0.7- and 1.3-mile radius circles for each known NSO AC.
13. Survey summary sheets, including the survey date, the survey start time, the survey results, including explanation and justification for any reasonable exception to the protocols.

14. Description of the definitions used for nesting, roosting and foraging habitat (current USFWS recommended definitions, Forest Practice Rule definitions, or other).
15. A clarification of the priority ranking used relative to habitat retention areas.
16. Description of the size, shape and configuration of habitat patches.
17. For take avoidance strategies that meet or exceed the requirements of 14 CCR §§ 895.1 (habitat descriptions) and 919.9(g) [939.9(g)] (protection measures and post-harvest habitat retention levels around known ACs), but do not meet the currently recommended USFWS measures for AC protection and post-harvest habitat retention, an analysis by a qualified person, which clearly and substantively demonstrates why the proposed, site-specific protection measures and level and configuration of post-harvest habitat retention will avoid take of the NSO. This analysis will need to address how the proposal will not significantly impair or disrupt feeding, breeding, nesting, and sheltering of the NSO (please see 14 CCR § 919.10 [939.10]) and may be performed by a biologist in direct employ of the timberland owner.

Field Review

The forest practice inspector will be responsible for determining and documenting (in the pre-harvest inspection report) whether:

1. Pre- and post-harvest habitat analysis provided in the plan for ACs located on the plan and within 1.3 miles of the plan boundary is consistent with the habitat descriptions used, the level of habitat retention proposed, rules requirements and ground conditions. Tools include: a review of aerial photos, ortho-photos, Google Earth (or other available tools), and field review. The evaluation will include field review of the habitat analysis contained in the plan to:
    a. Ensure habitat definitions used in the analysis reflect ground conditions.
    b. Determine whether the retained habitat quantities described in the plan appear accurate.
    c. Evaluate the priority ranking of habitat retention areas.
    d. Assess the appropriateness of the size, shape, and configuration of habitat patches.
2. Protection measures for activity centers appear adequate and in conformance with the rules.
3. Surveys appear complete and in adherence to protocol, insofar as is possible.[1]
4. Proposed operations are in compliance with 14 CCR § 919.9(g) [939.9(g)].

Second Review & Director's Signature:

The second review team (and Director's designee for signature) will review the plan record to ensure the plan is in compliance with 14 CCR § 919.9(g) [939.9(g)] and apply the criteria identified under 14 CCR § 919.10 [939.10] to determine whether take of the NSO will be avoided.

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[1] Reference "Protocol for Surveying Proposed Management Activities That May Impact Northern Spotted Owls," Revised March 17, 1992 (Endorsed by the U.S. Fish and Wildlife Service); and "Northern Spotted Owl Survey Data Analysis," February 27, 2008 (U.S. Fish and Wildlife Service)

CAL FIRE's Use of 14 CCR § 919.9(g) [939.9(g)] in Making Northern Spotted Owl Take Avoidance Determinations

The Forest Practice Rules (FPRs) require the California Department of Forestry and Fire Protection (CAL FIRE) to disapprove any timber harvesting plan (THP) if project implementation would result in the taking of the northern spotted owl (NSO) (14 CCR § 898.2 (f)). CAL FIRE bases its determination of take avoidance on substantial evidence provided by the registered professional forester (RPF) and other sources during the review of the THP. The information on which CAL FIRE bases its determination comes in the form of one of the six alternatives contained in 14 CCR § 919.9(a)-(g) [939.9(a)-(g)].

14 CCR § 919.9(g) [939.9(g)] is meant to be used where an NSO nest site or activity center has been located within the THP boundary or within 1.3 miles of that boundary. When the Board of Forestry and Fire Protection (BOF) adopted the NSO-related FPRs, 14 CCR § 919.9(g) [939.9(g)] gave THP submitters a performance standard to apply to known owl sites. BOF records note:

> The performance standards are based on the current [U. S.] F[ish and] W[ildlife] S[ervice] guidelines regarding their authoritative position on the adequate level of protection which must be afforded a known site. (Page 9, Final Statement of Reasons, BOF Rulemaking File #135)

Thus, authoritative biological expertise is built into the measures contained in 14 CCR § 919.9(g) [939.9(g)] and, when applied to a known NSO nest or activity center, are supposed to ensure avoidance of take. This built-in biological expertise should allow the RPF to apply the protection measures and post-harvest habitat retention levels prescribed in 14 CCR § 919.9(g) [939.9(g)] to known sites and avoid take. Therefore, individual review of such proposals by either the U. S. Fish and Wildlife Service (USFWS) or the California Department of Fish and Game (DFG) is not necessary, because of the inherent biological surety built into the protection measures and habitat retention levels contained in the rule.

In addition, 14 CCR § 919.10 [939.10] requires CAL FIRE to evaluate the information provided per 14 CCR § 919.9(g) [939.9(g)] to determine if "harm" or "harassment," the primary actions associated with timber operations that may result in take of the NSO, may occur. "Harm" may occur when timber operations adversely modify NSO habitat, and "harassment" may occur when timber operations significantly disrupt essential NSO life processes. Given that the measures contained in 14 CCR § 919.9(g) [939.9(g)] are based on USFWS guidelines regarding adequate protection for a known site against harm and harassment, as long as CAL FIRE is able to verify the location of any known NSO site, ensure the prescribed measures are adequately applied and post-harvest habitat retention should be achieved, then take of the NSO should be avoided.

However, since the adoption of the NSO-related FPRs in the early 1990s, USFWS has indicated that use of the measures contained in 14 CCR § 919.9(g) [939.9(g)] may not

always ensure avoidance of take of the NSO based upon more recent input by spotted owl researchers. USFWS notes:

> …use of [California] W[ildlife] H[abitat] Relationship[s] habitat definitions in the FPRs is unlikely to avoid take. This is because the WHR types considered to be NSO habitat (4M & 4D) are widely variable, and at the lower end of size class/density are typically poor habitat or non-habitat. 4M and 4D MAY be NSO habitat, but also may not. If no evaluation is made as to the ACTUAL stand characteristics, a large overestimation of available habitat may occur, harvest of "excess" habitat is permitted, and functional habitat is reduced to the point that take is likely. In addition, harvest within 4D and 4M stands typically reduces habitat quality significantly, sometimes to the point where take is likely, even when the post-harvest structure still meets 4M or 4D criteria. (1-24-2008 Email from USFWS' Brian Woodbridge to CAL FIRE's Chris Browder)

Relative to the coastal portion of the range in California USFWS notes:

> 919.9,939.9(g)(1) Within 500 ft. of the active nest site or pair activity center the characteristics of functional nesting habitat must be maintained. No timber operations shall be conducted in this area during the breeding season unless reviewed by the Department of Fish and Game and approved by the Director as not constituting a take. Timber operations may be conducted in this area outside the breeding season if appropriate measures are taken to protect nesting habitat.
>
> First of all, "active nest site or pair activity center" is not inclusive enough to apply to all the sites entitled to protection under the [Federal] E[ndangered]S[pecies [A[ct]. But aside from that, this rule is way too vague. "Timber operations" refers to everything involved in a logging operation up to and including the removal of trees. When "timber operations" refers only to hauling on public roads, (g) is more restrictive than necessary to avoid take. I have often considered timber operations/hauling during the breeding season to be not likely to result in take even when within 500 feet of mainline, open year-round, public roads. Highway 20 is a good example of where this rule is impossible to enforce or be applicable.
>
> Of course, "timber operations" also refers to the removal of trees. Given the very wide variety of conditions in which spotted owl nests are found, I don't even bother to try to define "nesting habitat". It is virtually impossible for anyone to say exactly what characteristics of the habitat within 500 feet of an activity center the owls keyed in on when selecting the nest site. How then can an RPF, the DFG, the Director, or the Service for that matter determine what measures are appropriate to adopt to protect nesting habitat other than to prohibit tree removal? The Eureka office of the DFG recognized this over 10 years ago when in a Memorandum dated 6/20/98 their instructions to all PCBs included the harvest restriction within the 500 ft. radius of a tree containing an NSO nest. This document contains what became known as the "standard protection measures"

that are still in use today. I'd be happy to provide a copy of this document at your request.

919.9,939.9(g)(2) Within 500-1,000 ft. of the active nest site or a pair activity center, retain sufficient functional characteristics to support roosting and provide protection from predation and storms.

Again, besides not being inclusive enough to include all activity centers entitled to protection, this rule asks a non-biologist, the RPF, to determine what is sufficient in terms of functional characteristics to be provided post harvest. It does not even suggest the DFG or the Director need approve what the RPF considers "sufficient". Also, the rule does not take into consideration 1,000 foot circles that are shared by two adjoining landowners, and as the review process does not utilize any information from one landowner's plan to the next, it is quite possible you could have two unqualified RPFs making independent determinations regarding what is sufficient to retain within a single roost zone, and CAL FIRE would have no idea that half of the roost zone had already been reduced to the first RPF's idea of what is sufficient when it approves the second. Furthermore, considering the habitat fragmentation that has resulted from many decades of timber management, nest trees are often found nearer than 1,000 feet to the edge of blocks of habitat. With no requirement that the 1,000 foot circle contain even a minimum amount of habitat described in the rules as roosting prior to proposing operations within the circle, this rule could very easily result in the only actual roosting habitat contiguous with the nest tree being reduced to some RPFs idea of minimum functionality without benefit of review by DFG, the Director, or anyone else besides CAL FIRE. Highly possible that the removal of habitat necessary to provide sheltering would occur.

919.9,939.9(g)(3) 500 acres of owl habitat must be provided within a 0.7 mile radius of the active nest site or pair activity center, unless an alternative is reviewed by the Department of Fish and Game and approved by the Director as not constituting a take....

Again, besides not being inclusive enough to include all activity centers entitled to protection, this rule ignores the well documented fact (Zabel et. al., 2001, and subsequent publications by many of the same authors) that spotted owl territories require a combination of habitat types to provide habitat for breeding, feeding, and sheltering, be functional and retain occupancy. This rule would allow nearly 50% of the habitat within the entire 995 acre/0.7 mile circle to be removed completely, and the other 50% to be reduced to the lowest possible habitat quality still considered suitable, outside the 1,000 foot circle. I doubt that there is a single piece of peer reviewed literature anywhere that concludes that a landscape reduced to the minimums allowed by this rule provides enough of a variety of habitat types to sustain spotted owls. And lastly, on what would the DFG or the Director base a decision that not even retaining 500 acres of the worst possible

quality habitat within 0.7 mile of an activity center would not constitute a take? (4-3-2009 Email from USFWS' Ken Hoffman to CAL FIRE's Chris Browder)

Relative to the interior portion of the range in California USFWS notes:

Possibly the best way for me to begin a discussion of the Service's evaluation of the FPRs for northern spotted owls (NSO) is to strengthen the language you've used ("may not avoid take") to pose the question. Service staff in the Yreka Fish and Wildlife Office believe that application of the FPRs *typically does not* avoid or reduce the likelihood of take of NSO. This is because the habitat definitions and retention standards in the FPRs represent minimum values that are below the habitat parameters associated with reasonable levels of territory occupancy, survival, and reproduction by NSO. In our experience, "take avoidance" has been accomplished through technical assistance, which ensured that the actual quality and quantity of habitat retained in a THP was indeed adequate.

The draft report "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" is in final review stage. This will provide detailed support for the conclusions I describe below.

Below I've inserted brief paragraphs (in bold) following the portions of the rules in question. My comments are in addition to those already provided by Ken Hoffman.

895.1 Definitions

Functional Foraging Habitat is dependent upon the presence and availability of prey on the forest floor or in the canopy; presence of accessible perching limbs; and adjacency to stands with canopy closures >40%. Average stem diameter is usually >6" D.B.H. for hardwoods and >11" D.B.H. for conifers among dominants, and codominants, and the total overhead canopy closure, including intermediate trees is at least 40%. Where overall canopy closure is >80%, foraging habitat is limited to areas with ample flight space below limbs and among stems. Foraging habitat in smaller size classes and lower percentage canopy closures must be justified by local information.

Functional Nesting Habitat means habitat with a dominant and codominant tree canopy closure of at least 40% and a total canopy (including dominant, codominant, and intermediates) of at least 60%. Usually the stand is distinctly multi-layered with an average stem diameter in dominant, and codominant conifers, and hardwoods >11" D.B.H. The stand usually consists of several tree species (including hardwoods) of mixed sizes. All nests, snags, down logs, and decadent trees shall also be considered as part of the habitat. Nesting substrates are provided by broken tops, cavities, or platforms such as those created by a hawk or squirrel nest, mistletoe broom, or accumulated debris. Owls are known

to occasionally nest in less than optimal habitat. Nesting areas may also be associated with characteristics of topographic relief and aspect which alter microclimates.

Functional Roosting Habitat during the territorial breeding season, consists of stands where average stem diameter is >11" D.B.H. among dominant and codominant trees. Hardwood and conifers provide an average of at least 40% canopy closure but the stand can have a high degree of variability. Stand size and configuration must be sufficient to provide multiple perch sites which are suitable for protection from various environmental conditions, including wind, heat, and precipitation.

The habitat definitions contained in 895.1 describe habitats typically considered unsuitable, or at best represent bare minimum conditions. Take may easily occur as repeated harvest entries reduce stand structure from whatever the owls originally occupied to the uniformly low values allowed under the Rules. For example, Functional Nesting Habitat is defined essentially as 4M/D or greater; however virtually all NSO research describes nesting habitat as consisting of stands of much larger trees, with nest sites associated with very dense clumps. The description of Functional Foraging Habitat suffers the same problem. In our review/assessment of NSO habitat relationships in the Interior zone, were unable to find any support for significant NSO use of habitat conditions allowed under the definitions in 895.1.

919.9, 939.9 Northern Spotted Owl

(g) Where a nest site or activity center has been located within the THP boundary or within 1.3 miles of that boundary, the RPF shall determine and document that the habitat described in (1)-(5) below will be retained after the proposed operations are completed:

(1) Within 500 ft. of the active nest site or pair activity center the characteristics of functional nesting habitat must be maintained. No timber operations shall be conducted in this area during the breeding season unless reviewed by the Department of Fish and Game and approved by the Director as not constituting a take. Timber operations may be conducted in this area outside the breeding season if appropriate measures are adopted to protect nesting habitat.

(2) Within 500-1000 ft. of the active nest site or pair activity center, retain sufficient functional characteristics to support roosting and provide protection from predation and storms.

There is strong evidence that habitat modification within the critical nesting core area is likely to result in take – this is partially the result of the low habitat quality allowed under the Rules (see comment above), but also because the actual habitat features selected by a given pair of NSO are unknown and likely associated with features such as dense clumps, deformed

trees, shading, aspect, water..etc that in combination form a nest site. Timber harvest typically disrupts, modifies, and removes these elements.

(3) 500 acres of owl habitat must be provided within a .7 mile radius of the active nest site or pair activity center, unless an alternative is reviewed by the Department of Fish and Game and approved by the Director as not constituting a take. The 500 acres includes the habitat retained in subsections (1) and (2) above and should be as contiguous as possible. Less than 50% of the retained habitat should be under operation in any one year, unless reviewed by the Department of Fish and Game and approved by the Director.

Studies of NSO territory occupancy and fitness relative to habitat quality and quantity strongly indicate that in the Interior zone, NSO rely on functional (= high quality) habitat at much larger scales than described in the Rules. The small patches of habitat within 500 – 1000' buffers (even if maintained well above the minimum "suitable habitat" definition) are much less than the 200-300-acre core areas associated with continued occupancy and reproduction by NSO. NSO nesting core areas often consist of multiple nest sites within a cluster of stands…not just one.

The 500 acre/0.7 mile COULD be an effective standard for take avoidance IF the retention acres were clumped closest to the nest and consisted of a balance of high-quality habitat. As written, however, 919.9(g)(3) allows harvest of virtually the entire core area down to unsuitable conditions.

(4) 1336 total acres of owl habitat must be provided 1.3 miles of each nest site or pair activity center, unless an alternative is reviewed by the Department of Fish and Game and approved by the Director as not constituting a take. The 1336 acres includes the habitat retained within subsections (1) - (3) above.

The buffer size and number of acres to be retained under 919(g)(4) are adequate. The problem here, as with (g)(3), is the poor quality habitat allowed under the definitions.

(5) The shape of the areas established pursuant to subsections (1) and (2) shall be adjusted to conform to natural landscape attributes such as draws and streamcourses while retaining the total area required within subsections (1) and (2) above.

This could be described as getting at the abiotic considerations in the FWS guidelines. Research on foraging behavior and nest-site selection demonstrate that NSO are strongly associated with landscape features such as lower slopes and stream courses The FPRs do not require any consideration of the spatial distribution of retained habitat; enabling harvest operations to occur in preferred areas where effects to NSO are relatively greater than, for example, upper slopes. (4-22-2009 Email from USFWS' Brian Woodbridge to CAL FIRE's Chris Browder)

In order to provide CAL FIRE with up-to-date guidance on how to avoid take of the NSO associated with timber operations, USFWS developed take avoidance scenarios and associated protection measures and post-harvest habitat retention levels. These are contained in USFWS documents entitled, "*Northern Spotted Owl Take Avoidance*

Scenarios," "*Attachment A: Take Avoidance Analysis-Coast*" and "*Attachment B: Take Avoidance Analysis-Interior*" (http://www.fire.ca.gov/resource_mgt/downloads/Revised%20USFWS%20Attachement%20B%20NSO%20Take%20Avoidance%20Analysis--%20Interior%202-27-08.pdf, http://www.fire.ca.gov/resource_mgt/downloads/U.S.%20Fish%20and%20Wildlife%20Service%20Review%20of%20THPs%20and%20NTMPs,%20Transition%20Documents%202-1-08.pdf and http://www.fire.ca.gov/resource_mgt/downloads/Revised%20USFWS%20Attachement%20A%20NSO%20Take%20Avoidance%20Analysis--%20Coast%202-27-08.pdf). The documents (USFWS guidelines) are meant to be used by CAL FIRE THP reviewers when assessing NSO take avoidance proposals, and by RPFs in designing NSO take avoidance strategies for inclusion in THPs. The USFWS documents indicate, in part:

> The following describes how the Fish and Wildlife Service determines whether take is likely to occur for spotted owls. While we believe this is the most effective manner in avoiding take, it is likely not the only manner in which take can be avoided. The [USFWS guidelines] are recommended tools to avoid take, but are not required approaches imposed by the Fish and Wildlife Service.

Clarifying the use of the take avoidance scenarios, USFWS notes:

> The guidelines describe how the U. S. Fish and Wildlife Service (Service) determines when take is likely at a course *[sic]* scale. That is, without any site-specific information, the guidelines outline the general methods that the Service employs to determine if take is likely. As stated in the guidelines, "while we believe [the guidelines are] the most effective manner in avoiding take, it is likely not the only manner in which take can be avoided."
>
> In years past, it was commonplace for our biologists to travel to the THP site and assess the habitat, conditions, local climate, habitat edge, and many other site-specific factors that aided in determining if take would be likely. We encourage your staff to adopt a similar approach in assessing THPs, as there are many instances when site-specific conditions provide insights that the guidelines cannot capture by virtue of their broad nature in describing the likelihood of take. The guidelines were not intended to be a hard rule for when take is likely; they simply describe how we evaluated the likelihood of take in a general manner.
>
> We encourage your staff to assess each THP in light of site-specific conditions and under the broader context of the guidelines we provided. (5-22-2008 letter from USFWS' Darrin Thome to CAL FIRE's Ruben Grijalva, http://www.fire.ca.gov/resource_mgt/downloads/USFWS%20Letter%20Regarding%20Clarification%20of%20Guidelines%20for%20Review%20of%20THPs%205-22-08.pdf)

Based on the guidelines and the subsequent clarification, CAL FIRE encourages RPFs proposing timber operations within the NSO evaluation area (synonymous with the range

of the NSO), or within 1.3 miles of a known NSO activity center outside of the NSO evaluation area, to adhere to the USFWS guidelines where possible. This is due to the USFWS' observation that following its guidelines "is the most effective manner in avoiding take." As stated, CAL FIRE recommends use of the USFWS guidelines, but, consistent with USFWS' statement that its guidelines are "likely not the only manner in which take can be avoided," CAL FIRE allows plan submitters to propose different NSO take avoidance strategies.

For those THP submitters that propose something different than the USFWS guidelines, CAL FIRE requires them to meet or exceed the minimum standards contained in 14 CCR § 919.9(g) [939.9(g)] and provide a site-specific analysis explaining how deviation from the USFWS Guidelines will still ensure take avoidance. This analysis must be performed by a qualified person and must clearly and substantively demonstrate why the proposed, site-specific protection measures and level and configuration of post-harvest habitat retention should avoid take of the NSO. This analysis has to address how the proposal should not significantly impair or disrupt feeding, breeding, nesting, and sheltering of the NSO. CAL FIRE believes that this approach is consistent with USFWS observations about the need to evaluate the actual timber stand characteristics and to assess each THP in light of site-specific conditions. This approach takes into account USFWS' observations that use of the measures contained in 14 CCR § 919.9(g) [939.9(g)] may not always ensure avoidance of take of the NSO and that its guidelines are "likely not the only manner in which can be avoided" and should not be viewed as regulation.

CAL FIRE believes that this approach is consistent with the requirements of the California Environmental Quality Act (CEQA). USFWS has presented a fair argument, based on substantial evidence, that use of the standards contained in the FPRs may not always avoid take of the NSO. CAL FIRE views this fair argument as applying to all THPs within the range of the NSO. Thus, CAL FIRE needs substantial evidence in the plan record that take of NSO has been avoided (PRC § 21081(a), 14 CCR §§ 15065(a)(1), 15091(a)(1) and (b)). By requiring THP submitters who propose deviations from the most recent guidance provided to CAL FIRE by USFWS to provide a site-specific data and analysis performed by a qualified person, CAL FIRE ensures that its decision is based on substantial evidence in light of the whole record.

The process that CAL FIRE goes through to determine that take of the NSO should be avoided is similar to that currently used by USFWS and private biologists. Details of the general process that CAL FIRE uses on THPs that propose to avoid take using 14 CCR § 919.9(g) [939.9(g)] is described in the July 7, 2008 CAL FIRE "*Evaluation Process for Northern Spotted Owl Information to Determine Compliance with 14 CCR §§ 919.9(g) [939.9(g)] and 919.10 [939.10]*" memorandum (http://www.fire.ca.gov/resource_mgt/downloads/Evaluation%20Process%20for%20NSO%20Info%20to%20Determine%20Compliance%20919.9(g)%20and%20919.10.pdf).

The process generally consists of:

a. Establishing historic activity center locations: CAL FIRE uses the DFG NSO database reports 1, 2 and 3 to identify activity centers on, and within 1.3 miles of, the plan area that require protection measures or habitat retention or both.

b. Assessing historic activity center habitat and protection measures:
   i. For activity centers (AC) located on the THP area, CAL FIRE evaluates each AC to ensure sufficient habitat is retained post harvest and appropriate protection measures are applied.
   ii. For activity centers located within 1.3 miles of the plan area (but not within the plan area), CAL FIRE evaluates each AC to ensure sufficient habitat is retained.

c. Confirming activity center locations and establishing new activity centers:
   i. CAL FIRE evaluates the most current year's survey results using the 3/17/92 "*Protocol for Surveying Proposed Management Activities that May Impact Northern Spotted Owls*" and any applicable USFWS technical assistance pertaining to survey protocol to confirm or change historic activity center locations and establish new activity centers.
   ii. If activity center locations change or new activity centers are identified, CAL FIRE requires the plan submitter to change the plan to reflect the new location(s) and apply necessary protection measures and retain sufficient habitat.

CAL FIRE uses the general process described above whether a THP submitter chooses to address the NSO using the protection measures and habitat retention levels recommended by USFWS or contained in the FPRs.

Revised February 27, 2008
Replaces February 1, 2008 version

Attachment B: Take Avoidance Analysis-Interior

I. Accuracy of NSO activity center location and status

1) Location
    a. Confirm plotted activity center location accuracy
        i. CDFG Reports 2 and 3
        ii. Data from adjacent landowners
        iii. Recent surveys
    b. Document deviations from CDFG locations
    c. Update habitat analysis maps as necessary
2) Status
    a. Valid site
        i. Review page 11 of protocol to determine
        ii. If not valid, report to CDFG for inclusion in next database update
    b. Current occupancy status
    c. Current reproductive status, if determined

II. Survey Effort

1) Coverage
    a. Surveys of nesting/roosting habitat out to 0.7 miles from THP boundary
        i. Use THP habitat map(s) to verify
2) Protocol survey
    a. Time of day
    b. Spacing between visits
    c. Number of surveys
    d. Survey dates
    e. Time spent at each call point
3) Follow up visit(s)
    a. Confirm that the area searched covers suitable habitat within response location/last known location within a logical distance.
    b. Time of follow up and duration of follow up
    c. Additional night surveys
        i. Review page 10 of protocol

III. Habitat

1) Typing
    a. Verify habitat typing with aerial photos, equivalent imagery, or field visits
    b. Changes to typing need to be reflected in the NSO habitat acres table and habitat analysis maps
    c. Post harvest typing

i. Post-harvest habitat typing must agree with the silviculture prescription

2) Definitions
   a. Nesting/roosting
      i. High Quality Nesting/roosting Habitat
         1. Basal Area = 210+ square feet, **and**
         2. ≥ 15" quadratic mean diameter (QMD) , **and**
         3. ≥ 8 trees per acre (TPA) of trees ≥ 26" in diameter at breast height (DBH) , **and**
         4. ≥ 60% canopy closure
      ii. Nesting/roosting Habitat
         1. A mix of basal areas ranging from 150-180+ square feet, **and**
         2. ≥ 15" QMD, **and**
         3. ≥ 8 TPA of trees ≥ 26" DBH, **and**
         4. ≥ 60% canopy closure
   b. Foraging
      i. Foraging Habitat
         1. A mix of basal areas ranging from 120-180+ square feet, **and**
         2. ≥ 13" QMD, **and**
         3. ≥ 5 TPA of trees ≥ 26" DBH, **and**
         4. A mix of ≥ 40%-100% canopy closure
      ii. Low Quality Foraging Habitat
         1. A mix of basal areas ranging from 80-120+ square feet, **and**
         2. ≥ 11" QMD, **and**
         3. ≥ 40% canopy closure

3) Quantities
   a. Within 1000 feet of activity center
      i. Outside breeding season (September 1 through January 31): no timber operations other than use of existing roads
      ii. During the breeding season (February 1 through August 31): no timber operations other than the use of existing, permanent, year-round roads

   b. Within 0.5 mile radius (502 acres) centered on activity center
      i. Retention of habitat should follow Section III. 4 of this document
      ii. At least 250 acres nesting/roosting habitat present, as follows:
         1. 100 acres High Quality Nesting/roosting Habitat, **and**
         2. 150 acres Nesting/roosting Habitat

      –AND–

      iii. At least 150 acres foraging habitat must be present, as follows:
         1. 100 acres Foraging Habitat, **and**
         2. 50 acres Low Quality Foraging Habitat
      iv. No more than 1/3 of the remaining suitable habitat may be harvested during the life of the THP

   c. Between 0.5 mile radius and 1.3 miles radius circles centered on activity center

i. Retention of habitat should follow Section III. 4 of this document
ii. ≥935 acres suitable habitat must be present, as follows:
    1. At least 655 acres Foraging Habitat, **and**
    2. At least 280 acres Low Quality Foraging, **and**
    3. No more than 1/3 of the remaining suitable habitat may be harvested during the life of the THP

4) Applying Habitat Definitions to Forest Stands
    a. Because the structural characteristics of forest stands used by Northern Spotted Owls are heterogeneous, management based on average values is unlikely to retain habitat suitability. For this reason, the habitat definitions provided under Section III.2.a and b. (above) are intended for application at the scale of roughly 20 acres (may be somewhat more or less depending on plot density or measurement technique). This means that within any given 20-acre area intended to serve as Nesting/Roosting or Foraging habitat, the values for QMD, basal area, TPA, and canopy closure should be variable, but stand averages should follow the standards provided under each habitat definition. Where ranges of values are provided (e.g. 150-180 ft^2 basal area), this means that the mean values can vary across the many 20-acre areas that make up a spotted owl core area and home range. It is important to recognize habitat quality will be compromised by timber harvesting that moves stand parameters towards uniformly low average values for stand density and tree size, even during multiple entries. This is particularly true at spotted owl territories with low (at or below quantities in Section III.3.a-c) amounts of habitat; in these cases the highest-quality habitat available should be identified and retained before treatment of other suitable habitat is considered.

5) Priority Ranking of Habitat Retention Acres
    d. Tree species composition
        i. Mixed conifer stands should be selected over pine dominated stands
    e. Abiotic considerations
        i. Distance to nest
            1. Nesting/roosting and foraging habitat closest to identified nest trees, or roosting trees if no nest trees identified
        ii. Contiguous
            1. Nesting/roosting habitat within the 0.5 mile radius must be as contiguous as possible
            2. Minimize fragmentation of foraging habitat as much as possible
        iii. Slope position
            1. Habitats located on the lower 1/3 of slopes provide optimal micro-climate conditions and an increased potential for intermittent or year-round water sources
        iv. Aspect
            1. Habitats located on northerly aspects provide optimal vegetation composition and cooler site conditions

v. Elevation
   1. Habitat should be at elevations of less than 6000 feet, though the elevation of some activity centers (primarily east of Interstate 5) may necessitate inclusion of habitat at elevations greater than 6000 feet.

6) Size and Shape of Habitat Patch
   a. Narrow strips of habitat (WLPZs, retention areas between clearcuts, etc.) may contain the characteristics of nesting/roosting habitat. However, when these narrow strips of habitat are surrounded by unsuitable or low quality habitats, they function as foraging habitat at best.
   b. Narrow strips of habitat (100m or less), provide for a lot of edge habitat and little to no interior habitat. Franklin et al (2000) describe interior habitats as the amount of spotted owl habitat ≥100m from an edge. They describe edge habitat as edge between spotted owl habitat and all other vegetation types.
   c. Because WLPZs, for example, are 100m or less in total width, they are considered edge habitats if surrounded by unsuitable habitat. Edge habitats do not provide for protection from predators nor do they provide the microclimates of interior habitats.

IV. Determination

1) If surveys are inadequate or do not meet the intent of protocol, take determination may not be possible.
2) If habitat typing is inadequate, take determination may not be possible.
3) If NSO home range habitat acres are below desired conditions (Section III. 2, 3, and 4), additional loss of suitable habitat can lead to take.
4) If NSOs are nesting, utilize seasonal restriction for all timber operations within 0.25 mile of nest (February 1 through August 31).
5) If effects are limited to noise disturbance (e.g., no suitable habitat in harvest units, but suitable habitat within 0.25 mile of units), a modified seasonal restriction may be used from February 1 through July 9
   a. Seasonal restriction applies to unsurveyed suitable habitat within 0.25 mile of unit boundary.
   b. If protocol surveys were conducted **and** did not detect reproductive NSOs, seasonal restrictions not warranted.
6) Multiple THPs located within a given NSO territory need to be considered collectively or a take determination may not be possible.

V. TA Letter Contents

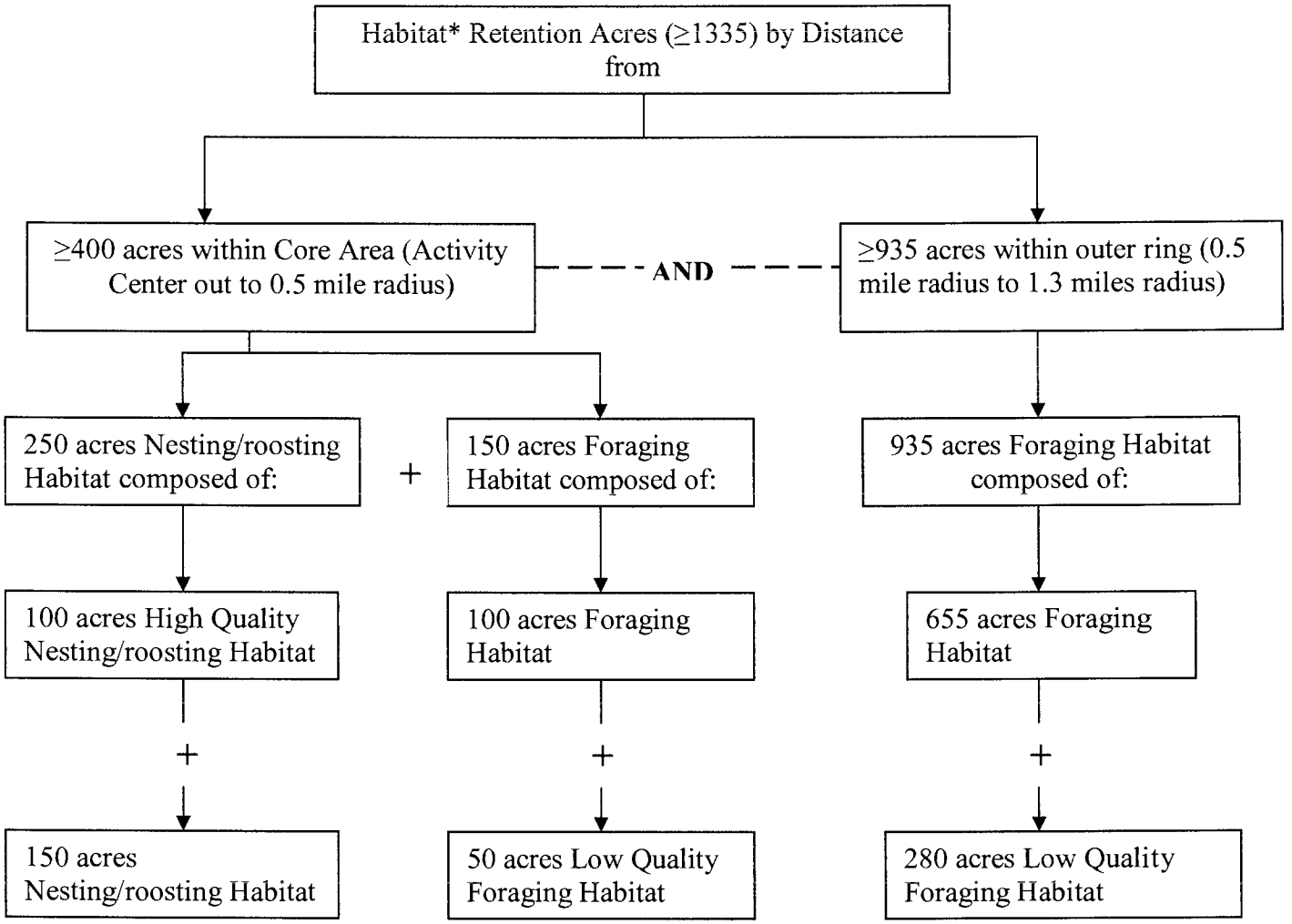
1) Date of written TA request
2) Date request received
3) Note if previous TA(s) provided in past
4) Number of acres within THP units
5) Amounts and types of silviculture prescriptions

6) Location of THP
    a. Township, Range, and Section
    b. Meridian
    c. County
7) Identify NSO activity centers returned by CDFG reports
8) Surveys conducted and activity center status
9) Logic behind take determination
    a. Habitat considerations
        i. Acres, quality, and location of suitable habitat pre- and post-harvest
        ii. Effects of timber operations on suitable habitat
            1. Degrade: suitable habitat is harvested but still functions in the capacity it did pre-harvest (i.e. Foraging habitat before harvest functions as foraging habitat post-harvest, nesting/roosting habitat pre-harvest functions as nesting/roosting habitat post-harvest)
            2. Downgrade: pre-harvest nesting/roosting habitat becomes foraging habitat post-harvest
            3. Remove: nesting/roosting or foraging habitat is harvested such that it no longer functions as habitat post-harvest
    b. Proximity of activity center to operations
    c. Survey data
10) Sunset date and seasonal restrictions
    a. If 2 year protocol and surveys are current and negative, additional TA needed if operations not completed by February 1, *YEAR* (review protocol page 3).
    b. If 1 year protocol and surveys are current and negative, additional TA needed if operations not completed by February 1, *YEAR* (review protocol page 3).
    d. If NSOs detected in previous surveys and operations are not complete before February 1, surveys are required to determine location and status of NSOs prior to operations during each breeding season that operations are ongoing.
    e. If no owls within 1.3 miles of THP (CDFG reports), no suitable habitat within units, **and** no suitable habitat within 0.25 mile of units, additional technical assistance may not be required.
11) Name of agency person to contact if there questions regarding TA

Literature Cited

Franklin, A., D. Anderson, R. Gutierrez, and K. Burnham. 2000. Climate, Habitat Quality, and Fitness in Northern Spotted Owl Populations in Northwestern California. *Ecological Monographs,* 70(4), pp. 539-590

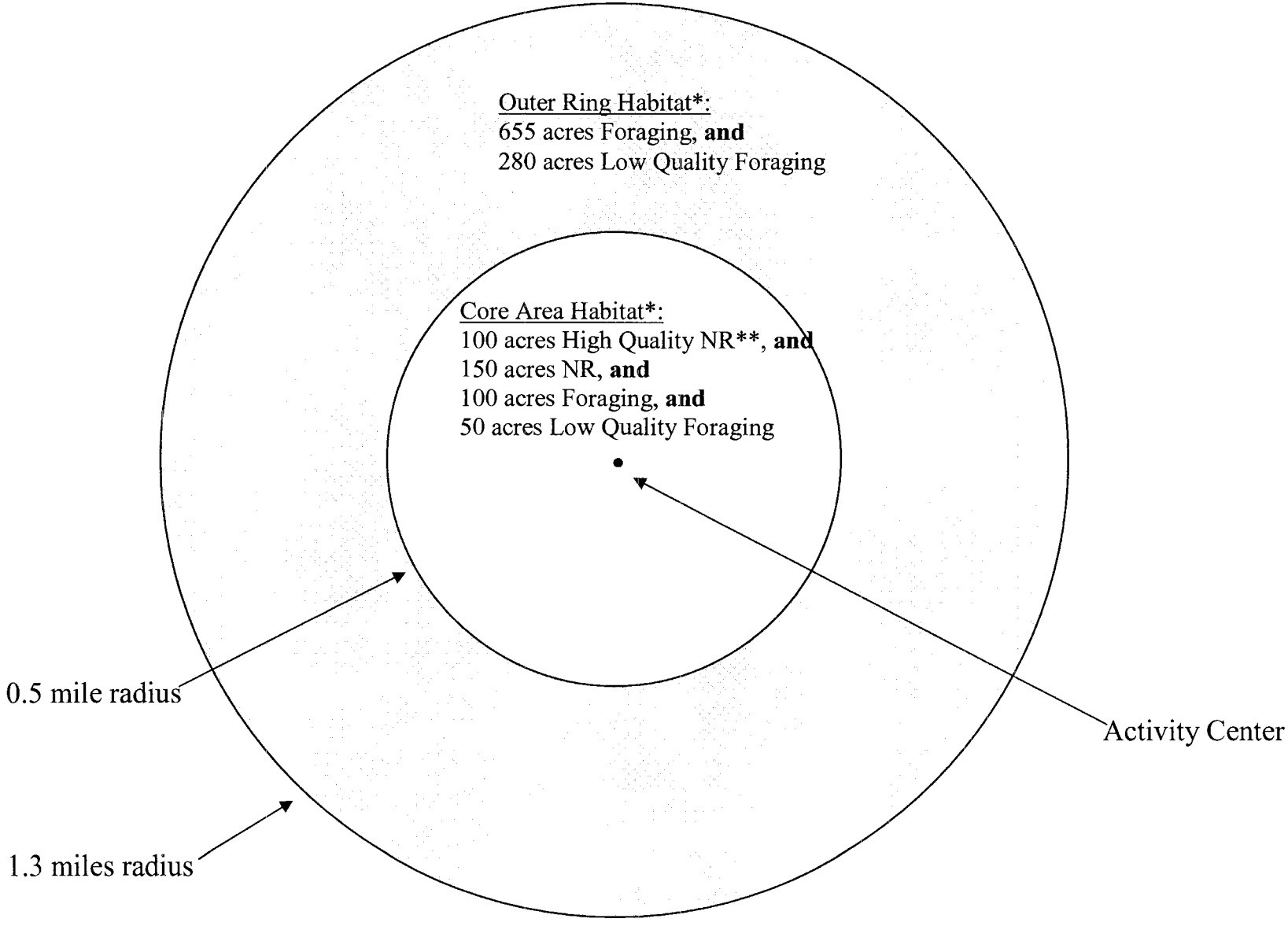
Revised February 27, 2008
Replaces February 1, 2008 version



*See Section III.2 for habitat definitions

Revised February 27, 2008
Replaces February 1, 2008 version

Habitat Retention within Core Area and 1.3 mile Home Range–Interior



*See Section III.2 for habitat definitions
**NR = Nesting/roosting

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

Introduction

Section I: Regulatory and operational aspects of take evaluation guidelines
A. – Regulation and definition of "take" under Endangered Species Act
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Regulatory definition of take
Process for estimating the likelihood of incidental take and establishing habitat retention guidelines
B. – Evidence indicating that regulatory guidance in the current Forest Practice Rules are not adequate to avoid incidental take of northern spotted owls
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Analysis indicating loss of territories under Forest Practice Rules

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Core area
D. – Habitat definitions
Nesting/roosting habitat
Foraging habitat
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Introduction

In 1999, the California Department of Forestry and Fire Protection (CALFIRE) requested that the U.S. Fish and Wildlife Service (FWS) review timber harvest plans (THP) and Non-industrial Timber Management Plans to ensure that such plans would not result in incidental take of northern spotted owls (NSO). For nearly a decade, the FWS

provided this technical assistance. At first, the criteria and thresholds employed by the FWS to make our take evaluations were based on habitat retention regulations in the California Forest Practice Rules (Title 14, California Code of Regulations) (FPRs), which were originally developed collaboratively by the FWS, California Department of Fish and Game (CDFG), CALFIRE, and the California Board of Forestry. However, as knowledge of the habitat relationships of this species increased after 1992, the FWS increasingly made use of new scientific information to guide our evaluations of the potential for incidental take. The accumulation of published research results, combined with direct field experience with management of NSO and their habitat, resulted in substantial changes in the quantity and quality of habitat the FWS considered necessary to maintain continued occupancy and reproduction at NSO territories.

In 2008, the FWS returned responsibility for THP review to CALFIRE, the authorized agency under the California Environmental Quality Act. As a part of this transfer, the FWS provided CALFIRE with documentation of the criteria and thresholds currently used by the FWS in making take evaluations. This documentation, hereafter called the FWS guidelines, represents the best scientific information available to the FWS upon which to base evaluations of the likelihood of incidental take resulting from timber harvest operations in the Northern Interior Region. The FWS guidelines are not regulations and are not intended to substitute for regulations; they do, however, provide the scientific and biological foundation for reviewing proposed projects and determining the likelihood of incidental take of NSO. In this report, we provide the scientific basis for the FWS guidelines.

The habitat descriptions within the FWS guidelines were developed to enable CALFIRE personnel (who may not have extensive experience with NSO biology and habitat associations) to evaluate the likelihood of take posed by a proposed THP. This process contrasts with the technical assistance process formerly conducted by the FWS, wherein NSO experts conducted detailed evaluations of stand structure, habitat quantities, and NSO survey results to support a determination of the likelihood of take. While the FWS believes that expert review should play a central role in these evaluations, it is also true that robust habitat retention guidelines may be used to avoid take. Application of habitat retention guidelines in the absence of expert review, however, may limit managers' flexibility to classify habitat based on specific local conditions and to design harvest proposals based on these conditions.

Evaluation of the scientific bases of the FWS guidelines for NSO in the Interior Region of California (Klamath Province) is dependant on understanding the concept and regulatory definition of take, the practical and operational considerations of determining the likelihood of take, and the information supporting our conclusion that existing habitat guidelines in the FPRs are not sufficient for avoiding take. It is also important to recognize the difference between the use of habitat guidelines in the determination of take versus descriptions of desired habitat conditions for conservation of NSO.

Section I: Regulatory and operational aspects of take evaluation guidelines

A. Regulation and definition of take under Endangered Species Act

Regulatory Authority

Section 9(a)(B) of the Endangered Species Act of 1973 (ESA) prohibits the take of listed species within the United States, except as provided in section 10 of the ESA, which allows for permitted incidental take on private lands. Section 9 is intended to protect individual members of listed species.

Regulatory definition of take

The ESA defines "take" as "…to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct." The term "harm" is further defined in 50 CFR 17.3:

> "Harm" in the definition of "take" in the Act means an act which actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering.

Process for estimating the likelihood of incidental take and establishing habitat retention guidelines

Although the regulatory definition of take clearly expresses the intent of the ESA's Section 9, it does not provide any metrics or criteria upon which a determination of take should be made. Because our reviews of proposed projects under section 9 are

typically conducted prior to project implementation, our determination is an estimate of the likelihood of take, based on the predicted effects of the project. Habitat retention guidelines such as those in the FPRs are intended to provide guidance as to the amount and quality of habitat that must be retained in order to avoid incidental take of NSO at sites where the species is known to occur. When the FPR guidelines were adopted in 1992, data relating habitat variables to occupancy, reproduction, and survival of NSO were limited. The FPR guidelines for avoiding incidental take of NSO were therefore based on comparison of proposed post-harvest habitat conditions with the amount and quality of habitat observed at occupied NSO sites described in various studies. Under this standard, habitat modification potentially could result in substantial reduction of reproduction, survival, and occupancy at NSO activity centers without the appearance of take, because habitat conditions still resemble other lower-quality NSO territories. NSO are known to occupy low-quality sites where their reproduction and survival are substantially reduced (Franklin *et al*. 2000, Dugger *et al.* 2005); the existence of these low-quality sites suggests that reliance on habitat conditions corresponding to the presence or absence of owls at historic territories represents a low bar for determining habitat thresholds and take.

Recent results from demographic studies of NSO in the Klamath Province provide new insights into the relationships between habitat and NSO population rates (e.g., occupancy, reproduction, and survival). By developing predictive models of these relationships, Franklin *et al*. (2000) and Dugger *et al*. (2005) introduce the concept of habitat fitness potential (HFP); "the fitness conferred on an individual occupying a territory of certain habitat characteristics" (Franklin *et al.* 2000:558). Habitat fitness

potential is a function of both the survival and reproduction of individuals within a given territory. Evaluation of habitat parameters influencing these rates provides a more rigorous measure of "significant impairment of essential behavioral patterns such as breeding, feeding, or sheltering" that is readily incorporated into review of timber harvest plans. By incorporating the concept of HFP, the FWS can evaluate the predicted effects of habitat modification on fitness of NSO potentially affected by a project. Evaluation of incidental take based on habitat modification that measurably and significantly reduces the fitness of NSO within the project area (as estimated by HFP models) provides a quantitative element to our estimation of "significant impairment of breeding, feeding and sheltering" in Section 9 of the ESA. Furthermore, HFP models also provide information allowing determination of significant thresholds that may occur, such as average habitat conditions corresponding to HFP < 1.0 (territorial pair not replacing themselves).

Description of the structural characteristics of NSO habitat and delineation of the range of habitat conditions corresponding to essential activities such as nesting, roosting, and foraging is a critical element of developing guidelines for evaluating the likelihood of incidental take. Determination of the amount of suitable habitat that must be retained in order to avoid incidental take of NSO is strongly influenced by the range of forest conditions that are classified as suitable habitat. The HFP models of Franklin *et al.* (2000), Olson *et al.* (2004), and Dugger *et al.* (2005) contain a limited number of habitat variables and relatively coarse definitions of NSO habitat, and therefore must be supplemented with additional information on forest structural parameters that support classification of forest habitat as suitable for nesting and foraging. Because the

structural attributes of habitat immediately surrounding nests are easily quantified, data supporting classification of nesting habitat are readily available (see section III.C). Foraging habitat, on the other hand, is more variable and spatially extensive, requiring intensive radio-telemetry studies to measure use of various habitat conditions by NSO. In recent studies by the National Council for Air and Stream Improvement (NCASI), correlations between habitat data from detailed forest inventories and nocturnal locations of radio-tagged NSO and California spotted owls were used to estimate resource selection function (RSF) models (Irwin et al. 2007a,b) that quantify complex relationships between the owls and their environment. These models allow evaluation of the relative use of specific forest structural variables, such as tree size class distribution and stand density, by foraging NSO. The studies of Irwin *et al.* (2007), combined with other telemetry studies (Solis and Gutierrez 1990), provide the basis of our definitions of suitable foraging habitat for NSO in the Northern Interior Region.

Criticism of the THP review process is frequently focused on the use of "thresholds" that simplify complex gradients of habitat quality into a single value (e.g., 40% suitable habitat within 1.3 mile radius, or 185 ft^2 of basal area). The FWS has long recognized that many different combinations of habitat structure and amount may support a viable NSO territory; evaluation of these combinations by technical experts has been our primary role in technical assistance. However, to maintain consistency and incorporate new information it is necessary to implement unambiguous habitat standards and criteria (i.e., thresholds) that delineate conditions under which take is deemed unlikely. Thresholds do not represent arbitrary lines through consistent data sets; rather, they represent the preponderance of evidence derived from careful evaluation of the

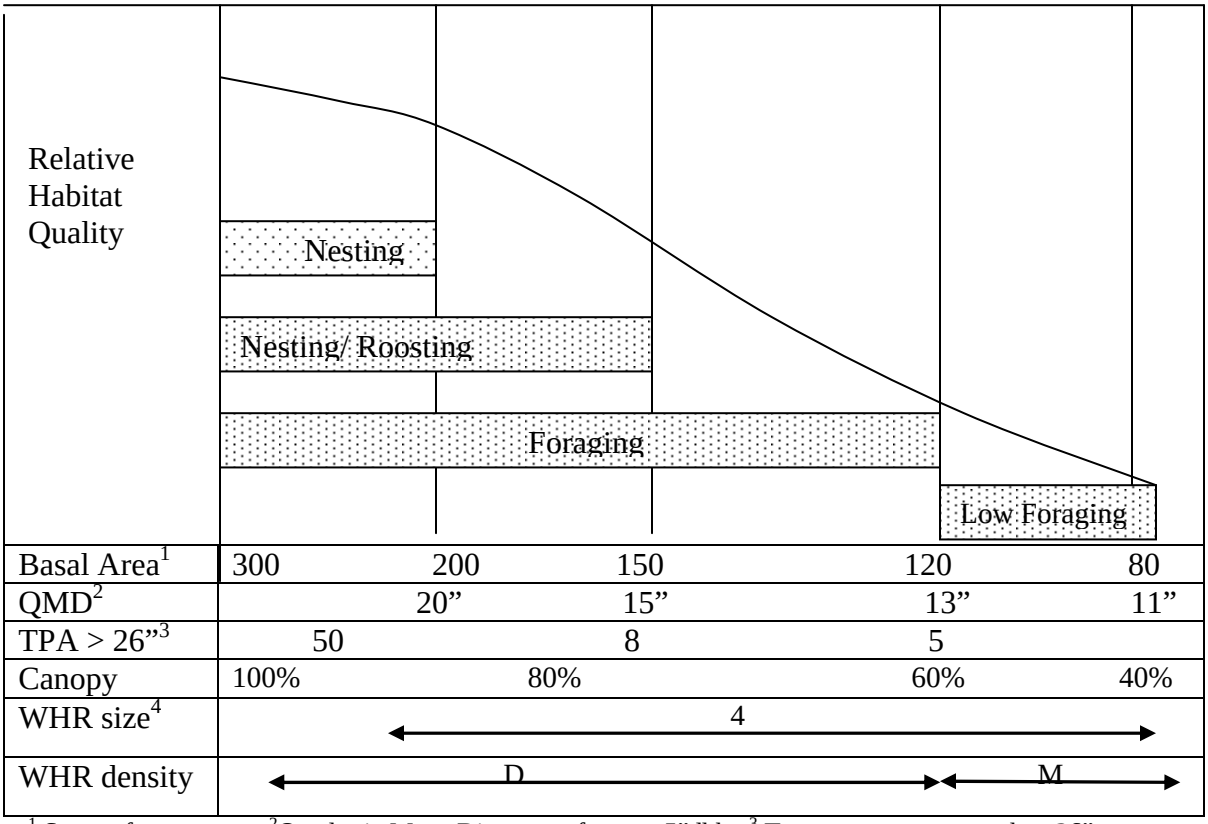
results and conclusions of many published studies, supplemented by data sets from credible sources.

Derivation of habitat thresholds from published studies consists of two consecutive steps. First, we consider the relationship or trend between habitat features and spotted owls. For example, most studies show that habitat use by foraging NSO is positively correlated with increasing tree size. These consistent, statistically significant relationships then serve as the foundation for subsequent choice of habitat values that correspond with viable NSO territories. We emphasize habitat parameters that receive disproportionate use by NSO, or are correlated with fitness. In this second step, we evaluate the pattern and distribution of data from a wide range of sources and attempt to identify ranges of values that correspond to consistent use. Deriving the central tendencies within complex, inconsistent data is a difficult task, and often requires input from the researchers responsible for published studies.

Despite consistent patterns of habitat selection by NSO, structural conditions of forest habitats occupied by NSO are highly variable, particularly in the diverse conifer-hardwood forests of the Klamath Province. We recognize that habitat retention guidelines must incorporate the range of habitat conditions used by NSO for nesting, roosting, and foraging, while at the same time ensuring that habitat conditions are not degraded to the point where significant impairment of breeding, feeding, and sheltering occurs. The FWS guidelines achieve this balance and provide a robust method for evaluating the likelihood of take because they describe a range of habitat conditions representing the central tendency for high-quality nesting habitat, nesting roosting

habitat, foraging habitat, and low-quality foraging habitat that may provide prey resources (Fig. I.A.1).

Figure I.A.1: Conceptual model of spotted owl habitat functions, relative habitat quality, and associated forest structural conditions.



[1] Square feet per acre, [2]Quadratic Mean Diameter of trees >5”dbh, [3] Trees per acre greater than 26” diameter at breast height, [4] California Wildlife Habitat Relationships System

This process must be distinguished from the simple application of “minimum habitat standards” that correspond to the lowest denominator of observed habitat use. To illustrate this, Figure I.A.1 depicts the relationship between California Wildlife Habitat Relationships system (WHR) class 4M and relative use of habitat by NSO. The FPRs classify 4M stands as suitable for nesting, roosting, and foraging by NSO. Although 4M encompasses a wide range of stand conditions, some of which may be suitable as

foraging habitat, it largely consists of stand conditions rarely used by NSO. For this reason, the use of existing minimum habitat standards such as those currently in the FPRs may result in take of NSO and are insufficient for programmatic use in take avoidance reviews of THPs.

B. Evidence indicating that regulatory guidance in the current Forest Practice Rules is not adequate to avoid incidental take of NSO

New information available

The current FPRs governing habitat retention for NSOs were developed in 1992 and predate much of the published research used in the FWS guidelines. In particular, studies correlating habitat and NSO fitness measures, and radio-telemetry studies of habitat use by foraging NSO (Irwin *et al*. 2007b) provide information directly applicable to evaluation of timber harvest-related impacts to NSO. During the past decade, the FWS has incorporated the results of new research into Technical Assistance on a plan by plan basis. However, with the February 2008 return of THP review to CALFIRE, the large number of recently published studies requires that a full synthesis of current knowledge be conducted and incorporated into updated take evaluation guidelines. This synthesis, and the habitat retention guidelines that it supports, are presented in section III of this report.

FWS experience in technical assistance process

The FWS' primary source of information regarding habitat conditions and NSO status on industrial timberlands in the Northern Interior Region has been our review of

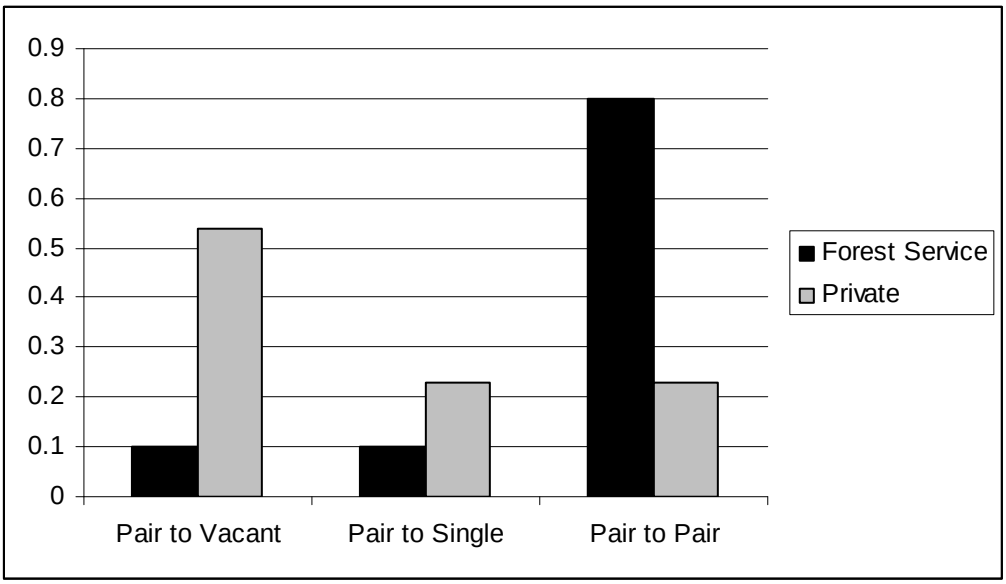
THPs. In the THP review process, FWS staff carefully evaluated historical NSO records and results of current surveys conducted in the plan area, as well as the habitat data provided in support of the THP. In cases where timber harvest was proposed in close proximity to an NSO activity center, the FWS evaluated habitat conditions in the field. The THP review process was conducted on a plan-by-plan basis, which does not permit systematic assessment of habitat conditions and NSO status across an entire ownership. However, our combined experience with hundreds of THPs indicates that the cumulative effects of repeated entries within many NSO home ranges has reduced habitat quality to a degree causing reduced occupancy rates and frequent site abandonment. In a large proportion of technical assistance letters to CALFIRE and industrial timberland owners during the past five years, we noted the lack of NSO responses at historic territories, and described habitat conditions considered inadequate to support continued occupancy and reproduction. This highlights the need for refined, objective criteria to determine the likelihood of NSO take when assessing THPs.

Analysis indicating loss of territories under Forest Practice Rules

To quantify the pattern of territory loss identified during the technical assistance process, we compared results of protocol surveys conducted at verified NSO territories supporting at least one year of occupancy by paired owls on Forest Service lands (N=196) with similar data from private timberlands (N=75) in Shasta and Trinity counties. The data set consisted of activity center status records in the California Department of Fish and Game's Spotted Owl Database (CDFG-NSO database), supplemented with territory locations and recent survey records received during technical

assistance. We first evaluated the validity of activity center records in the CDFG-NSO database, and eliminated 18 sites on private lands due to lack of verification of status. The remaining 57 private-land activity centers had verified NSO status in at least one year between 1989 and 2007; 44 of these sites had supported pairs during at least one year. Of these verified pair sites, 54% declined from pair status to no response, and an additional 23% declined from pair status to a territorial single owl during subsequent protocol surveys (Figure I.B.1). On Forest Service-administered lands, 80% of pair sites did not change status during the same time periods. While we recognize that annual variation in survey effort and results at this relatively coarse scale of resolution may influence this type of analysis, the strong differences in trends observed on private versus federal lands supports the contention that management on private timberlands is creating habitat conditions that do not support sustained occupancy by NSO.

Figure I.B.1. Status of valid historical northern spotted owl activity centers (pair sites only) when resurveyed after 5-10 years. Data are from U.S. Fish and Wildlife Service technical assistance records and USFS monitoring records



Section II: Summary of the FWS NSO Take Evaluation Guidelines

The FWS guidelines provide a step-by-step process for evaluation of the likelihood of incidental take posed by proposed THPs (Appendix A). The steps include: (1) verifying the accuracy of NSO activity center location and status; (2) reviewing survey coverage and results to determine whether protocol has been met; and (3) evaluating the quantities and quality of habitat to be retained at each NSO home range potentially affected by the proposed THP. To assist the reader, this section briefly summarizes the analysis areas, habitat quantities, and habitat definitions used in step (3) of the FWS guidelines. See Appendix A for the full take avoidance analysis guidance provided to CALFIRE.

The FWS guidelines specify three spatial scales that form appropriate analysis areas for evaluation of habitat at NSO home ranges. The fourth analysis area, the 'outer core' represents the area between the core area and the total home range area (Table II.1). Within each analysis area, the FWS guidelines describe the quantities of habitat that must be retained in each of four functional habitat categories to avoid incidental take of NSO. These categories are: (1) high-quality nesting/roosting habitat; (2) nesting/roosting habitat; (3) foraging habitat; and (4) low-quality foraging habitat (Table II.2). Descriptions of the stand structural attributes corresponding to each functional habitat category are given in Table II.3. Table II.4 provides additional considerations for use in prioritizing habitat areas for retention.

Table II.1: Spatial scales used to evaluate habitat conditions at northern spotted owl activity centers in the Northern Interior Region

Analysis Area	Radius	Area
Nest Site	1000 feet	70 acres
Core Area	0.5 mile	502 acres
Outer Ring	0.5 – 1.3 mile	2,908 acres
Home Range	1.3 miles	3,410 acres

Table II.2: Minimum quantities of habitat to be retained within four functional habitat types to avoid incidental take of northern spotted owls on private timberlands in the Northern Interior Region

Analysis Area	Functional Habitat Type				
	High-quality NR	Nesting/ Roosting	Foraging	Low-quality Foraging	Total Suitable
Core area	100 acres	150 acres	100 acres	50 acres	300 acres
Outer 'ring'			655 acres	280 acres	935 acres
Home range (total)	100 acres	150 acres	755 acres	330 acres	1335 acres

Table II.3: Values for selected stand structural parameters used to classify nesting/roosting and foraging habitat for northern spotted owls in the Northern Interior Region

Parameter	Functional Habitat Type			
	High-quality NR	Nesting/Roosting	Foraging	Low-quality Foraging
Basal area	≥ 210 ft^2 /acre	Mix ranging from 150 to ≥180 ft^2 /acre	Mix ranging from 120 to ≥180ft^2 /acre	Mix ranging from 80 to ≥120ft^2 /acre
Quadratic mean diameter	≥ 15 inches	≥ 15 inches	≥ 13 inches	≥ 11 inches
Large trees per acre	≥ 8	≥ 8	≥ 5	NA
Canopy closure	≥ 60%	≥ 60%	≥ Mix ranging from 40 to 100%	≥ 40%

Table II.4: Guidelines for prioritizing habitat to be retained to avoid incidental take of northern spotted owls on private timberlands in the Northern Interior Region

Tree Species composition	Mixed conifer stands should be selected over pine-dominated stands
Abiotic considerations	
Distance to nest	Nesting/roosting and foraging habitat closest to identified nest trees, or roosting trees if nest unknown
Contiguity	Nesting/roosting and foraging habitat within the 0.5 mile radius must be as contiguous as possible
	Minimize fragmentation of foraging habitat as much as possible
Slope position	Habitats located on the lower 1/3 of slopes provide optimal microclimate conditions and increased potential for intermittent or perennial water sources
Aspect	Habitats located on northerly aspects provide optimal vegetation composition and cooler microclimates
Elevation	Habitat should be at elevations < 6000 feet, lower elevations are preferred

Section III: Scientific Basis for NSO Take Evaluation Guidelines

A. Fundamentals of spotted owl habitat relationships

Northern spotted owls exhibit clear, consistent patterns of habitat association, and these associations must provide the foundation of habitat management guidelines. In the 1990 *Conservation Strategy for the Northern Spotted Owl*, the Interagency Scientific Committee (Thomas *et al.* 1990) stated that:

"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....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."

Fifteen years later, the conclusions of the Interagency Scientific Committee were echoed in the *Scientific Evaluation of the Status of the Northern Spotted Owl* (Courtney *et al.* 2004), who found that the habitat attributes identified by Thomas *et al.* (1990) remain important components of NSO habitat. Notably, positive relationships were found with the aforementioned attributes whether the samples of owl and random locations were

within old-growth forest, non-old growth forest, National Parks, public land, private land, or an Indian Reservation. In 2008, the *Recovery Plan for the Northern Spotted Owl* (USFWS 2008) again reiterated the association of NSO with older forest conditions, stating; "Spotted owls generally rely on older forested habitats (Carroll and Johnson 2008) because such forests contain the structures and characteristics required for nesting, roosting, and foraging." A major advance in our understanding of NSO habitat relationships from Thomas et al. (1990) to the present is that we now have a much better understanding of the spatial scale of habitat selection (Hunter et al. 1995), Meyer et al. 1998, Zabel et al. 2003) and relationships of habitat to owl fitness (Franklin et al. 2000, Dugger et al. 2005).

III.B: Analysis Areas

Management guidelines for territorial organisms are typically spatially explicit; that is, they apply to an area corresponding to the movements and activity patterns of the individuals occupying a territory. Spotted owls are territorial raptors that range widely in search of prey but are 'anchored' during the breeding season to a nest site (central-place forager). Evaluations of NSO habitat are usually conducted at two spatial scales; the home range and core areas. The home range is the "area traversed by the individual in its normal activities of food gathering, mating, and caring for young" (Burt 1943:351). Within home ranges, areas receiving concentrated use, typically surrounding the nest site and favored foraging areas, are called core areas. Because the size and pattern of NSO space use are typically unknown, estimates of use areas are derived from radio-telemetry studies. The analysis areas employed in the FWS guidelines are based on a subset of

estimates that describe the outer perimeter of NSO activity areas, thus incorporating the areal extent most likely to contain important resources. In this section we review and summarize information related to home range size and patterns of space use within home ranges by NSO.

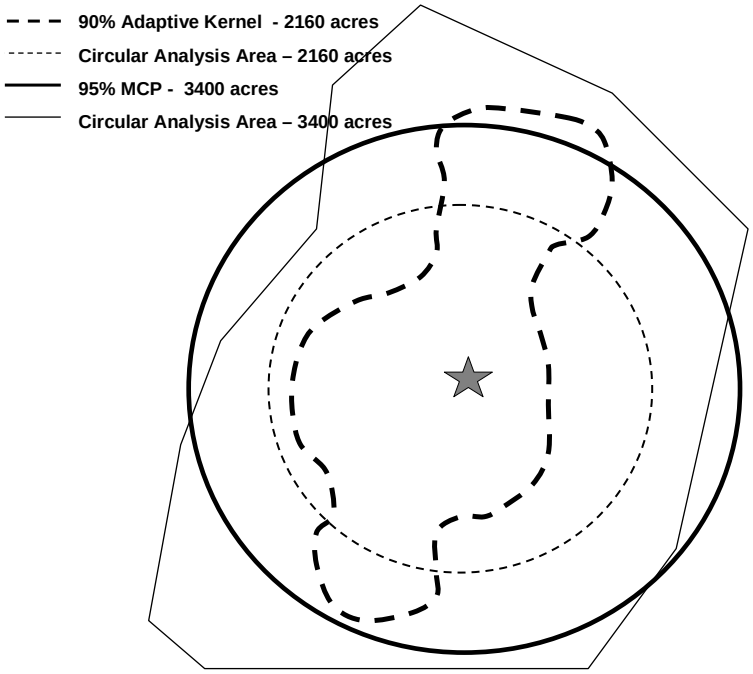
Home Range (1.3-Mile-Radius, 3,410-Acre) Analysis Area

The FPR guidelines for avoiding take of NSOs during timber operations in the Klamath Province indicate the amount of habitat to be retained within 1.3 miles of activity centers. The size of this area was originally based on estimated median annual home range sizes for NSO pairs in northern California, Oregon, and Washington (Thomas *et al.* 1990, USFWS 1992). There are numerous analytical techniques for estimating home range sizes based on animal locations (reviewed in Powell 2000). One of the most commonly used classes of home range estimators is the minimum convex polygon (MCP). Because MCP consists of a single polygon encompassing all or the majority of telemetry locations, this method may be viewed as providing a representation of the area *containing* the home range, including unused and infrequently used areas (Powell 2000, Laver and Kelly 2008). Generally biased large, MCP home range estimates provide relatively conservative values on which to base the size of habitat-analysis areas. Other home range estimators such as utilization distributions (e.g., kernel density estimates: see Powell 2000) de-emphasize areas less frequently used and typically yield smaller home range estimates that, when converted into circular analysis areas, may exclude distant, but potentially important, patches of habitat (see Figure 2.b.1). At the upper end of utilization distributions (e.g.; 90-100%), however, kernel estimates may resemble MCP polygons and circular analysis areas (Anthony and Wagner 1999).

Estimates of home range size are also important for developing management prescriptions and evaluating impacts of human activities on NSO. For the purpose of quantifying habitat and the impact of proposed modification of habitat, median home range estimates from radio telemetry studies are transformed into circular 'analysis areas' that are used as surrogates for actual home ranges (Fig. 2.b.1). Based on the median MCP home range estimate for NSO pairs in the Klamath Province, the FWS currently uses a circular analysis area of 1.3 mile radius (3,398 acres; Thomas *et al.* 1990, USFWS 1992). While this practice provides a practical and uniform method for quantifying NSO habitat, circular analysis areas will generally not correspond directly with areas actually used by NSO. Landscape pattern, both in terms of topographic features and vegetation pattern; prey distribution, abundance and availability; as well as distribution and/or abundance of competitors and predators are all likely to influence NSO territory and home range shape (Anthony and Wagner 1999).

Our understanding of space use by NSO is limited by lack of comparability among published studies due to variation in estimation methods, duration and seasonality of data collection, and whether estimates are for individuals or pairs. By looking for commonalities among studies and using a "strength of evidence" approach, however, we can evaluate whether the available information provides broadly modal values that are useful for conservation planning. Because the primary purpose of this review is to evaluate appropriate spatial scales for evaluation of effects to territorial paired NSO, we have focused on conservative estimates of year-round (annual) space use by NSO pairs.

Figure III.B.1: Comparison of MCP and adaptive kernel home range estimates with corresponding circular analysis areas at an actual northern spotted owl home range.



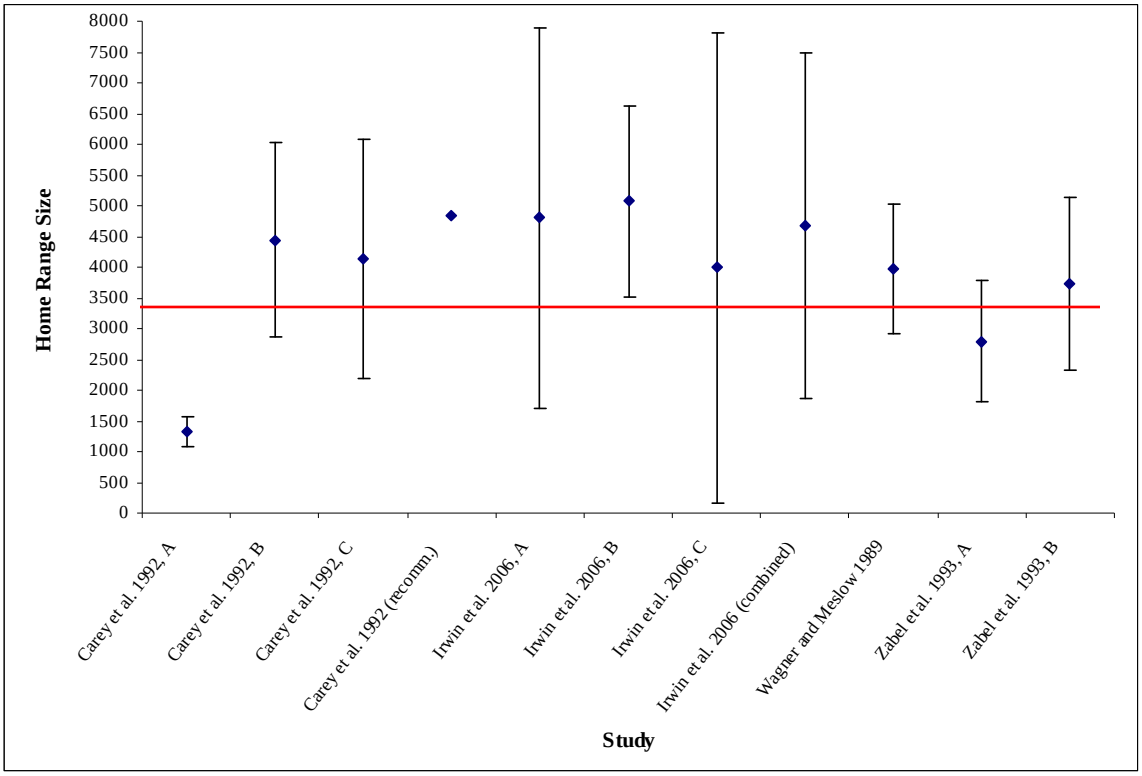
The sizes of NSO home ranges are influenced by a variety of factors, including geographic differences in diets and habitat characteristics (Carey *et al.* 1992, Zabel *et al.* 1995). Therefore, we restricted our assessment of the validity of the 1.3-mile-radius analysis area to home range studies conducted within the Klamath Province. Because the outer analysis area should be large enough to include habitat needed to meet all major life history requirements and should accommodate areas important to both members of most pairs, we largely restricted our evaluation to studies that provided MCP estimates of the sizes of home ranges used year-round by pairs or paired individuals.

Home range studies conducted in the Klamath Province after the FPR guidelines were formulated support the use of a 1.3 mile radius analysis area, as this distance is encompassed by the confidence intervals of nearly all the home range studies we

compiled. (see Figure III.B.2). Carey *et al.* (1992) found that the sizes of NSO pairs' home ranges were related to the type of forest and the degree of forest fragmentation (Table III.B.1). Pairs' home ranges in clumped, old forest were substantially smaller than the 1.3-mile-radius analysis area, whereas those in fragmented forest were somewhat larger than the analysis area. The authors suggested that management areas should be slightly larger than 1.3 miles, however, to encompass oblong-shaped home ranges. Zabel *et al.* (1993) provided estimates of 21 pairs' home ranges in two different study areas in the region (see Table III.B.2). They did not report the sizes of pairs' annual home ranges, but the average sizes of pairs' nonbreeding season home ranges were similar to the size of the FWS guidelines' outer analysis area. Pairs' annual home ranges would likely be larger than these values because their breeding- and nonbreeding-season home ranges probably do not completely overlap. In a different study, the mean cumulative pair MCP home range size for 9 pairs in the Medford, Oregon area was 3,971 acres (SD=1,063 acres), which is also similar to the 1.3-mile radius analysis area (Wagner and Meslow 1989). A fourth study by Irwin et al. (2006) showed greater mean home range sizes for 3 study areas in the region than the 1.3-mile radius analysis area used in the existing FWS guidelines (see Table III.B.3). The FWS recognizes that because of differences in methodology between these studies and those originally used to support the 1.3-mile radius analysis area (see Thomas *et al.* 1990, USFWS 1992), the results cannot be rigorously compared (see Powell 2000, Laver and Kelly 2008). Nonetheless, mean MCP values for home range area from more recent studies suggests that the outer analysis area should be somewhat larger than the 1.3-mile (3,410-acre) guideline (Figure III.B.2). We elected to retain the current guideline because, 1) the high degree of variability in MCP

estimates in Figure III.B.2 does not compel us to reject the home range estimate in our existing guidelines in exchange for any particular alternative size, and 2) disproportionately high use of habitats closer to nest sites by NSO (see core areas, below) leads us to emphasize habitat conditions closer to nests, rather than expanding home range area.

Figure III.B.2: Mean Minimum Convex Polygon home range sizes (acres) for northern spotted owls in the Klamath Province, CA and OR. Error bars represent ±1 standard deviation. Horizontal line shows the size of the Fish and Wildlife Service guidelines' outer analysis area (3,410 acres).



Carey et al. 1992 = pairs' annual home ranges, A = Klamath Mountains, clumped forest, B = Klamath Mountains, fragmented forest, C = Umpqua, fragmented forest; Irwin et al. 2006 = paired-individuals' annual home ranges, A = Hilt, B = Medford, C = Yreka; Zabel et al. 1993 = pairs' nonbreeding-season home ranges, A = Mad River, B = Ukonom.

Table III.B.1: Minimum Convex Polygon estimates of annual home range sizes (acres) for northern spotted owl pairs within different types of forest in the Klamath Province, Oregon (Carey *et al.* 1992)

Area*	No. Pairs	Mean	SE
MCC	3	1317	143
MCF1	5	4139	870
MCF2	6	4438	645
Recommended	-	4843	-

*MCC = mixed-conifer, clumped, Klamath Mountains old forest; MCF1 = mixed-conifer, fragmented, Umpqua River Valley, old forest; MCF2 = mixed-conifer, fragmented, Klamath Mountains old forest.

Table III.B.2: Minimum Convex Polygon (100%) estimates of home range sizes (acres) for northern spotted owls in the Klamath Province, California (Zabel *et al.* 1993)

Study Area	Mad River		Ukonom	
	Mean	SD	Mean	SD
Individuals				
NB*	1989	890	2572	857
B*	1043	447	1460	578
A*	2456	1124	2847	1374
Pairs				
NB*	**2787**	986	**3721**	1409
B*	1436	368	1900	756

*NB = nonbreeding season home range; B = breeding season home range; A = annual home range.

Table III.B.3: Estimated cumulative (100%Minimum Convex Polygon) home range sizes (acres) for selected* territorial individual northern spotted owls in the Klamath Province, California (Irwin *et al.* 2006)

Study Area	Yreka	Medford	Hilt	Combined
No. Individuals	7	9	10	26
Mean	3987	5073	4805	4678
SD	3819	1557	3098	2816

*Excludes owls that did not exhibit normal ranging behavior (i.e., moved to new territory, or influenced by active timber harvest).

Core Area (0.5-Mile-Radius, 500-Acre) Analysis Area

The FPR guidelines for avoiding take of NSO during timber operations specified the amounts of habitat to be retained within 0.7 mile (986 acres) of activity centers. The 0.7-mile-radius scale was adopted in the FPR guidelines based on a study by Thomas *et al.* (1990), who found that circles of this size surrounding NSO nest sites contained significantly more suitable habitat compared with random circles. This study, however, only illustrated the importance of suitable habitat, rather than the amount of habitat required by NSO or the appropriate scales for evaluating and managing habitat (Bart 1995). The results of studies conducted after the FPR guidelines were formulated (see below) have indicated that a 0.5-mile-radius (500-acre) area around activity centers is a more appropriate scale at which to evaluate the amounts of habitat required by breeding NSO in the Klamath Province. These studies provide three primary lines of support for the core area size used in the FWS guidelines; distribution of locations of radio-telemetered NSO, territorial spacing of NSO, and studies comparing relative habitat selection at different scales.

Resources such as food and breeding and resting sites are patchily distributed in heterogeneous landscapes, such as those prevalent within the Klamath Province. In such landscapes, animals are likely to disproportionately use areas that contain relatively high densities of important resources (Powell 2000). These disproportionately used areas are referred to as core areas. One of the most influential studies of wildlife core areas was focused on NSOs in northern California (Bingham and Noon 1997). Although this study's sample size was small, it used an unusually rigorous method for determining the sizes of core areas (Powell 2000). Bingham and Noon (1997) noted that the combined

size of NSO pair members' core areas is probably more meaningful than the sizes of individuals' core areas. Bingham and Noon (1997) estimated core areas by evaluating the ratio of total home range area to the area encompassing different adaptive kernel utilization distributions (UD), and found that individual NSO in northern California spent 60 to 75% of their time in their core areas, which comprised only 21 to 22% of their home ranges. The mean core area size for NSO pairs in the Klamath Province was 411 acres (166 ha; SE=26 ha; range=168-455 acres [68-184 ha]; n=7 pairs). Bingham and Noon (1997) also recommended that management guidelines attempt to meet the area requirements of most individuals in a population by accounting for variability in core area size; for example, by using the mean core area size plus one standard error. The addition of one standard error to the mean size of pairs' core areas totaled 475 acres (192 ha) for the Klamath Province data set. NSO core areas had diverse shapes due to variation in the distribution of foraging and roosting locations (Bingham and Noon 1997). However, assuming a circular shape for the purposes of evaluating and managing habitat, an area this size would have a radius of 0.49 mile. Carey and Peeler (1995) found remarkably similar results outside the Klamath Province, in southern Oregon.

We evaluated home range estimates from other studies in the Klamath Province in light of these patterns. By approximating Bingham and Noon's (1997) methodology, we evaluated kernel estimates in Irwin et al. (2004; Table 2) to estimate core area size (only 50%, 75% and 95% UD estimates were available). The 75 percent fixed kernel estimate accounted for 21 to 27 percent of the total (95%) home range, and the 75 percent adaptive kernel accounted for 23 to 30 percent, suggesting that a UD somewhat lower than 75 percent would yield core area estimates very similar to those obtained by Bingham and

Noon (1997). The addition of one standard error to individuals' mean 50 percent and 75 percent kernel density home range estimates from three different study areas in the province suggested that 500-acre analysis areas would include much of the important habitat for most breeding NSOs (Irwin *et al.* 2004, Table 2.b.4). Application of the same criteria to the results of a telemetry study in southwestern Oregon suggested that pairs used somewhat larger core areas than in other parts of the Klamath Province (Anthony and Wagner 1999, Table 2.b.5). Much of this study area is comprised of a checkerboard of public lands and industrial timberlands (Anthony and Wagner 1999, Dugger *et al.* 2005). To the extent that the amounts, quality, or contiguity of habitat have been reduced on these timberlands due to timber harvesting, NSO in this area may have larger area requirements than in parts of the province with less harvesting (Carey *et al.* 1990, 1992, Zabel et al. 1992, 1995).

Table III.B.4: Fixed kernel and adaptive kernel cumulative home range estimates (acres) for individual NSOs in the Klamath Province (Irwin *et al.* 2004).

Study Area	**Yreka**	**Medford**	**Hilt**	**Combined**
No. Individuals	9	10	11	30
No. Telemetry Points	3151	5041	2414	10606
50% Fixed Kernel				
Mean	128	210	147	162
SE	18	26	22	14
Mean + 1 SE	146	236	169	**176**
75% Fixed Kernel				
Mean	364	510	435	439
SE	38	47	54	29
Mean + 1 SE	402	557	489	**468**
50% Adaptive Kernel				
Mean	239	303	262	269
SE	47	39	42	24
Mean + 1 SE	286	342	304	**293**
75% Adaptive Kernel				
Mean	584	706	673	657
SE	124	68	91	54
Mean + 1 SE	708	774	764	**711**

Table III.B.5: Adaptive kernel home range estimates (acres) for NSO pairs in southwestern Oregon (Anthony and Wagner 1999).

Utilization Distribution	**50%**	**75%**
Mean	413	1443
SE	67	259
Mean + 1 SE	**480**	**1702**

The territorial spacing of NSO provides additional support for using a 0.5-mile-radius core area to evaluate and manage habitat for NSO in the Klamath Province. An individual's territory is thought to be the portion of the home range that both contains important resources and is economically defensible (Meyer *et al.* 1998). Therefore, average territory size provides a useful scale at which to evaluate core area habitat.

Wildlife biologists frequently use half the mean or median nearest neighbor distance to estimate the size of the defended portions of home ranges, or the portions of home ranges that are used exclusively by resident pairs (e.g., Reynolds and Joy 1998). Half the mean and median nearest neighbor distances for nesting NSO near Willow Creek were 0.49 mile (0.79 km: Hunter *et al.* 1995) and 0.44 mile (0.71 km: Franklin *et al.* 2000), respectively.

A third line of support for using a 0.5-mile-radius area for evaluating and managing habitat is provided by studies that modeled the habitat relationships of NSOs in the Klamath Province. Two studies in the region found that habitat within a 0.5-mile radius of nests differed more strongly from the general landscape compared with larger areas around nests (Hunter *et al.* 1995, Meyer *et al.* 1998, Zabel et al. 2003). While these results do not necessarily indicate that NSO are most selective of habitat at the 0.5-mile-radius scale, they do show that evidence of habitat selection by NSO is weaker at scales larger than this. Stronger support for the validity of assessing and managing habitat at the 0.5-mile-radius scale is provided by studies that modeled habitat-based fitness (Franklin *et al.* 2000, Dugger *et al.* 2005) and presence (Zabel *et al.* 2003) for NSO in the region. These studies found that important NSO-habitat relationships were well-captured at scales of 0.44 to 0.50 mile around activity centers.

III.C: Quantity, Distribution, and Configuration of Habitat

The FPR take-avoidance guidelines required that 40% of the 1.3-mile-radius analysis area and 50% of the 0.7-mile-radius analysis area be retained as suitable habitat. The FWS guidelines kept the 40% requirement because it is consistent with the results of

research in the Klamath Province. However, the FWS guidelines require greater concentration of habitat near the nest or activity center than did the FPR guidelines. This concentration occurs through: (1) a decrease in the size of the inner analysis area (from 0.7- to 0.5-mile radius; see *Analysis Areas*) and (2) requirement that part of the total amount of foraging habitat (see *Habitat Definitions*) in the home range be retained within the inner analysis area. These changes are supported by studies conducted in the Klamath Province after the FPR guidelines were formulated.

Several types of information are available for evaluating the quantities, distribution, and configuration of habitat that must be retained in order to avoid take of NSO. The strongest type of information relevant to evaluation of take relates the fitness of NSO to characteristics of their habitat (Franklin *et al.* 2000, Olson *et al.* 2004, Dugger *et al.* 2005). Habitat-based fitness, or habitat fitness potential (HFP), is "the fitness conferred on an individual occupying a territory of certain habitat characteristics" (Franklin *et al.* 2000:558). HFP is a function of both the survival and reproduction of individuals within a given territory. Habitat-based modeling that accurately predicts the presence ("occupancy") of breeding NSO (Zabel *et al.* 2003) is another important tool for evaluating the species' habitat relationships. This modeling assumes that NSO gravitate toward areas likely to confer high fitness but does not directly relate habitat characteristics to the survival and reproduction of owls. Descriptions of areas around nests, and comparisons between them and random areas, are additional sources of information for investigating NSO-habitat relationships. This approach provides information about the habitat associations and preferences of NSO but must be cautiously considered because it does not relate habitat descriptions to the fitness of owls. For

example, the average quantity of habitat around a sample of NSO nests could be higher than what is available around random locations, but still be lower than what is required for persistence of individuals or the population.

Comparisons among habitat studies can be problematic because researchers often define habitat differently and use different source data to classify vegetation (see Table III.C.1). Nonetheless, all studies in the Klamath Province have found that NSO exhibit strong relationships with older, more structurally complex, conifer-dominated forest classes. The concordance of these findings enabled the FWS to evaluate the guidelines relative to the quantities, distributions, and configurations of older forest within analysis areas. Spotted owls also forage within intermediate (younger and/or more open) forest classes (see *Habitat Definitions*, below). One study (Zabel *et al.* 2003; see below) found a positive association between NSO in the Klamath Province and moderate amounts of intermediate forest (see Table III.C.1) at the core area scale. This habitat class was based on conditions known to be used by foraging NSO. Other studies in the region have described the proportions of analysis areas comprised of intermediate forest classes but have not found positive associations between them and NSO. These forest classes often included conditions that receive little or no use by NSO, however, and are therefore not directly comparable with foraging habitat as defined by Zabel *et al.* (2003) and the FWS guidelines (see *Habitat Definitions*, below). There is currently no information for evaluating the proportion of intermediate forest that should be retained at the home range scale in order to avoid take of NSO in the Klamath Province.

Table III.C.1: Descriptions of suitable or selected habitat from studies of northern spotted owl-habitat relationships in the Klamath Province

Study	Location	Classification Method	Description of Selected or Suitable Habitat
USFWS 1992, Bart 1995	Washington, Oregon, northern California	research synthesis (various methods)	conifer-dominated forest with a multi-layered canopy, average DBH[1] >30 inches, ≥60% canopy cover, decadence (snags, logs, deformed trees)
Anthony and Wagner 1999	southwestern Oregon	aerial photographs, ground reconnaissance	conifer-dominated forest with a multi-layered canopy, ≥40% canopy cover, decadence, large snags and logs; characterized by trees ≥30 inches DBH and ≥200 yrs
Carey *et al.* 1992	southwestern Oregon	aerial photographs, forest inventory data, ground reconnaissance	multi-layered canopy, average DBH of dominant trees >39.4 inches, large snags and logs
Dugger *et al.* 2005	southwestern Oregon	aerial photographs, ground reconnaissance	conifer or mixed forest, ≥100 yrs; characterized by trees ≥13.8 inches DBH
Franklin *et al.* 2000	northwestern California	satellite imagery	forest comprised of ≥40% conifers, conifer QMD[2] ≥21 inches, hardwood QMD ≥6 inches, canopy cover ≥70%
Gutiérrez *et al.* 1998	northwestern California	satellite imagery	≥30% canopy cover, >50% of conifer basal area comprised of trees ≥21 inches DBH
Hunter *et al.* 1995	northwestern California	satellite imagery	≥30% canopy cover, >50% of conifer basal area comprised of trees ≥21 inches DBH
Meyer *et al.* 1998	western Oregon	aerial photographs	conifer-dominated forest, trees ≥80 yrs and/or multi-layered canopy
Ripple *et al.* 1997	southwestern Oregon	aerial photographs	conifer-dominated forest, average DBH ≥19.7 inches, canopy cover ≥60%
Solis and Gutiérrez 1990	northwestern California	timber type classification	average DBH >20.7 inches
Zabel *et al.* 1993	northwestern California	topographic maps, aerial photographs, and orthophotoquads	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	modified timber type classification, varied geographically	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

[1] DBH: Diameter at breast height
[2] QMD: Quadratic mean diameter

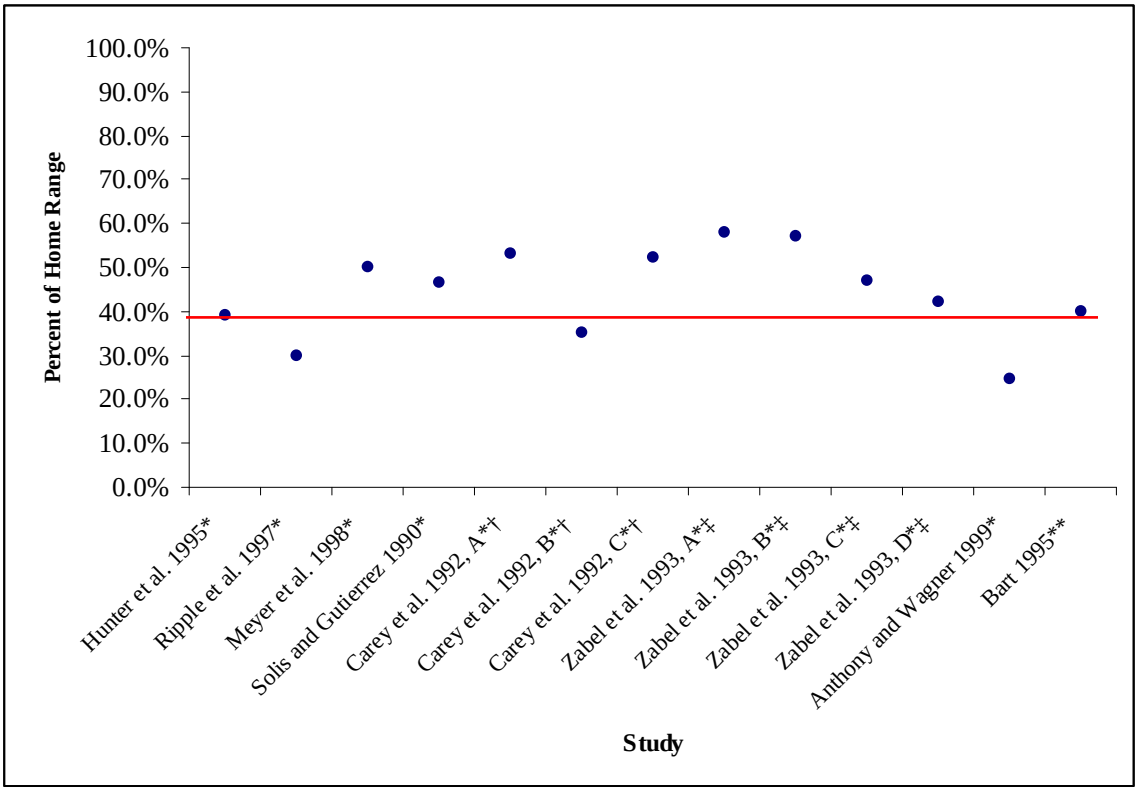
H*ome Range (1.3-Mile Radius)*

Bart (1995) evaluated the 1992 draft recovery plan's (USFWS 1992) requirement that at least 40 percent of the estimated home range be retained as suitable habitat. Using demographic data from throughout the NSOs' range, including the Klamath Province, he calculated that populations are stable when the average proportion of suitable habitat in home ranges is 30 to 50 percent. In a related comment on the FPR take-avoidance guidelines, Bart (1992:3) noted that "…lambda probably reaches 1.0 (stable population) when suitable habitat declines to somewhere between 40 and 55 percent. Since the Service must have good evidence that take did occur, not just that it might have occurred, using a value of 40 percent seems reasonable." Bart's (1992) conclusions continue to be supported by the results of recent research.

Studies have reported a wide range of mean proportions of older forest (ca. 24 - 58 percent; see Figure III.C.1) in home range-sized areas around NSO nests or roosts in the Klamath Province and adjacent areas (Solis and Gutiérrez 1990, Carey *et al.* 1992, Zabel *et al.* 1993, Hunter *et al.* 1995, Ripple *et al.* 1997, Meyer *et al.* 1998, Anthony and Wagner 1999). Variation in proportions of habitat was likely due to multiple factors, particularly differences in habitat classification (see Table III.C.1), but also including sizes of analysis areas and study season (i.e., breeding versus non-breeding), as well as geographic differences in the abundance and quality of habitat. Regardless, the central tendency of these means is about 45 percent; a somewhat higher percentage than the FWS guidelines. We retained the 40 percent threshold, however, because; 1) the FWS guidelines specify amounts of high-quality habitat, rather than a single 'suitable habitat'

category, and; 2) FWS guidelines incorporate a higher standard for classifying forest habitat as 'suitable' than was used in many of the studies in Figure III.C.1, and; 3).

Figure III.C.1: Proportions of older forest (see Table III.C.1) at home range scales around northern spotted owl territory centers in the Klamath Province, CA and OR. Horizontal line shows the proportion of older forest required by the Fish and Wildlife Service guidelines (40 percent).

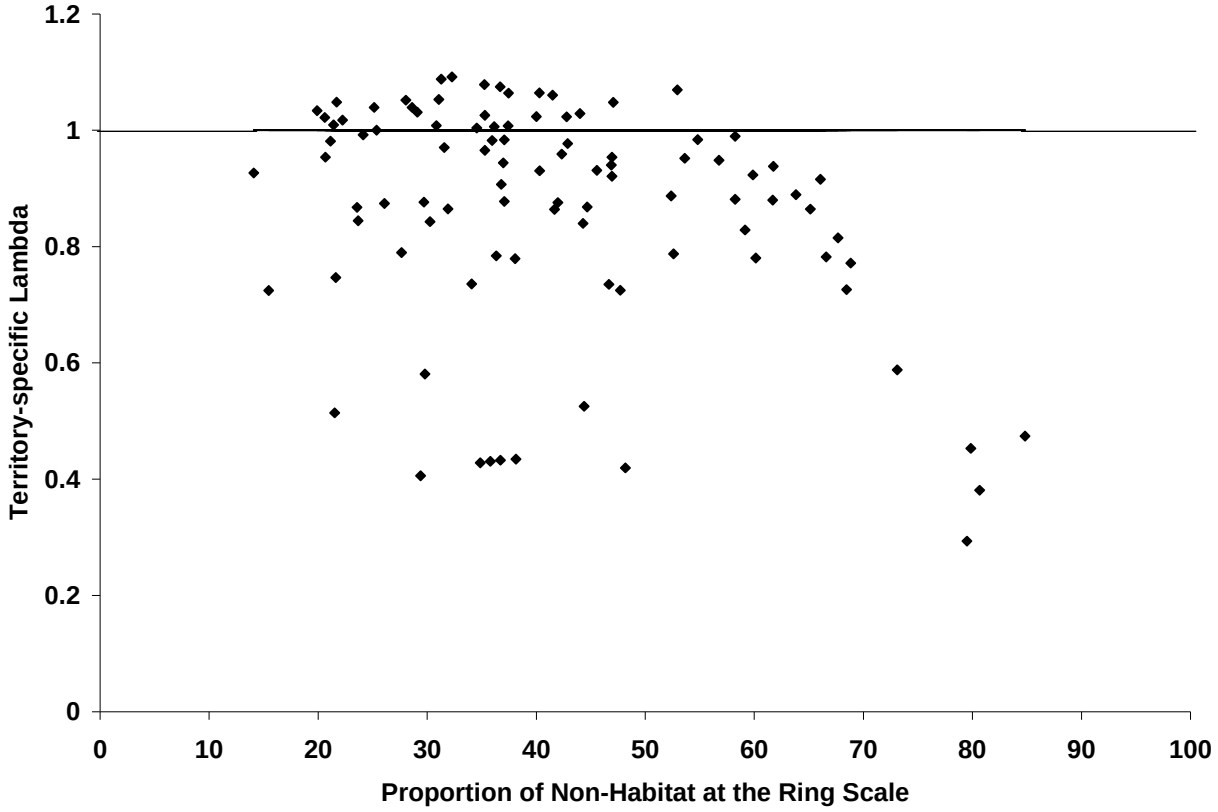


*Mean proportion. **Recommendation for take-avoidance guidelines. †Carey et al. 1992: A = Klamath Mountains, clumped forest, B = Klamath Mountains, fragmented forest, C = Umpqua, fragmented forest. ‡Zabel et al. 1993: A = Ukonom, breeding season, B = Ukonom, nonbreeding season, C = Mad River, breeding season, D = Mad River, nonbreeding season.

Research in the Klamath Province and adjacent areas indicates that NSO habitat should be concentrated at the core area scale around nests and interspersed with other land cover classes in the rest of the home range. For this reason, the FWS guidelines require retention of a higher proportion of the home range's total suitable habitat

(particularly nesting/roosting habitat) to be within the core area, and allow a wider range of forest conditions in the outer ring. A study in southwestern Oregon showed that HFP was optimal for NSO when the estimated home range beyond the core area (3,430-acre ring) was comprised of large amounts of forest (young, mature, and old classes) and an intermediate amount (ca. 38%) of "nonhabitat" (nonforest, early seral forest, heavily harvested forest) (Dugger *et al.* 2005; see Figure III.C.2). At this scale, HFP was below 1.0 at all territories with >50 percent nonhabitat. A similar study just outside the Klamath Province in southern Oregon found that high survival of NSO usually occurred with large proportions (ca. 70 percent was optimal) of conifer forest (average DBH >9.5 inches) in estimated home ranges (1,747 acres), whereas high reproduction was associated with large amounts of edge between "nonforest" (average diameter at breast height (DBH) <9.5 inches) and other vegetation classes (Olson *et al.* 2004). These findings suggest that HFP is highest when home ranges consist of large amounts of both forest and forest-edge. Zabel *et al.* (2003) found that the best large-scale (2,224-acre) model for probability of occupancy by NSO in northwestern California was an intermediate amount of old forest (≥24 inches DBH and ≥70 percent canopy cover) edge. Thus, both the demography and presence of NSO in the Klamath Province appear to be positively associated with an intermediate amount of horizontal heterogeneity at the home range scale.

Figure III.C.2: Association between habitat fitness potential (territory-specific lambda) and proportion of "nonhabitat" (nonforest, early seral stages, older forest receiving timber harvest entries removing >40 percent basal area in the portion of the estimated home range outside the estimated core area (3,430-acre ring) in southwestern Oregon (Dugger *et al.* 2005).



Core Area (0.5-Mile Radius)

The disproportionate importance of habitat conditions within NSO core areas is indicated by the species' concentrated use of areas close to the territory center (see *Analysis Areas* and *Habitat Definitions*). The core area's relevance has also been demonstrated by strong associations between habitat patterns and the demography (Franklin *et al.* 2000, Dugger *et al.* 2005) and occurrence (Zabel *et al.* 2003) of NSO.

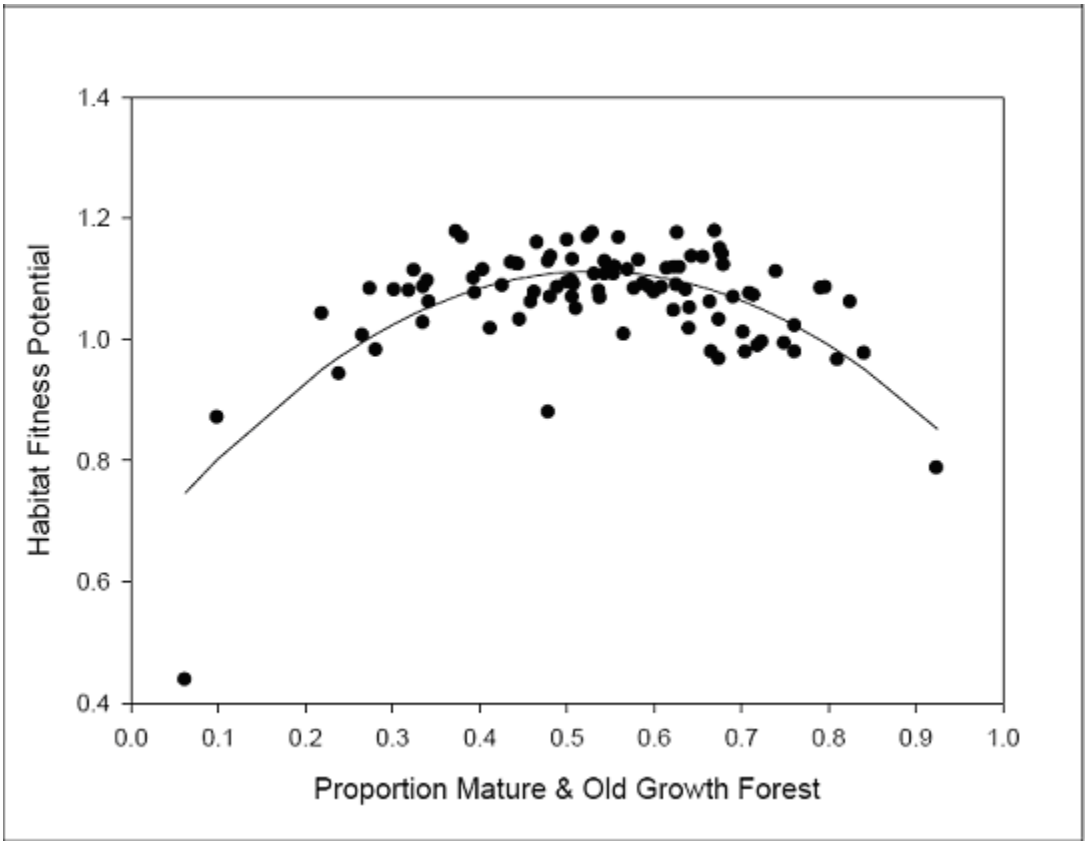
The results of two rigorous demographic studies of NSO in the Klamath Province (Franklin *et al.* 2000, Dugger *et al.* 2005) provide strong, consistent inferences regarding the relationship between habitat conditions and measures of NSO fitness such as adult survival and HFP at the core area scale. Although the habitat-based fitness models of Franklin *et al.* (2000) and Dugger *et al.* (2005) differ somewhat, both studies indicated that HFP for NSO in the Klamath Province was most likely to be $\geq$1 when at least 50% of the estimated core area was comprised of older forest (see Table III.C.1 for habitat criteria). An HFP of $\geq$1 indicates that a territory has the characteristics required for breeding females to replace themselves or contribute a surplus to the population (Franklin *et al.* 2000).

Franklin *et al.* (2000) found that territory-specific adult survival was strongly associated with the amounts of interior older forest in addition to the amount of edge between older forest and other vegetation types (see Table 7 in Franklin *et al*. 2000) at the core area scale (390 acres, 158 ha). Interior older forest was the amount of older forest 328 feet (100 m) from an edge and is not equivalent to the simple amount of older forest within a core. Interestingly, HFP declined overall when the core area contained more interior old forest. This was apparently due to a tradeoff between habitat characteristics associated with survival (amount of interior habitat and length of habitat edge) and reproduction (amount of habitat edge). High quality territories typically had core areas comprised of large patches of older forest with convoluted edges. Estimates of the amount of interior older forest that correlated with HFP >1 were provided to the FWS by Dr. Franklin (personal communication, September 19, 2005). The minimum proportion of interior older forest corresponding to HFP >1 was 41 percent; addition of

the older forest area within the 328-foot “edge buffer” yielded a proportion of 62 percent (“total core”: Franklin 1997). Based on this evaluation, Dr. Franklin recommended that 60 percent of the core area be comprised of older forest (Franklin, personal communication, September 19, 2005). The FWS guidelines incorporate the apparent positive influence of moderate amounts of edge by 1) requiring that retention of high-quality habitat be concentrated at the core scale and 2) specifying amounts of older forest and foraging habitat in the core.

Data sets used in Franklin *et al.* (2000) were recently re-analyzed to evaluate the relationship between HFP and the simple proportion of older forest within NSO core areas (Franklin 2006). The results of this analysis, proposed in Appendix D of the 2007 Draft Recovery Plan for the Northern Spotted Owl (USFWS 2007), indicated a quadratic relationship between HFP and older forest, with optimum HFP occurring when 53 percent of the estimated core area consisted of older forest (Franklin *et al.* 2000; Figure III.C.3). More than half (55 percent) of the high-quality (HFP $\geq$1) territories had core areas comprised of 50 to 65% older forest. This pattern is consistent with the previously described recommendations of Dr. Franklin and the habitat retention guidelines developed by the FWS.

Figure III.C.3: Relationship between habitat fitness potential for northern spotted owls and proportion of older forest (see Table III.C.1) within 0.44 mile of territory centers in northwestern California (courtesy A. Franklin)



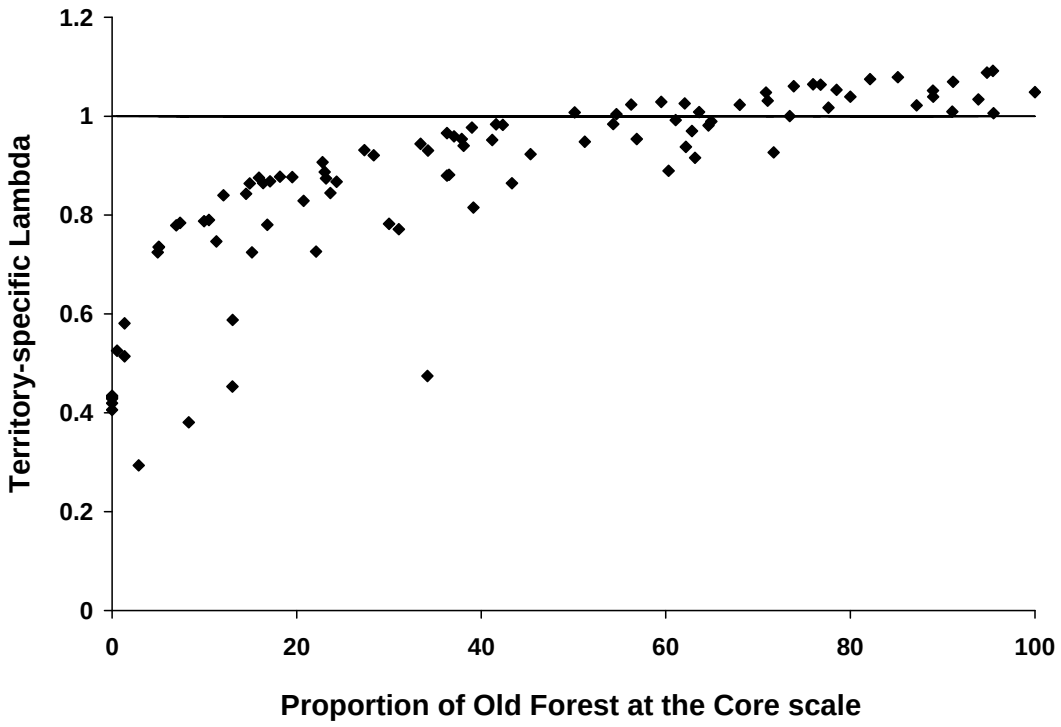
Because roughly 29 percent of high-quality territories (HFP ≥1) (Figure III.C.3) contained less than 50 percent old forest, some have suggested that a substantially lower habitat retention guideline would be adequate to avoid incidental take in timber harvest operations. Use of Franklin (2006) as the sole means of support for habitat retention guidelines is inappropriate (Franklin 2007) however, because the model estimating survival based on simple amounts of older forest was not well-supported and had only 3 percent of the weight in the model set (as opposed to 42.7 percent for the best-supported model which included interior old forest and amount of edge; see Table 7 in Franklin *et*

al. 2000). Use of the simple amount of older forest for evaluating take of NSO is inappropriate because it ignores the model selection process used in Franklin *et al.* (2000), which found that simple amounts of older forest alone did not explain variation in survival nearly as well as amounts of interior older forest and edges (Franklin 2007). Nichols and Pollock (2008) reviewed the use of HFP in the draft NSO Recovery Plan and concurred with Franklin (2007), stating that plots based on a single variable (percent old forest) instead of multiple covariates in the model of Franklin *et al.* (2000) are potentially misleading. Consequently, the analysis using solely percent old forest was deleted from the final 2008 NSO Recovery Plan, and was not used by the FWS to develop recent NSO habitat retention guidelines.

In a similar study in southern Oregon, Dugger *et al.* (2005) found that HFP was positively related to the proportion of older forest in the estimated core area (413 acres, 167 ha), although it became decreasingly sensitive to increased proportions (see Figure III.C.4; Dugger, unpub. data). Roughly 72 percent of core areas with HFP greater than 1.0 had more than 50 percent older forest; whereas cores with HFP less than 1.0 never contained more than 50 percent older forest. In contrast to the conclusions of Franklin *et al.* (2000), the correlation of HFP with proportion of older forest in the estimated core area was roughly linear; HFP did not decline at high levels of older forest. It is unclear why these studies found differences in the nature of the NSOs' relationships with quantities of older forest in the core area. Possible reasons for this dissimilarity include differences in the availability and quality of habitat in the study areas and in the studies' classifications of habitat (see Table III.C.1). For example, the area studied by Dugger *et al.* (2005) was strongly fragmented by industrial timberlands in a checkerboard pattern,

whereas the area studied by Franklin *et al.* (2000) was dominated by less-intensively managed federal lands. Regardless, both studies found that high quality territories typically had core areas comprised of at least 50 percent older forest.

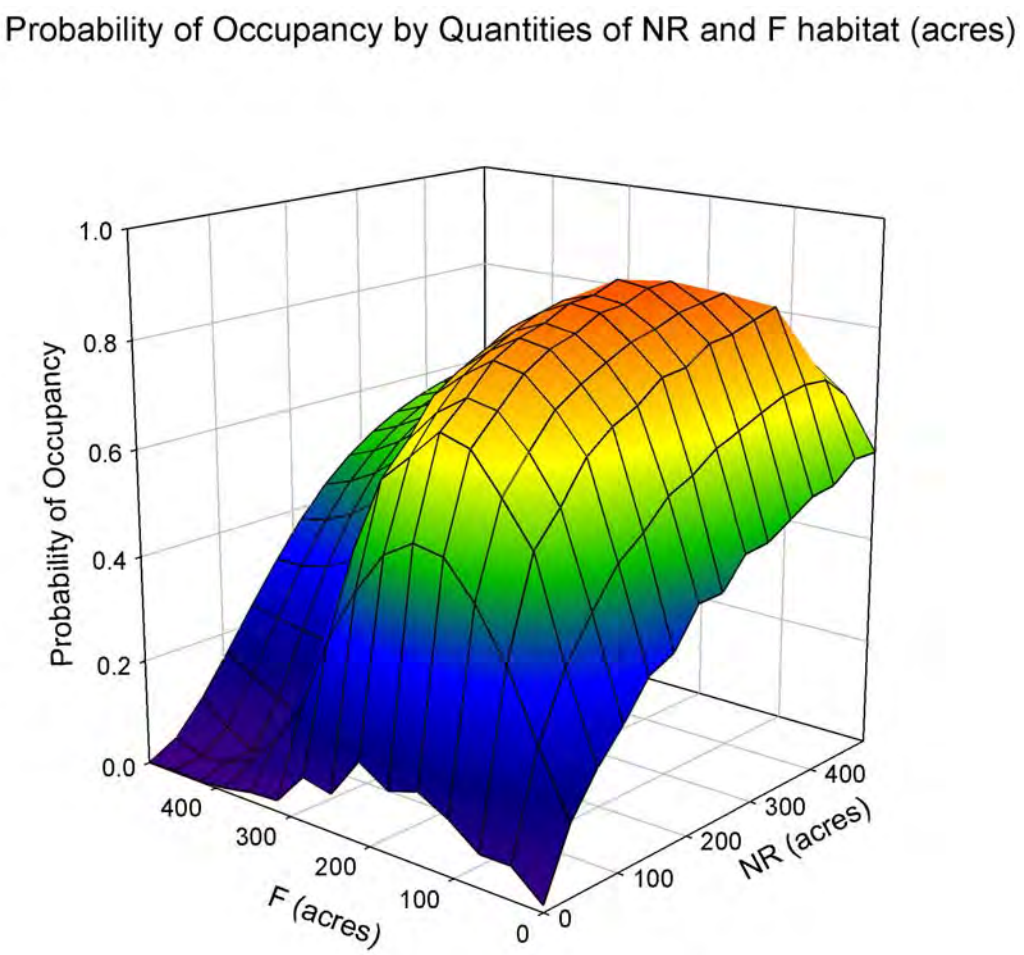
Figure III.C.4: Relationship between habitat fitness potential (territory-specific lambda) for northern spotted owls and proportion of older forest (see Table III.C.1) within 413 acres around territory centers in southwestern Oregon (courtesy K. Dugger)



Zabel *et al.* (2003) modeled the probability of occupancy for NSO in the Klamath Province based on habitat conditions at the core area scale (500 acres). The overall best model in this study indicated that the probability of NSO occurring in a given location was positively, albeit diminishingly, influenced by increased amounts of nesting-roosting habitat and by intermediate amounts of foraging habitat at the core area scale (see Table

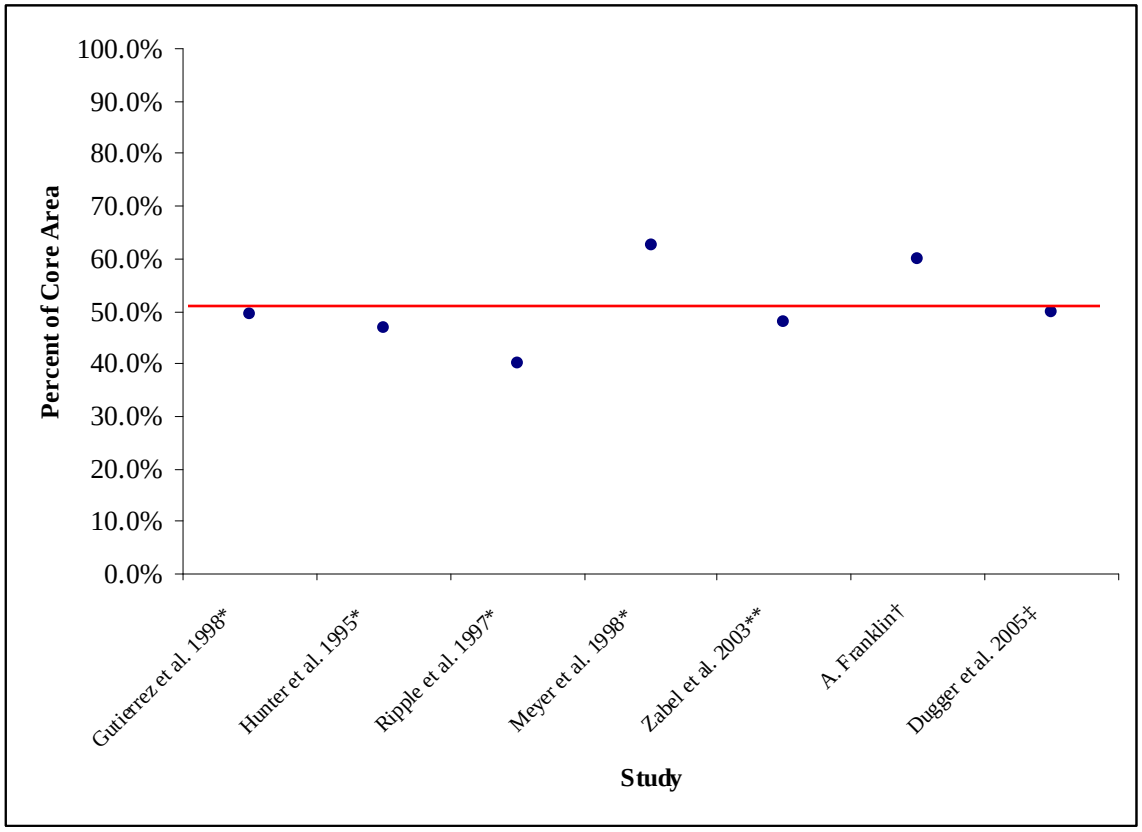
III.C.1 for habitat definitions). The highest probability of occupancy occurred when the core area scale consisted of 60 to 70 percent nesting-roosting habitat and 30 to 40 percent foraging habitat (see Figure III.C.5). The averages for all combinations of habitat associated with a high probability (≥0.70) of occupancy were 48 percent nesting-roosting habitat and 28 percent foraging habitat.

Figure III.C.5: Probability of northern spotted owl occupancy in the Klamath Province associated with amounts of nesting-roosting (NR) and foraging (F) habitats (see Table III.C.1) at the 500-acre (200 ha) scale (Zabel *et al.* 2003)



Researchers have reported a wide range of mean proportions of older forest (ca. 35-60 percent; see Figure III.C.6) at the core area scale around NSO nests in the Klamath Province and adjacent areas (Hunter *et al.* 1995, Ripple *et al.* 1997, Gutiérrez *et al.* 1998, Meyer *et al.* 1998). It is difficult to assess how much of this variation was due to differences in ecological setting, spatial scale, habitat classification, and individual variation among owls. Nonetheless, the central tendency of these results was roughly 50-60 percent, which is consistent with the FWS guidelines' requirement for proportion of nesting and roosting habitat (see *Habitat Definitions*) in the core area (see Figure III.C.6). The mean proportions of older forest at core area scales were higher than those around locations chosen for comparison (random or "unused" locations). Thus, NSO in the Klamath Province appear to select home ranges with large amounts of older forest concentrated around suitable nest locations.

Figure III.C.6: Proportions of older forest (see Table III.C.1) at core area scales around northern spotted owl territory centers in the Klamath Province, CA and OR. Horizontal line shows the proportion of older forest required by the FWS guidelines (50 percent)



*Mean proportion. **Mean proportion associated with ≥70% probability of occupancy. †Recommendation based on the combined proportions of interior and edge-buffer older forest associated with a habitat fitness potential greater than 1 (Franklin et al. 2000). ‡Approximate proportion of older forest associated with a habitat fitness potential of at least 1.

Taken together, the results of studies conducted in the Klamath Province support the conclusion that at least 50 percent of the core area should consist of older forest. Older forest is more likely than other vegetation classes to provide NSO with suitable structures for perching and nesting, a stable, moderate microclimate at nest and roost sites, and visual screening from both predators and prey (see *Habitat Definitions*).

Franklin *et al.* (2000) found that survival and HFP were highest when older forest occurred as large patches in the core area. Larger patches of forest likely buffer NSO from wind and heat associated with forest-opening edges (Chen *et al.* 1995) and predators and competitors associated with open or fragmented forest (e.g., great horned owls [*Bubo virginianus*]: Johnson 1993). Modeling by Franklin *et al.* (2000) also indicated that a balance of interior older forest and edge habitat in the core area is important to NSO in the region. The value of habitat edges for NSO might be related to the availability of woodrats and other prey species associated with more open, early-seral vegetation. The positive influence of large-bodied prey species such as woodrats on NSO reproductive success has been described in northwestern California (White 1996). However, habitat edges in the Franklin *et al.* study occurred wherever habitat was juxtaposed with other land cover classes, and was not necessarily related to the presence of woodrat habitat. In fact, the survival and reproduction of NSO did not appear to be influenced by woodrat habitat in the core area. Zabel *et al.* (2003) found that probability of occupancy by NSO was highest when the core area scale contained some foraging habitat, as well as nesting-roosting habitat. This result suggests that horizontal heterogeneity in the core area should be partially provided by a range of forest conditions suitable for use by NSO, dominated by older forest conditions, (see *Habitat Definitions*, below), not simply the juxtaposition of suitable and unsuitable habitat.

III.D: Habitat Definitions:

Determination of the amount of suitable habitat that must be retained in order to avoid incidental take of NSO is strongly influenced by the range of forest conditions that

are classified as suitable habitat. The HFP models of Franklin *et al.* (2000), Olson *et al.* (2004), and Dugger *et al.* (2005) contain a limited number of habitat variables and relatively coarse definitions of NSO habitat, and therefore must be supplemented with additional information on forest structural parameters that support classification of forest habitat as suitable for nesting and foraging. Description of the structural characteristics of NSO habitat and delineation of the range of habitat conditions corresponding to essential activities such as nesting, roosting, and foraging is a critical element of developing guidelines for evaluating the likelihood of incidental take. Because the structural attributes of habitat immediately surrounding nests are easily quantified, data supporting classification of nesting habitat are readily available (see section III.C).

Foraging habitat, on the other hand, is more variable and spatially extensive, requiring intensive radio-telemetry studies to measure use of various habitat conditions by NSO. In recent studies by the National Council for Air and Stream Improvement (NCASI), correlations between habitat data from detailed forest inventories and nocturnal locations of radio-tagged NSO and California spotted owls were used to estimate resource selection function (RSF) models (Irwin *et al.* 2007a,b) that quantify complex relationships between the owls and their environment. These models allow evaluation of the relative use of specific forest structural variables such as tree size class distribution and stand density by foraging NSO. The studies of Irwin *et al.* (2007a, b), combined with other telemetry studies (Solis and Gutiérrez 1990), provide the basis of our definitions of suitable foraging habitat for NSO.

NSO are generally associated with structurally complex conifer or mixed-conifer forests containing dense, multilayered canopies and significant components of large-

diameter trees and decadence in the form of deformed trees, snags, and down wood (Thomas *et al.* 1990, Gutiérrez 1996, Courtney *et al.* 2004, USFWS 2008). Variation in seral stage association has been reported for individuals within study areas and for populations in different study areas (Gutiérrez 1996). However, extensive use of younger forests by spotted owls tends to be reported in unusually productive forest types in coastal areas (Folliard *et al.* 1993, Thome *et al.* 1999) or in stands containing structural complexity retained from previous stands (Blakesley *et al.* 1992, Zabel *et al.* 1993, Carey and Peeler 1995, Irwin *et al.* 2000). In particular, NSO have been shown to nest and forage successfully in young redwood forests; in such areas their densities are among the highest on record (Diller and Thome 1999). Young redwood forests have also been associated with high reproduction in spotted owls (Thome et al. 1999). The ability of NSO to successfully occupy young redwood forests has been attributed to resource availability; young forests have been found to produce the highest abundance of woodrats in Douglas-fir/tanoak forests (Sakai and Noon 1993), and in the redwood/Douglas-fir zone, woodrats were most abundant in stands 5 to 20 years of age (Hamm et al. 2007: USDA Forest Service Gen. Tech. Rep. PSW-GTR-194). Ward et al. (1998) described the benefit of an energy rich woodrat diet; and White (1996) describes the positive influence of woodrat consumption on nesting success. The value of younger forest to NSO in the drier portions of the Klamath Province is poorly understood, whereas numerous studies in the Klamath Province and adjacent regions have demonstrated that NSO selectively use older, denser forest at a variety of spatial scales (e.g., Solis and Gutiérrez 1990, Bart and Forsman 1992, Blakesley *et al.* 1992, Carey *et al.* 1992, Hunter *et al.* 1995, Ripple *et al.* 1997, LaHaye and Gutiérrez 1999, Zabel *et al.* 2003) and that such forest is positively

associated with measures of reproduction and survival (e.g., Ripple *et al.* 1997, Meyer *et al.* 1998, Franklin *et al.* 2000, Olson *et al.* 2004, Dugger *et al.* 2005).

Although spotted owls are generally associated with and preferentially select older, denser forest, suitable habitat for the species can be viewed as a continuum of structural conditions. Owls tend to use parts of this continuum more frequently than others, and to focus their activities within certain parts of it for meeting particular life history needs. The FWS has classified this continuum into habitat categories based on the conditions' primary function and apparent quality for NSO (nesting/roosting or foraging habitat, high or low quality habitat; see Table III.D.1 and Figure III.D.1). The FWS recognizes that conditions within a habitat category may be used by NSO to meet multiple life history needs; for example, NSO may forage in nesting/roosting habitat or roost in foraging habitat. We also acknowledge that rigorous classification of habitat quality requires an understanding of the relationships between habitat conditions and the demography of NSO. However, because NSO are mobile animals with large home ranges, most studies have used low-resolution vegetation data and broad habitat categories to explore their habitat relationships (see Table III.C.1). These studies have greatly improved our understanding of NSO-habitat relationships but provide limited insight into the specific structural conditions used by owls.

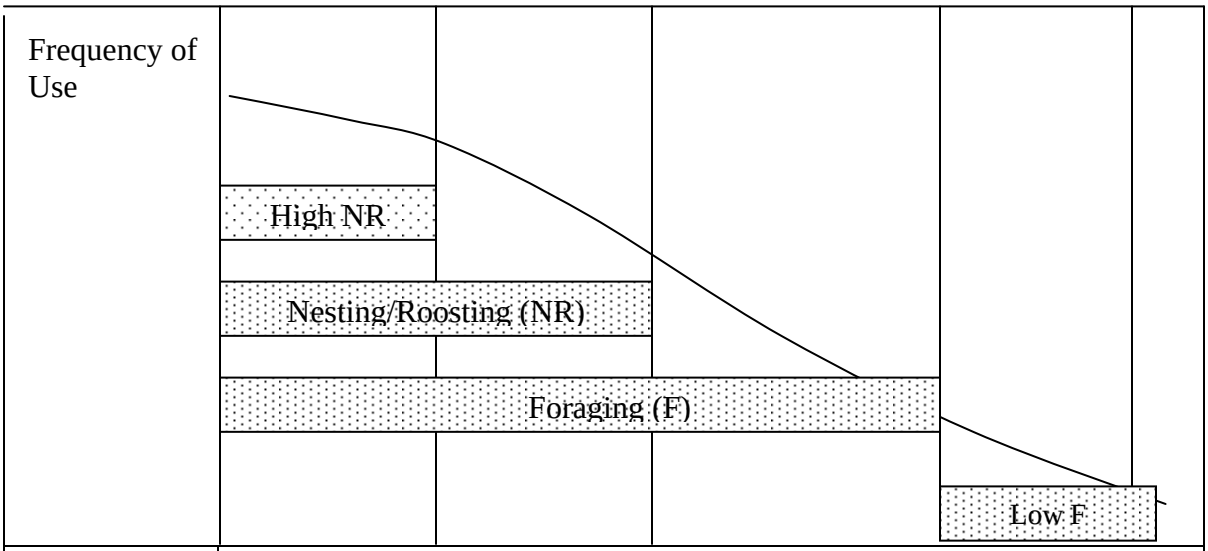
Table III.D.1: Values for selected structural parameters used in the Fish and Wildlife Service guidelines to classify nesting/roosting and foraging habitat for northern spotted owls.

Habitat category	Tree Size (QMD)[1]	Basal Area[2]	Trees > 26"dbh	Canopy closure
High nesting/roosting	≥ 15"	≥ 210 ft^2	8 per acre	≥60%
Nesting/roosting	≥ 15"	150–180+ ft^2	8 per acre	≥ 60%
Foraging	≥ 13"	120-180+ ft^2	5 per acre	≥ 60%
Low foraging	≥ 11"	80-120+ ft^2		≥ 40%

1: Quadratic Mean Diameter (inches) of trees > 5" diameter
2: Square feet per acre, trees > 5"

A few studies have provided plot-level descriptions of areas used by NSO. Habitat definitions in the FWS guidelines are primarily based on the statistical distributions of habitat parameters correlated with use by owls in these studies. Yet, the average conditions in small study plots around owl locations may poorly represent the inherent variability of stands and landscapes in owl territories. Therefore, the FWS guidelines distribute habitat categories in terms of ranges of values within analysis areas, rather than as stand averages. This approach ensures that a range of suitable habitat conditions is well-distributed at appropriate spatial scales, without being unrealistically or unreasonably prescriptive.

Figure III.D.1: Conceptual model of northern spotted owl habitat functions and associated forest structural conditions.



Basal Area	300+	200	150	120	80
QMD[1]	20”		15”	13”	11”
TPA > 26”[2]	50		8	5	
Canopy[3]	100%		60%		40%
Structure	Large tree/dense	Large/open to medium/dense		small/dense to open/brushy	

1: QMD= quadratic mean diameter of trees > 5 inches dbh
2: TPA>26”= trees per acres of trees >26 inches dbh
3: Canopy= percent cover of overstory trees

The FWS guidelines use a suite of structural metrics to classify NSO habitat (basal area, quadratic mean diameter, large-diameter [>26 inches DBH] trees per acre, and canopy cover) (Table III.D.1). We chose these metrics because they describe different aspects of stand structure that appear to be important to NSO and because they are commonly used by silviculturists to evaluate forest conditions. The FWS discourages the use of broad vegetation classification categories for defining habitat for NSO in the Klamath Province. These classification schemes are inappropriate for defining habitat in take-avoidance guidelines because they encompass broad ranges of vegetation parameters that often do not correspond to habitat used by NSO. For example, habitat class 4M in the CWHR system (average DBH 11 - 24 inches and average canopy cover 40-59 percent)

might describe anything from infrequently-used foraging habitat to nesting and roosting habitat. Furthermore, use of broad habitat classification schemes can mask the effects of habitat modification. For example, timber harvests could remove important habitat elements (e.g., snags, deformed trees, dense groups of large trees) while maintaining the minimum average canopy cover and tree diameter values in a given habitat category and masking the loss of habitat quantity and quality.

Habitats Used for Nesting and Roosting

The 2008 NSO Recovery Plan (USFWS 2008:50) stated that: "Features that support nesting and roosting typically include a moderate to high canopy closure (60 to 90 percent); a multi-layered, multi-species canopy with large overstory trees (with diameter at breast height [dbh] of greater than 30 inches); a high incidence of large trees with various deformities (large cavities, broken tops, mistletoe infections, and other evidence of decadence); large snags; large accumulations of fallen trees and other woody debris on the ground; and sufficient open space below the canopy for spotted owls to fly." The validity of applying this rangewide habitat definition to the Klamath Province has been supported by numerous studies in and adjacent to the region (e.g., Solis and Gutiérrez 1990, Blakesley *et al.* 1992, Carey *et al.* 1992, Hershey *et al.* 1998, LaHaye and Gutiérrez 1999), including on private timberlands (Self *et al.* 1991, SPI 1992, Farber and Crans 2000).

The characteristic structure of nesting/roosting habitat probably serves a variety of functions for NSO. NSO may partly favor older, more decadent forest for nesting because it frequently contains suitable nest structures. Nests are usually located in older, larger-

diameter, deformed, decadent, or diseased trees containing cavities or platforms (Forsman *et al.* 1984, Hershey *et al.* 1998, LaHaye and Gutiérrez 1999, North *et al.* 2000). Northern spotted owls may also nest and roost in older, denser forest because it tends to provide a more moderate, stable microclimate compared with other kinds of forest. NSO are less able to dissipate body heat than other owls and appear to compensate by nesting and roosting in relatively cool, humid sites (Barrows 1981, Ganey *et al.* 1993, Ting 1998, Weathers *et al.* 2001). NSO also appear to use dense, multilayered canopies for protection from cold, wet weather (Forsman *et al.* 1984, North *et al.* 2000). Northern spotted owls may also prefer nesting and roosting in denser forest because it provides visual screening from predators (Carey 1985, Buchanan *et al.* 1995).

High-quality nesting/roosting habitat

As defined by the FWS guidelines, high-quality nesting/roosting habitat occurs where structural conditions resemble or exceed those of most observed NSO nest sites in northern California (see Table III.D.2). To date, no Klamath Province study has directly compared plot-level vegetation data for nest and roost sites to the demography of NSO, so it is unknown if the average structural conditions used by owls in the region are associated with high reproduction and survival. Therefore, a definition of high-quality nesting/roosting habitat must account for variability in habitat-use patterns among individuals by ensuring that the range of habitat values associated with owl use are well-represented, rather than prescribing a single criterion based on mean values.

Nesting/roosting habitat

The FWS' definition of nesting/roosting habitat is similar to high-quality nesting/roosting habitat, but is intended to reflect both variability in the structure of sites used by nesting and roosting owls and the variability typical of forest stands or patches encompassing denser nest and roost sites (see Table III.D.1and III.D.2). The FWS guidelines' requirement for a mix of basal areas in nesting/roosting habitat allows land managers some operational flexibility but also discourages homogenization of stands during harvesting. Although it is more stringent than that used in the FPR guidelines, the FWS guidelines provide definitions of habitats used for nesting and roosting that consistent with the range of conditions found at many spotted owl nest cores on private timberlands.

Table III.D.2: Mean structural characteristics of areas used by spotted owls for nesting, roosting, and foraging (rounded to the nearest whole number). The habitat variables are basal area (BA), quadratic mean diameter (QMD), large trees per acre (TPA), and canopy cover (CC)

Source **Location**	**FWS Guidelines** Klamath Province	**White 1996** Klamath National Forest*	**Self et al.**** Klamath Province and So. Cascades	**Farber and Crans 2000** Klamath Province and So. Cascades	**Irwin et al. 2007** Northern Sierra Nevada (CSOs)	**L. Irwin, unpubl.** Medford, Klamath Province
Habitat Type **Plot Size** **BA (ft2/ac)** **QMD (in)** **TPA >26"** **TPA >35"** **CC%**	High-Quality Nesting/ Roosting - ≥210 ≥15 ≥8 - ≥60	Nest & Roost Sites 0.2-0.3 ac 246† 8 73	Nest Sites 1 ac 212‡ 16‡	Nest Sites 0.1 ac, 2.5 ac 210, 166† 14, 12† 70, 67	Roost Sites 216† 16† 8 75	
Habitat Type **BA (ft2/ac)** **QMD (in)** **TPA >22"** **TPA >26"** **TPA >32"** **CC%**	Nesting/ Roosting (High-Quality Foraging) mix >150 ≥15 - ≥8 - ≥60		Nest Patches 173‡ 16 4	Nest Stands 124† 13†	Foraging Locations 190 14 7 69	Foraging Locations 180† 20† 8
Habitat Type **BA (ft2/ac)** **QMD (in)** **TPA >26"** **CC%**	Foraging mix >120 ≥13 ≥5 mix ≥40					Foraging Locations (Lower 25%) 120 14 0
Habitat Type **BA (ft2/ac)** **QMD (in)** **CC%**	Low-Quality Foraging mix >80 ≥11 ≥40					Foraging Locations (Lower Values) See Figure III.D.2 See Figure III.D.3

*Excludes data from the Goosenest Ranger District in the southern Cascade Range. **SPI = Self *et al.* 1991, SPI 1992, and Table III.D.2. †All trees >5" DBH (lower cutoff reported for QMD, assumed for BA). ‡All trees >6" DBH (lower cutoff reported for QMD, assumed for BA).

Foraging Habitat

Foraging habitat encompasses nesting and roosting habitat but includes a broader range of structure and might not support successful nesting by NSO (Gutiérrez 1996, USFWS 2008). Foraging NSO generally use older, denser, and more complex forest than expected based on its availability, but they also use younger forest (Solis and Gutiérrez 1990, Carey *et al.* 1992, Zabel *et al.* 1993, Carey and Peeler 1995, Anthony and Wagner 1999, Irwin *et al.* 2007b). The FWS guidelines incorporate this structural variability by specifying retention of habitat in four functional categories of habitat suitable for NSO. High-quality nesting/roosting and nesting/roosting habitat provide the upper range of stand structure selected by foraging NSO; foraging habitat encompasses a broad range of structure, and low-quality foraging habitat includes younger and more open habitats that may be important for prey production (Tables III.D.1 and III.D.2; Figure III.D.1). Northern spotted owls may prefer older, denser forest for foraging because it often contains both abundant prey and suitable structural characteristics for hunting. Several important prey species, including flying squirrels (*Glaucomys sabrinus*) and western red-backed voles (*Clethreionomys californicus*) tend to be most abundant in older, denser forest (Carey *et al.* 1992; Waters and Zabel 1995, 1998). Other important prey species, such as woodrats, have been found to be most abundant in young sapling stands (Sakai and Noon 1993), but can also reach high abundances in dense, old forest (Carey *et al.* 1992, Sakai and Noon 1993). Spotted owls usually hunt by listening and scanning for prey from elevated perches (Forsman *et al.* 1984). Dense, multilayered forest might provide owls with hunting perches at a variety of canopy levels (North *et al.* 1999). Dense vegetation might also visually screen foraging NSO from predators and prey

(Carey 1985, Buchanan *et al.* 1995). Conversely, spotted owls require space for flying, which could place an upper limit on the understory density of suitable habitat (Irwin *et al.* 2007b).

Descriptions of habitat structure used by foraging NSO are typically based on studies employing radio telemetry to monitor owl movements. While the habitats associated with nocturnal telemetry locations are commonly termed 'foraging locations', some researchers point out that the owl locations simply indicate the distribution of movements, and may not correspond to sites and habitats actually used by actively foraging NSO. During radio telemetry studies in northwestern California, Diller (unpub. data), found that owls moved frequently during monitoring periods (7.5 minutes/perch for 6 males; 17.0 minutes/perch for 4 females), suggesting that the process of triangulating azimuths for each location was unlikely to detect a specific site used for foraging. Conversely, owls in this study also were stationary for long periods of time, possibly resting, preening, or other activities not associated with active foraging. For these reasons, the FWS recognizes that our descriptions of NSO foraging habitat likely represent the range of habitat conditions used by owls at night, and may not represent the specific habitat qualities of sites where NSO successfully obtain prey.

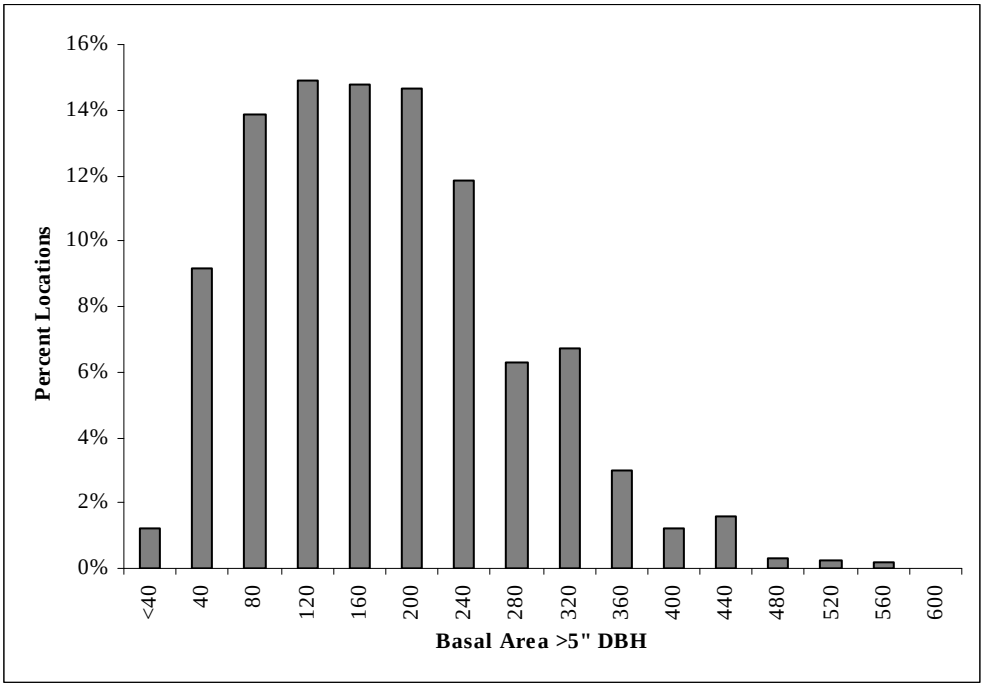
There are currently no published plot-based descriptions of NSO foraging habitat in the Klamath Province. We therefore strongly considered the results of both unpublished studies of NSO and a published study of California spotted owls (*Strix occidentalis occidentalis*, CSOs) in the northern Sierra Nevada (Irwin *et al.* 2007b) while formulating these habitat definitions. Much of the CSO study was conducted in a mixed-conifer/hardwood forest similar to forest types used by NSO in the Klamath Province.

Although spotted owls often selectively foraged in older forest, these telemetry studies show that they also use a relatively wide range of forest structure (Irwin *et al*. 2004, 2007).

The range of forest structure specified in the FWS guidelines is also based on the distribution of habitat use by foraging NSO in the Klamath Province. Analysis of radio-telemetry data from NSO in southern Oregon (L. Irwin, unpublished data) indicates that roughly 46 percent of nocturnal (foraging) locations occurred in nesting/roosting habitat (basal area ≥210 ft^2/acre), and 76 percent occurred in stands classified as foraging, nesting, and roosting habitat (Figure III.D.2). Only 14% of locations were in stands classified as low-quality foraging habitat. Thus, the functional habitat categories specified in the FWS guidelines capture about 90 percent of the observed distribution of actual use by NSO, but also require retention of the full range of structural conditions corresponding to nesting, roosting, and foraging.

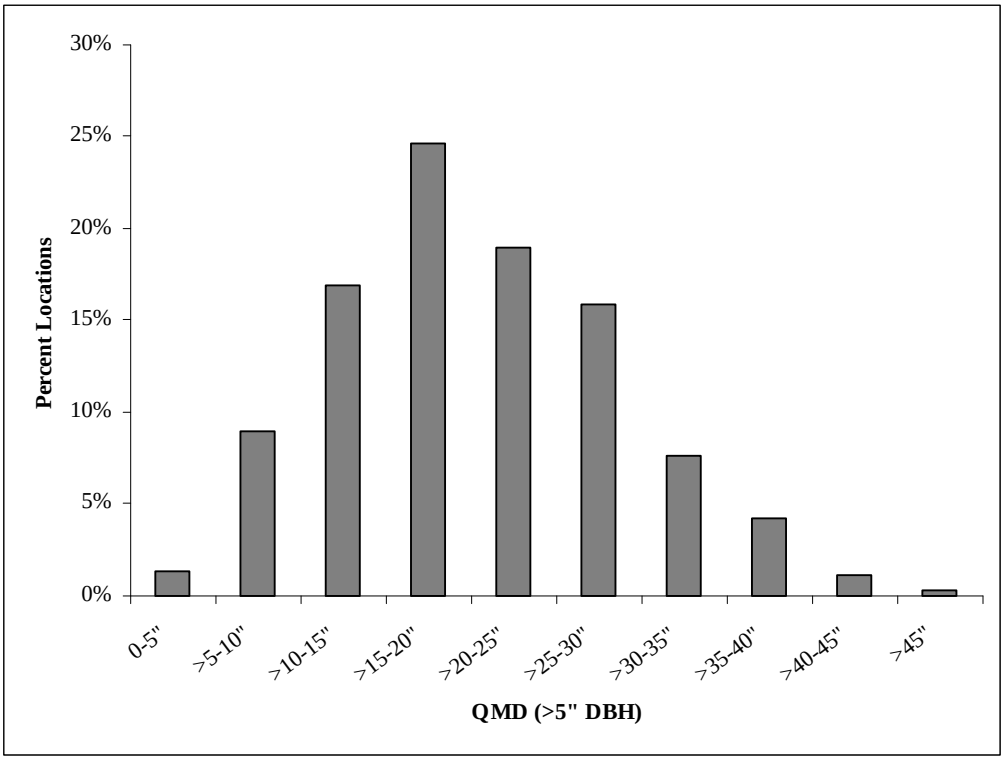
In addition to the structural characteristics addressed in the FWS guidelines, studies have indicated that certain conifer species such as Douglas-fir, as well as hardwoods and dead woody materials are important features of spotted owl foraging habitat (North *et al.* 1999, Irwin *et al.* 2000, Glenn *et al.* 2004, Irwin *et al.* 2007).

Figure III.D.2: Distribution of basal area at inventory plots near nocturnal telemetry locations for northern spotted owls in the Medford area of the Klamath Province (L. Irwin, unpublished data). This figure shows some of the range of basal area values used for foraging; it is does not show selection or avoidance of particular values since available conditions were not described.



DBH: diameter at breast height, in inches

Figure III.D.3: Distribution of quadratic mean diameter (QMD) at inventory plots near nocturnal telemetry locations for northern spotted owls in the Medford area of the Klamath Province (L. Irwin, unpublished data). This figure shows some of the range of QMD values used for foraging; it is does not show selection or avoidance of particular values since available conditions were not described.



DBH: diameter at breast height, in inches

Abiotic Habitat Characteristics

Habitat selection by breeding NSO is strongly influenced by spatial and topographic features such as proximity to nest, distance to water, slope position, and elevation. Termed 'abiotic considerations' in the FWS guidelines, these factors act to influence the habitat value of forest stands, and subsequently the importance of retaining habitat based on landscape position as well as stand structure. Abiotic considerations are explicitly incorporated into the FWS guidelines through a prioritization system that ranks habitat retention areas based on distance to nest, contiguity, slope position, aspect, and elevation.

Because the guidelines for abiotic considerations are less prescriptive than the guidelines for stand structure, they are more easily applied during habitat evaluations on a case by case basis.

Habitat selection by breeding NSO is strongly associated with proximity to the nest, as well as with vegetation characteristics (Carey and Peeler 1995, Rosenberg and McKelvey 1999, Glenn *et al.* 2004, Irwin *et al.* 2007b). Spotted owls appear to be central-place foragers, disproportionately using areas near the nest in order to minimize travel costs and maximize their energetic return from foraging (Carey and Peeler 1995, Rosenberg and McKelvey 1999). Home range studies have also indicated the importance of the territory center to spotted owls (see *Analysis Areas*). Combined, spatial patterns of habitat selection and habitat use suggest that NSO may be more sensitive to reductions of habitat in their core areas than in other parts of their home ranges. The FWS guidelines therefore emphasize retention of habitat at the core area scale.

Topography also appears to influence habitat use by NSO; which use lower slope positions more frequently than higher ones (Forsman *et al.* 1984, Blakesley *et al.* 1992, Hershey *et al.* 1998, LaHaye and Gutiérrez 1999, Irwin *et al.* 2007b). Lower slopes likely provide cooler, more humid microclimates for nesting and roosting and favor growth of the denser forest structure preferred by spotted owls. Furthermore, lower slope positions tend to have less frequent and severe fire regimes, potentially allowing trees to attain greater density, sizes and ages than on higher slopes (Beaty and Taylor 2001, Skinner *et al.* 2006). Spotted owls also appear to prefer areas close to streams, which often occur at the bottoms of slopes (Solis and Gutiérrez 1990, LaHaye and Gutiérrez 1999, Irwin *et al.* 2007b). Areas near streams likely tend to be more productive and have cooler, more

humid microclimates than upland areas. Additionally, prey abundance can be high in riparian areas (Carey *et al.* 1992, Anthony *et al.* 2003) and NSO may use streams for drinking and bathing (Forsman *et al.* 1984). Some studies have found that NSO in the Klamath Province selectively use northerly aspects, but others found different patterns or no pattern at all (Solis and Gutiérrez 1990, Blakesley *et al.* 1992, Carey *et al.* 1992, Zabel *et al.* 1993, Farber and Crans 2000). Suitable microclimates for nesting and roosting, and for the vegetation structure preferred by NSO, may occur more frequently on north-facing slopes than on other aspects. However, aspect does not appear to influence vegetation distribution as strongly in some areas as in others (e.g., Zabel *et al.* 1993). Elevation also seems to influence habitat-use by spotted owls (Solis and Gutiérrez 1990, Blakesley *et al.* 1992, Hershey *et al.* 1998, LaHaye and Gutiérrez 1999, Irwin *et al.* 2007b). This might be related both to spotted owls' disproportionate use of lower slope positions and to the influence of elevation on vegetation distribution. The productive vegetation types favored by NSO, such as mixed-evergreen forest, primarily occur at lower elevations in the Klamath Province (Sawyer 2007).

III. E. Conclusions:

The FWS has conducted a thorough review and synthesis of published literature, unpublished data sets, and direct communication with NSO researchers in support of a rigorous process for evaluating the effects of habitat management on NSO. It is important to recognize that the habitat conditions described in the document are intended for use in estimating the likelihood of take of individual NSO under the ESA; they do not represent habitat conditions required for population growth or recovery. The FWS

guidelines focus solely on individual NSO territories and do not incorporate larger-scale issues such as connectivity and dispersal habitat, wintering habitat, or longer-term habitat disturbance patterns. The FWS habitat evaluation guidelines that this science review document supports are complex; reflecting the complex nature of forest environments in the Klamath Province and the forest products industry's requirement to retain maximum flexibility to conduct timber harvests in the vicinity of occupied NSO territories.

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Appendix A: Full text of U.S. Fish and Wildlife Service Guidance for Evaluation of Take for Northern Spotted Owls on Private Timberlands in California's Northern Interior Region

I. Accuracy of NSO activity center location and status

1) Location
    a. Confirm plotted activity center location accuracy
        i. CDFG Reports 2 and 3
        ii. Data from adjacent landowners
        iii. Recent surveys
    b. Document deviations from CDFG locations
    c. Update habitat analysis maps as necessary
2) Status
    a. Valid site
        i. Review page 11 of protocol to determine
        ii. If not valid, report to CDFG for inclusion in next database update
    b. Current occupancy status
    c. Current reproductive status, if determined

II. Survey Effort

1) Coverage
    a. Surveys of nesting/roosting habitat out to 0.7 miles from THP boundary
        i. Use THP habitat map(s) to verify
2) Protocol survey
    a. Time of day
    b. Spacing between visits
    c. Number of surveys
    d. Survey dates
    e. Time spent at each call point
3) Follow up visit(s)
    a. Confirm that the area searched covers suitable habitat within response location/last known location within a logical distance.
    b. Time of follow up and duration of follow up
    c. Additional night surveys
        i. Review page 10 of protocol

III. Habitat

1) Typing
    a. Verify habitat typing with aerial photos, equivalent imagery, or field visits

b. Changes to typing need to be reflected in the NSO habitat acres table and habitat analysis maps
c. Post harvest typing
    i. Post-harvest habitat typing must agree with the silviculture prescription

2) Definitions
    a. Nesting/roosting
        i. High Quality Nesting/roosting Habitat
            1. Basal Area = 210+ square feet, **and**
            2. ≥ 15" quadratic mean diameter (QMD) , **and**
            3. ≥ 8 trees per acre (TPA) of trees ≥ 26" in diameter at breast height (DBH) , **and**
            4. ≥ 60% canopy closure
        ii. Nesting/roosting Habitat
            1. A mix of basal areas ranging from 150-180+ square feet, **and**
            2. ≥ 15" QMD, **and**
            3. ≥ 8 TPA of trees ≥ 26" DBH, **and**
            4. ≥ 60% canopy closure
    b. Foraging
        i. Foraging Habitat
            1. A mix of basal areas ranging from 120-180+ square feet, **and**
            2. ≥ 13" QMD, **and**
            3. ≥ 5 TPA of trees ≥ 26" DBH, **and**
            4. A mix of ≥ 40%-100% canopy closure
        ii. Low Quality Foraging Habitat
            1. A mix of basal areas ranging from 80-120+ square feet, **and**
            2. ≥ 11" QMD, **and**
            3. ≥ 40% canopy closure

3) Quantities
    a. Within 1000 feet of activity center
        i. Outside breeding season (September 1 through January 31): no timber operations other than use of existing roads
        ii. During the breeding season (February 1 through August 31): no timber operations other than the use of existing, permanent, year-round roads

    b. Within 0.5 mile radius (502 acres) centered on activity center
        i. Retention of habitat should follow Section III. 4 of this document
        ii. At least 250 acres nesting/roosting habitat present, as follows:
            1. 100 acres High Quality Nesting/roosting Habitat, **and**
            2. 150 acres Nesting/roosting Habitat

        –AND–

        iii. At least 150 acres foraging habitat must be present, as follows:
            1. 100 acres Foraging Habitat, **and**
            2. 50 acres Low Quality Foraging Habitat
        iv. No more than 1/3 of the remaining suitable habitat may be harvested during the life of the THP

c. Between 0.5 mile radius and 1.3 miles radius circles centered on activity center
    i. Retention of habitat should follow Section III. 4 of this document
    ii. ≥935 acres suitable habitat must be present, as follows:
        1. At least 655 acres Foraging Habitat, **and**
        2. At least 280 acres Low Quality Foraging, **and**
        3. No more than 1/3 of the remaining suitable habitat may be harvested during the life of the THP

4) Priority Ranking of Habitat Retention Acres
    a. Tree species composition
        i. Mixed conifer stands should be selected over pine dominated stands
    b. Abiotic considerations
        i. Distance to nest
            1. Nesting/roosting and foraging habitat closest to identified nest trees, or roosting trees if no nest trees identified
        ii. Contiguous
            1. Nesting/roosting habitat within the 0.5 mile radius must be as contiguous as possible
            2. Minimize fragmentation of foraging habitat as much as possible
        iii. Slope position
            1. Habitats located on the lower 1/3 of slopes provide optimal micro-climate conditions and an increased potential for intermittent or year-round water sources
        iv. Aspect
            1. Habitats located on northerly aspects provide optimal vegetation composition and cooler site conditions
        v. Elevation
            1. Habitat should be at elevations of less than 6000 feet, though the elevation of some activity centers (primarily east of Interstate 5) may necessitate inclusion of habitat at elevations greater than 6000 feet.

IV. Determination

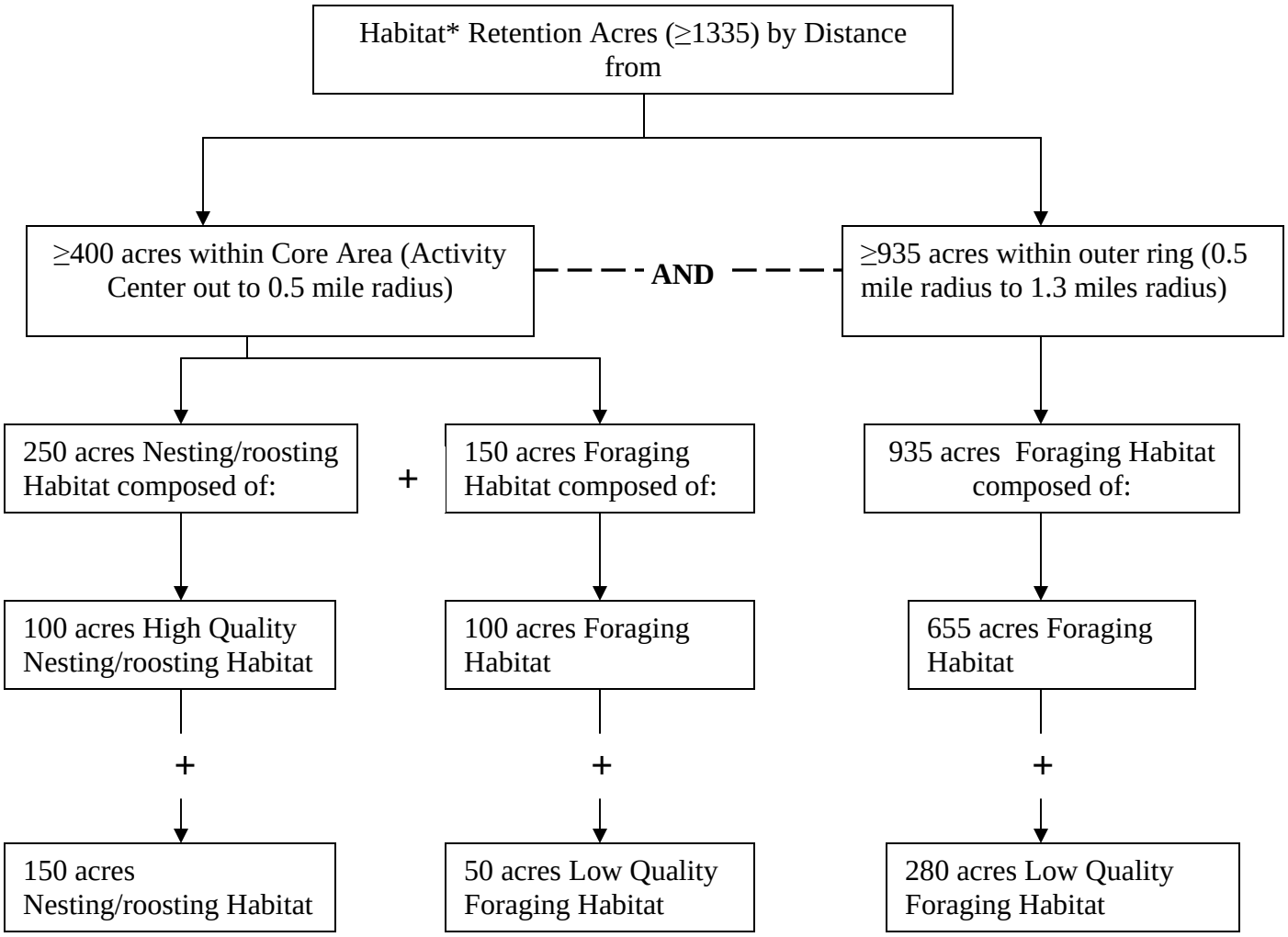
1) If surveys are inadequate or do not meet the intent of protocol, take determination may not be possible.
2) If habitat typing is inadequate, take determination may not be possible.
3) If NSO home range habitat acres are below desired conditions (Section III. 2, 3, and 4), additional loss of suitable habitat can lead to take.
4) If NSOs are nesting, utilize seasonal restriction within 0.25 mile of nest (February 1 through August 31).
5) If effects are limited to noise disturbance, a modified seasonal restriction may be used from February 1 through July 9

a. Harvest of unsuitable habitat, with unsurveyed suitable within 0.25 of unit boundary

6) Multiple THPs located within a given NSO territory need to be considered collectively or a take determination may not be possible.

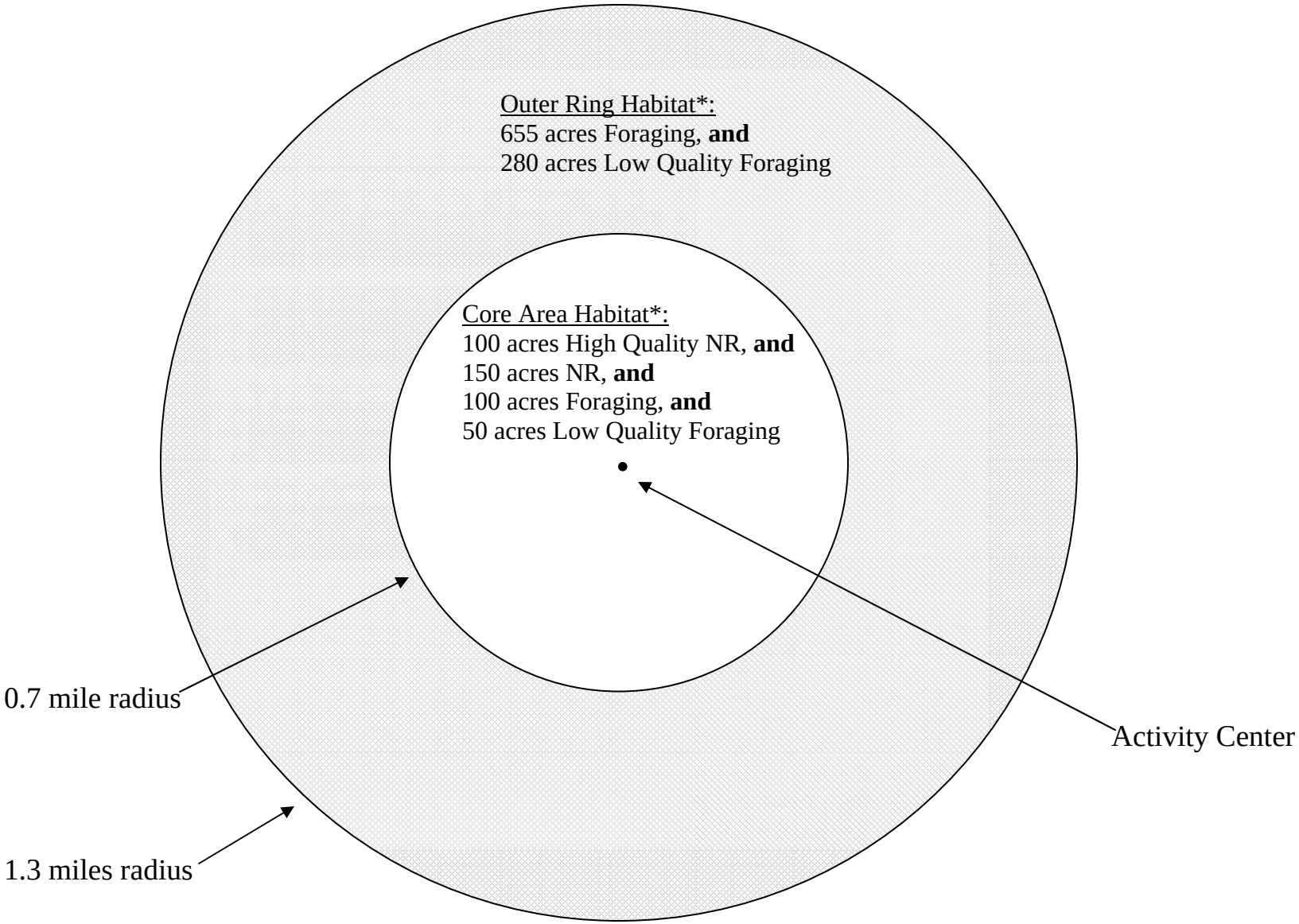
V. TA Letter Contents

1) Date of written TA request
2) Date request received
3) Note if previous TA(s) provided in past
4) Number of acres within THP units
5) Amounts and types of silviculture prescriptions
6) Location of THP
    a. Township, Range, and Section
    b. Meridian
    c. County
7) Identify NSO activity centers returned by CDFG reports
8) Surveys conducted and activity center status
9) Logic behind take determination
    a. Habitat considerations
        i. Acres, quality, and location of suitable habitat pre- and post-harvest
        ii. Effects of timber operations on suitable habitat
            1. Degrade: suitable habitat is harvested but still functions in the capacity it did pre-harvest (i.e. Foraging habitat before harvest functions as foraging habitat post-harvest, nesting/roosting habitat pre-harvest functions as nesting/roosting habitat post-harvest)
            2. Downgrade: pre-harvest nesting/roosting habitat becomes foraging habitat post-harvest
            3. Remove: nesting/roosting or foraging habitat is harvested such that it no longer functions as habitat post-harvest
    b. Proximity of activity center to operations
    c. Survey data
10) Sunset date and seasonal restrictions
    a. If 2 year protocol and surveys are current and negative, additional TA needed if operations not completed by February 1, *YEAR* (review protocol page 3).
    b. If 1 year protocol and surveys are current and negative, additional TA needed if operations not completed by February 1, *YEAR* (review protocol page 3).
    c. If NSOs detected in previous surveys and operations are not complete before February 1, surveys are required to determine location and status of NSOs prior to operations during each breeding season that operations are ongoing.
    d. If no owls within 1.3 miles of THP (CDFG reports) and no suitable habitat within units or 1.3 miles of units, additional technical assistance may not be required.
11) Name of agency person to contact if there questions regarding TA



*See Section III.2 for habitat definitions

Habitat Retention within Core Area and 1.3 mile Home Range–Interior



*See Section III.2 for habitat definitions

Information Needed for US Fish and Wildlife Service Timber Harvest Plan – Northern Spotted Owl Technical Assistance Analysis

1) All documentation submitted for Technical Assistance must be legible

2) Letter requesting technical assistance providing general information relevant to the Timber Harvest plan (THP):
    a. THP number
    b. Township-Range-Section location data
    c. Presence/absence of northern spotted owls (NSO)
    d. Other important information that might influence take determination, such as:
        i. Operating outside of breeding season
        ii. THP at high elevation (above 6000 feet)
        iii. Forest type or physiographic province

3) Overview map showing location of THP units in relation to NSO activity centers and detection locations

4) Silviculture information:
    a. Silviculture map(s) from THP showing location of THP units and type(s) of silviculture
        i. Silviculture prescription important in the case(s) where units are within 1.3 miles of NSO activity centers
    b. Description of silviculture from THP including number of acres of each silviculture prescription

5) Current California Department of Fish and Game (CDFG) California Natural Diversity Database (CNDDB)/Spotted Owl Viewer Reports 1, 2, and 3 for area extending 1.3 miles from THP boundary
    a. Report 1 is sufficient if no NSOs activity centers returned by query
    b. Version date (upper left corner) must correspond to the present rendition of the CDFG database
    c. If known NSO locations deviate from CDFG reports, submit documentation from landowner supporting placement of NSO activity centers and detections

6) Nesting/roosting and foraging habitat mapped out to 0.7 mile from THP boundary or out to 0.25 mile for THPs that will only operate in unsuitable habitat

7) Habitat typing maps pre- and post-harvest for each NSO activity center within 1.3 miles of THP boundary
    a. Extend typing to a 1.3 miles radius from the best-known location for NSO activity center(s)
        i. Not always be coincident with CDFG Report 2 or 3
        ii. Reasons for deviations from CDFG report documented
    b. Maps shall delineate 1000 foot, 0.5 mile, 0.7 mile, and 1.3 miles radii distances from activity center

8) Table listing number of acres of nesting/roosting and foraging habitat within 0.5 mile, 0.7 mile, and 1.3 miles of activity centers pre- and post-harvest based on maps provided for #6.

9) Survey data:
    a. Map of call route
    b. Survey forms or summary sheet including survey date, survey start time, and survey results
    c. Follow-up forms, if NSOs detected during surveys
    d. Maps of detection/response locations, if NSOs detected during surveys

10) For operations proposed within 1.3 miles of NSO activity centers, habitat typing must be verifiable
    a. Aerial photo coverage, or equivalent imagery, of the 1.3 miles area surrounding activity centers within which timber operations are proposed
    b. Include maps of timber operations within 1.3 miles of known NSOs that have occurred since the date of the aerial photo or equivalent imagery
    c. Include maps of approved timber operations within 1.3 miles of known NSOs

11) If requesting a determination of unoccupied status for an activity center, the following are also required:
    a. Activity center occupancy history
    b. Survey history
    c. Current condition of habitat
        i. Include discussion of past and approved timber operations and natural events such as fire that has or will alter the condition of the habitat.

Revised February 27, 2008
Replaces February 1, 2008 version

Attachment B: Take Avoidance Analysis-Interior

I. Accuracy of NSO activity center location and status

1) Location
    a. Confirm plotted activity center location accuracy
        i. CDFG Reports 2 and 3
        ii. Data from adjacent landowners
        iii. Recent surveys
    b. Document deviations from CDFG locations
    c. Update habitat analysis maps as necessary
2) Status
    a. Valid site
        i. Review page 11 of protocol to determine
        ii. If not valid, report to CDFG for inclusion in next database update
    b. Current occupancy status
    c. Current reproductive status, if determined

II. Survey Effort

1) Coverage
    a. Surveys of nesting/roosting habitat out to 0.7 miles from THP boundary
        i. Use THP habitat map(s) to verify
2) Protocol survey
    a. Time of day
    b. Spacing between visits
    c. Number of surveys
    d. Survey dates
    e. Time spent at each call point
3) Follow up visit(s)
    a. Confirm that the area searched covers suitable habitat within response location/last known location within a logical distance.
    b. Time of follow up and duration of follow up
    c. Additional night surveys
        i. Review page 10 of protocol

III. Habitat

1) Typing
    a. Verify habitat typing with aerial photos, equivalent imagery, or field visits
    b. Changes to typing need to be reflected in the NSO habitat acres table and habitat analysis maps
    c. Post harvest typing

i. Post-harvest habitat typing must agree with the silviculture prescription

2) Definitions
   a. Nesting/roosting
      i. High Quality Nesting/roosting Habitat
         1. Basal Area = 210+ square feet, **and**
         2. ≥ 15" quadratic mean diameter (QMD) , **and**
         3. ≥ 8 trees per acre (TPA) of trees ≥ 26" in diameter at breast height (DBH) , **and**
         4. ≥ 60% canopy closure
      ii. Nesting/roosting Habitat
         1. A mix of basal areas ranging from 150-180+ square feet, **and**
         2. ≥ 15" QMD, **and**
         3. ≥ 8 TPA of trees ≥ 26" DBH, **and**
         4. ≥ 60% canopy closure
   b. Foraging
      i. Foraging Habitat
         1. A mix of basal areas ranging from 120-180+ square feet, **and**
         2. ≥ 13" QMD, **and**
         3. ≥ 5 TPA of trees ≥ 26" DBH, **and**
         4. A mix of ≥ 40%-100% canopy closure
      ii. Low Quality Foraging Habitat
         1. A mix of basal areas ranging from 80-120+ square feet, **and**
         2. ≥ 11" QMD, **and**
         3. ≥ 40% canopy closure

3) Quantities
   a. Within 1000 feet of activity center
      i. Outside breeding season (September 1 through January 31): no timber operations other than use of existing roads
      ii. During the breeding season (February 1 through August 31): no timber operations other than the use of existing, permanent, year-round roads

   b. Within 0.5 mile radius (502 acres) centered on activity center
      i. Retention of habitat should follow Section III. 4 of this document
      ii. At least 250 acres nesting/roosting habitat present, as follows:
         1. 100 acres High Quality Nesting/roosting Habitat, **and**
         2. 150 acres Nesting/roosting Habitat

      –AND–

      iii. At least 150 acres foraging habitat must be present, as follows:
         1. 100 acres Foraging Habitat, **and**
         2. 50 acres Low Quality Foraging Habitat
      iv. No more than 1/3 of the remaining suitable habitat may be harvested during the life of the THP

   c. Between 0.5 mile radius and 1.3 miles radius circles centered on activity center

i. Retention of habitat should follow Section III. 4 of this document
ii. ≥935 acres suitable habitat must be present, as follows:
    1. At least 655 acres Foraging Habitat, **and**
    2. At least 280 acres Low Quality Foraging, **and**
    3. No more than 1/3 of the remaining suitable habitat may be harvested during the life of the THP

4) Applying Habitat Definitions to Forest Stands
    a. Because the structural characteristics of forest stands used by Northern Spotted Owls are heterogeneous, management based on average values is unlikely to retain habitat suitability. For this reason, the habitat definitions provided under Section III.2.a and b. (above) are intended for application at the scale of roughly 20 acres (may be somewhat more or less depending on plot density or measurement technique). This means that within any given 20-acre area intended to serve as Nesting/Roosting or Foraging habitat, the values for QMD, basal area, TPA, and canopy closure should be variable, but stand averages should follow the standards provided under each habitat definition. Where ranges of values are provided (e.g. 150-180 ft^2 basal area), this means that the mean values can vary across the many 20-acre areas that make up a spotted owl core area and home range. It is important to recognize habitat quality will be compromised by timber harvesting that moves stand parameters towards uniformly low average values for stand density and tree size, even during multiple entries. This is particularly true at spotted owl territories with low (at or below quantities in Section III.3.a-c) amounts of habitat; in these cases the highest-quality habitat available should be identified and retained before treatment of other suitable habitat is considered.

5) Priority Ranking of Habitat Retention Acres
    d. Tree species composition
        i. Mixed conifer stands should be selected over pine dominated stands
    e. Abiotic considerations
        i. Distance to nest
            1. Nesting/roosting and foraging habitat closest to identified nest trees, or roosting trees if no nest trees identified
        ii. Contiguous
            1. Nesting/roosting habitat within the 0.5 mile radius must be as contiguous as possible
            2. Minimize fragmentation of foraging habitat as much as possible
        iii. Slope position
            1. Habitats located on the lower 1/3 of slopes provide optimal micro-climate conditions and an increased potential for intermittent or year-round water sources
        iv. Aspect
            1. Habitats located on northerly aspects provide optimal vegetation composition and cooler site conditions

v. Elevation
   1. Habitat should be at elevations of less than 6000 feet, though the elevation of some activity centers (primarily east of Interstate 5) may necessitate inclusion of habitat at elevations greater than 6000 feet.

6) Size and Shape of Habitat Patch
   a. Narrow strips of habitat (WLPZs, retention areas between clearcuts, etc.) may contain the characteristics of nesting/roosting habitat. However, when these narrow strips of habitat are surrounded by unsuitable or low quality habitats, they function as foraging habitat at best.
   b. Narrow strips of habitat (100m or less), provide for a lot of edge habitat and little to no interior habitat. Franklin et al (2000) describe interior habitats as the amount of spotted owl habitat ≥100m from an edge. They describe edge habitat as edge between spotted owl habitat and all other vegetation types.
   c. Because WLPZs, for example, are 100m or less in total width, they are considered edge habitats if surrounded by unsuitable habitat. Edge habitats do not provide for protection from predators nor do they provide the microclimates of interior habitats.

IV. Determination

1) If surveys are inadequate or do not meet the intent of protocol, take determination may not be possible.
2) If habitat typing is inadequate, take determination may not be possible.
3) If NSO home range habitat acres are below desired conditions (Section III. 2, 3, and 4), additional loss of suitable habitat can lead to take.
4) If NSOs are nesting, utilize seasonal restriction for all timber operations within 0.25 mile of nest (February 1 through August 31).
5) If effects are limited to noise disturbance (e.g., no suitable habitat in harvest units, but suitable habitat within 0.25 mile of units), a modified seasonal restriction may be used from February 1 through July 9
   a. Seasonal restriction applies to unsurveyed suitable habitat within 0.25 mile of unit boundary.
   b. If protocol surveys were conducted **and** did not detect reproductive NSOs, seasonal restrictions not warranted.
6) Multiple THPs located within a given NSO territory need to be considered collectively or a take determination may not be possible.

V. TA Letter Contents

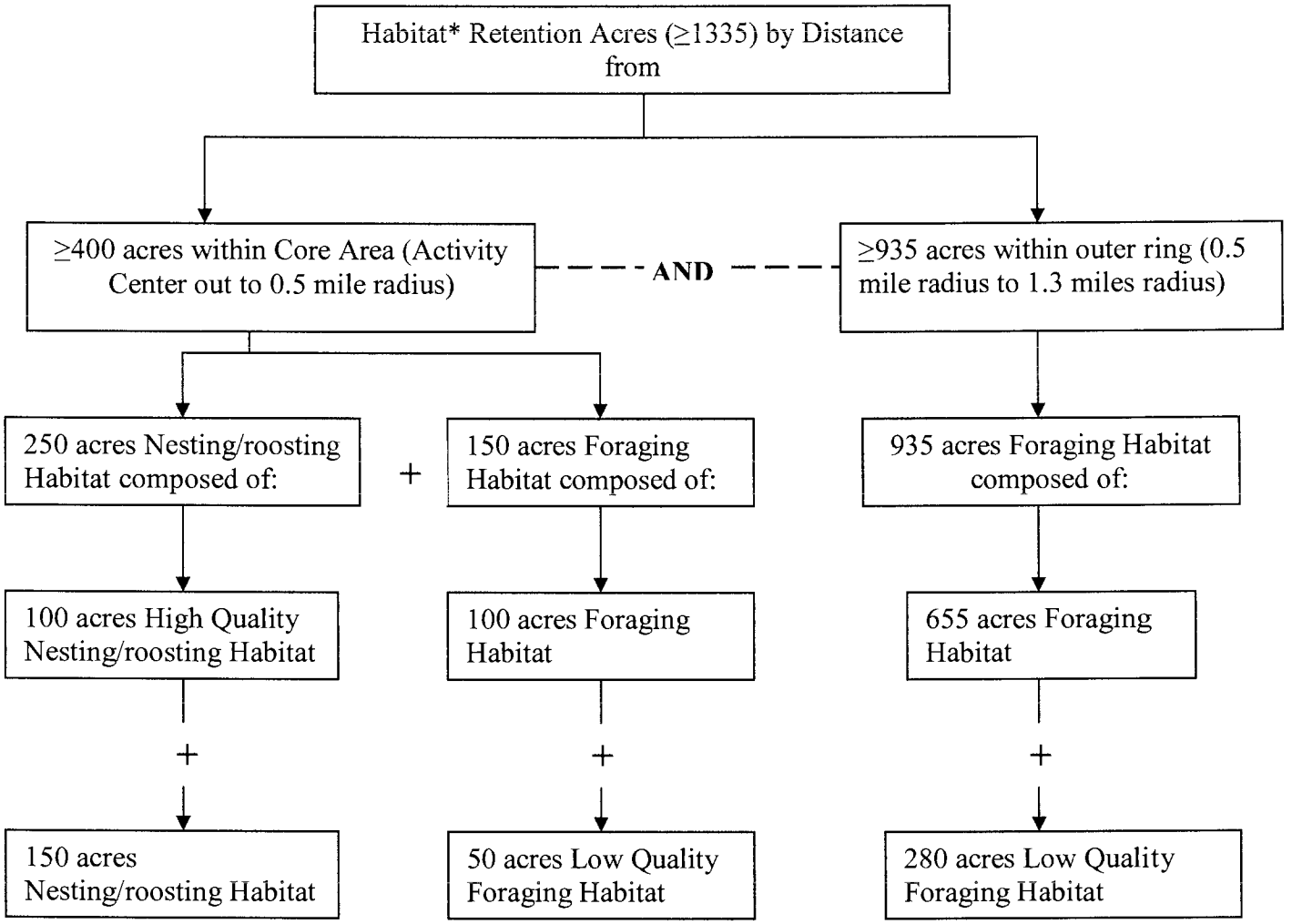
1) Date of written TA request
2) Date request received
3) Note if previous TA(s) provided in past
4) Number of acres within THP units
5) Amounts and types of silviculture prescriptions

6) Location of THP
    a. Township, Range, and Section
    b. Meridian
    c. County
7) Identify NSO activity centers returned by CDFG reports
8) Surveys conducted and activity center status
9) Logic behind take determination
    a. Habitat considerations
        i. Acres, quality, and location of suitable habitat pre- and post-harvest
        ii. Effects of timber operations on suitable habitat
            1. Degrade: suitable habitat is harvested but still functions in the capacity it did pre-harvest (i.e. Foraging habitat before harvest functions as foraging habitat post-harvest, nesting/roosting habitat pre-harvest functions as nesting/roosting habitat post-harvest)
            2. Downgrade: pre-harvest nesting/roosting habitat becomes foraging habitat post-harvest
            3. Remove: nesting/roosting or foraging habitat is harvested such that it no longer functions as habitat post-harvest
    b. Proximity of activity center to operations
    c. Survey data
10) Sunset date and seasonal restrictions
    a. If 2 year protocol and surveys are current and negative, additional TA needed if operations not completed by February 1, *YEAR* (review protocol page 3).
    b. If 1 year protocol and surveys are current and negative, additional TA needed if operations not completed by February 1, *YEAR* (review protocol page 3).
    d. If NSOs detected in previous surveys and operations are not complete before February 1, surveys are required to determine location and status of NSOs prior to operations during each breeding season that operations are ongoing.
    e. If no owls within 1.3 miles of THP (CDFG reports), no suitable habitat within units, **and** no suitable habitat within 0.25 mile of units, additional technical assistance may not be required.
11) Name of agency person to contact if there questions regarding TA

Literature Cited

Franklin, A., D. Anderson, R. Gutierrez, and K. Burnham. 2000. Climate, Habitat Quality, and Fitness in Northern Spotted Owl Populations in Northwestern California. *Ecological Monographs,* 70(4), pp. 539-590

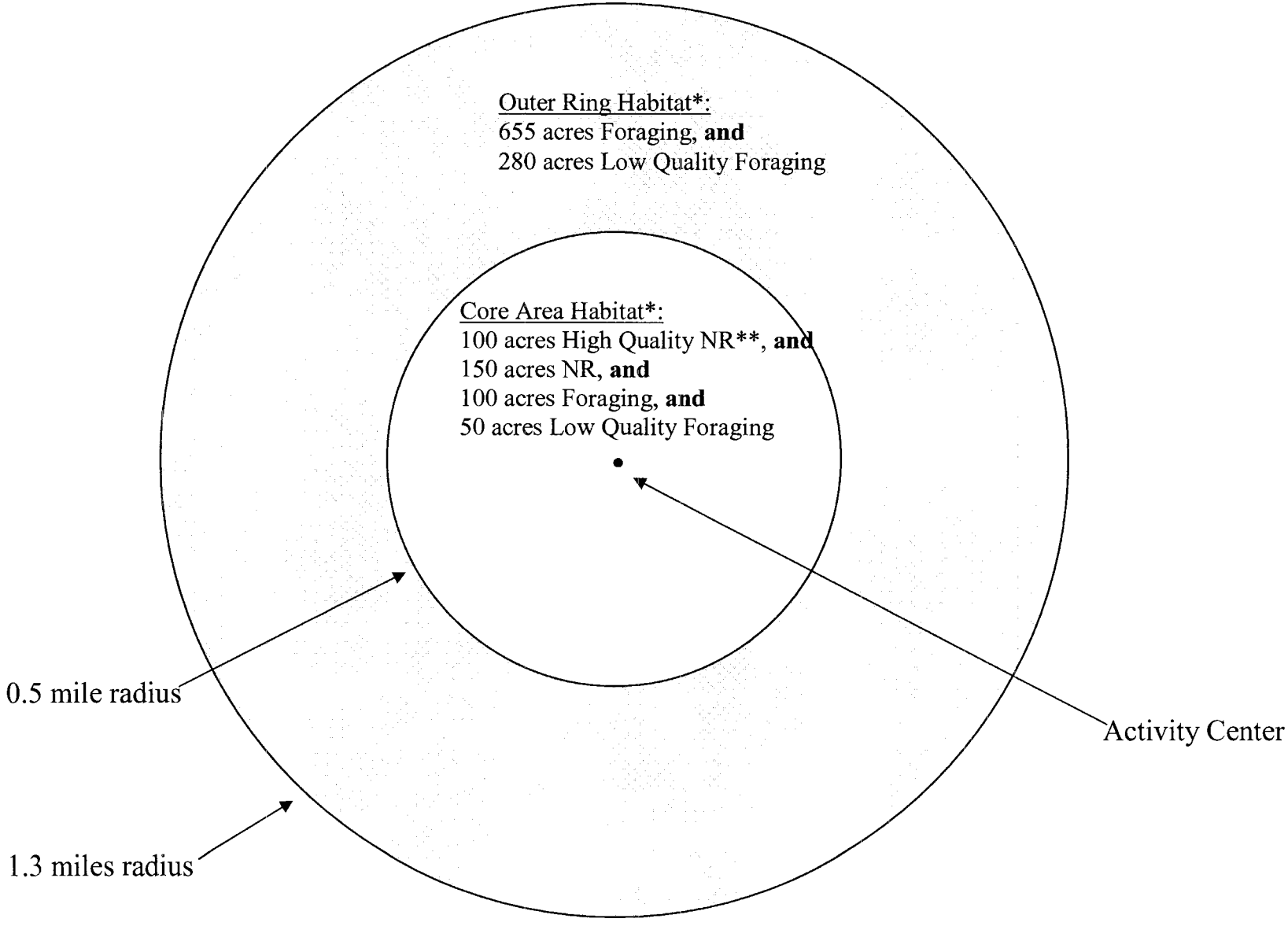
Revised February 27, 2008
Replaces February 1, 2008 version



*See Section III.2 for habitat definitions

Revised February 27, 2008
Replaces February 1, 2008 version

Habitat Retention within Core Area and 1.3 mile Home Range–Interior



*See Section III.2 for habitat definitions
**NR = Nesting/roosting

Northern Spotted Owl Disclosure and Impacts Analysis Using 14 CCR § 919.9(g) [939.9(g)]

The following impacts disclosure and analysis is intended for use in timber harvesting and non-industrial timber management plans that propose to avoid take of the northern spotted owl (NSO) through the use of 14 CCR § 919.9(g)[1] [939.9(g)]. The information may be needed in order for the California Department of Forestry and Fire Protection (CAL FIRE) to evaluate whether the proposed timber operations avoid take of the NSO per 14 CCR § 919.10 [939.10]. Take avoidance strategies that propose the use of 14 CCR § 919.9(g) [939.9(g)] must meet the requirements of 14 CCR §§ 895.1 and 919.9(g) [939.9(g)], but are not required to meet the currently-recommended U. S. Fish and Wildlife Service (USFWS) standards for activity center protection and post-harvest habitat retention. However, since USFWS has indicated that use of 14 CCR 919.9(g) [939.9(g)] may not avoid take of NSO[2], CAL FIRE may need additional information, which clearly and substantively demonstrates why the proposed, site-specific protection measures and the level and configuration of post-harvest habitat retention avoids take of the NSO. The following questions are meant to elicit the information that CAL FIRE may need to determine whether the proposed timber operations avoid take of the NSO.

NSO Habitat Definitions

1. Which definition of NSO habitat is used?

   ☐ 14 CCR § 895.1: Functional nesting, functional roosting and functional foraging habitat.

   ☐ USFWS Attachment B: High quality nesting-roosting, nesting-roosting, foraging and low quality foraging habitat.

   ☐ Other (provide basis):

2. If using functional nesting, roosting and foraging habitat contained in 14 CCR § 895.1 or "Other," discuss how using non-USFWS recommended habitat definitions will provide for the biological needs of the NSO:

NSO Activity Center Impacts Analysis

Complete the following tables and accompanying impacts analysis for <u>each</u> NSO activity center within 1.3 miles of the plan area and within 0.25 mile of appurtenant roads. The

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[1] This document is intended for use within the Coast and Northern Forest Districts wherever *Revised USFWS Attachment B Northern Spotted Owl Take Avoidance Analysis – Interior (2/27/08)* applies. It is not applicable to areas within the Coast Forest District where *Revised USFWS Attachment A NSO Take Avoidance Analysis – Coast Redwood 3-15-11* applies.

[2] See: http://www.fire.ca.gov/resource_mgt/downloads/USFWS_%20NSO_TakeAvoidanceGuidelines_ScienceSupportDocument_121409.pdf.

Habitat Summary in the following table presumes use of the owl habitat definitions of functional nesting, roosting and foraging habitat contained in 14 CCR § 895.1.

Activity center:			
Habitat Summary			
Within 0.5 mile radius (503 acres) of the activity center (acres)	**Pre-harvest**	**Post-harvest**	**Net change**
Nesting habitat			
Roosting habitat			
Foraging habitat			
Total owl habitat			
Non-habitat			
Within 0.7 mile radius (985 acres) of the activity center (acres)	**Pre-harvest**	**Post-harvest**	**Net change**
Nesting habitat			
Roosting habitat			
Foraging habitat			
Total owl habitat			
Non-habitat			
Within 1.3 miles radius (3398 acres) of the activity center (acres)	**Pre-harvest**	**Post-harvest**	**Net change**
Nesting habitat			
Roosting habitat			
Foraging habitat			
Total owl habitat			
Non-habitat			

Effect on USFWS Habitat					
Are timber operations proposed in NSO habitat that meets the USFWS definition of habitat within 0.5 mile of the activity center?			**If yes, provide the pre- and post-harvest habitat quantities and the net change in habitat (acres):**		
	No	**Yes**			
			Pre-harvest	**Post-harvest**	**Net change**
High quality nesting-roosting					
Nesting-roosting					
Foraging					
Low quality foraging					
Total owl habitat					

Effect on USFWS Habitat					
Are timber operations proposed in NSO habitat that meets the USFWS definition of habitat between 0.5 mile and 1.3 miles of the activity center?			**If yes, provide the pre- and post-harvest habitat quantities and the net change in habitat (acres):**		
	No	**Yes**			
			Pre-harvest	**Post-harvest**	**Net change**
High quality nesting-roosting					
Nesting-roosting					
Foraging					
Low quality foraging					
Total owl habitat					

Proposed Timber Operations			
During the NSO breeding season will timber operations occur within any of the following distances to an occupied or unsurveyed activity center?			**If yes, describe the type, timing and extent of timber operations:**
	Yes	**No**	
0 – 500 feet?			
500 – 1000 feet?			
1000 feet – 0.25 mile?			
0.25 – 0.5 mile? (Helicopter Use only)			
During the non-breeding season will timber operations occur within any of the following distances to the activity center?			**If yes, describe the type, timing and extent of timber operations:**
	Yes	**No**	
0 – 500 feet?			
500 – 1000 feet?			

Impacts Analysis

1. If the answer to any item under **Effect on USFWS Habitat** above is yes, address what measures have been incorporated into the plan in order to retain the best available habitat in light of the requirements of the Forest Practice Rules to avoid take of the NSO, the current USFWS recommendations regarding NSO habitat and the biological requirements for feeding, breeding, nesting and sheltering for the NSO:

2. If the answer to any item under **Proposed Timber Operations** above is yes, address whether the proposed timber operations have the potential to **harass** the NSO. Each item should demonstrate lack of direct and indirect impacts, and any conclusions will need to be supported by substantial evidence[3].

    a. Because the prey base or the ability to catch prey could be impaired, demonstrate how the proposed timber operations will avoid significantly disrupting feeding habits:

    b. Demonstrate how the proposed timber operations will avoid significantly disrupting breeding success:

    c. Because activities could be conducted near to the activity center, demonstrate how the proposed timber operations will avoid significantly disrupting nesting behavior:

    d. Because the ability to escape predators, survive severe weather, and find appropriate microclimes could be adversely altered, demonstrate how the proposed timber operations will avoid significantly disrupting sheltering, which includes roosting, nesting, and feeding:

3. If timber operations are proposed within 1.3 miles of an activity center, address the following relative to whether the proposed timber operations have the potential to **harm** the NSO. Each item should demonstrate lack of direct and indirect impacts, and any conclusions will need to be supported by substantial evidence.

    a. Because the prey base or the ability to catch prey could be impaired, demonstrate how the proposed timber operations will avoid significantly impairing feeding habits:

    b. Because of a possible reduction in surrounding owl habitat before the young have had an opportunity to successfully disperse from the activity center, demonstrate how the proposed timber operations will avoid significantly impairing breeding success:

[3] 14 CCR §15384(b): Substantial evidence shall include facts, reasonable assumptions predicated upon facts, and expert opinion supported by facts.

c. Because the activity center or adjoining area up to 500 feet from the activity center could be adversely altered, demonstrate how the proposed timber operations will avoid significantly impairing nesting behavior:

d. Because the ability to escape predators, survive severe weather, and find appropriate microclimes could be adversely altered, demonstrate how the proposed timber operations will avoid significantly impairing sheltering, which includes roosting, nesting, and feeding:

Attachment 1-2013 THPs Sorted by NSO option

HarvestDocument	landowner	District	Acreage	NSO Option
2-13-079-SHA	Wyntoon Timberlands	Northern	245	e-SOMP
2-13-075-SIS	Michigan-California Timber. Co.	Northern	753	e-SOMP
2-13-073-TRI	Michigan-California Timber Co.	Northern	312	e-SOMP
2-13-070-TRI	Michigan-California Timber Co.	Northern	237	e-SOMP
2-13-026-SIS	Wyntoon Timerlands, LLC	Northern	631	e-SOMP
				5
2-13-081-TRI	Sierra Pacific	Northern	401	e
1-13-059-HUM	Prior Family Trust	Coast	740	e
1-13-135-MEN	Usal Redwood Forest	Coast	214	e
1-13-133-MEN	Usal Redwood Forest	Coast	435	e
1-13-129-MEN	Hawthorne	Coast	14	e
1-13-125-MEN	Jackson Demonstration SF	Coast	240	e
1-13-122-HUM	Sierra-Pacific	Coast	125	e
1-13-119-MEN	Hawthorne	Coast	117	e
1-13-118-MEN	Jon Cook	Coast	76	e
1-13-117-MEN	Coastal Ridges	Coast	459	e
1-13-115-MEN	Coastal Ridges	Coast	550	e
1-13-112-HUM	Sierra-Pacific	Coast	383	e
1-13-102-LAK	Sanhedrin Holdings, LLC	Northern	2212	e
1-13-101-MEN	Jackson Demonstation SF	Coast	331	e
1-13-097-MEN	Hawthorne	Coast	186	e
1-13-096-MEN	City of Fort Bragg	Coast	8	e
1-13-095-HUM	Hunter Ranch, LLC	Coast	262	e
1-13-094-HUM	Fort Baker Ranch Company	Coast	649	e
1-13-093-MEN	Hawthorne	Coast	223	e
1-13-090-TRI	Jeff Bryant	Northern	44	e
1-13-089-TRI	Jeff Bryant	Coast	45	e
1-13-087-SON	Glen Proctor, et. Al	Coast	89	e
1-13-078-MEN	Hawthorne	Coast	98	e
1-13-077-SON	George and Lois Parmeter	Coast	104	e
1-13-076-HUM	Charles Mountain Ranch	Coast	618	e
1-13-069-HUM	FGF US	Coast	415	e
1-13-065-HUM	Robert Schroeder & Amalia Borga	Coast	8	e
1-13-063-HUM	L.D. O'Rourke Foundation	Coast	227	e
1-13-062-SON	Richardson Ranch, LLC	Coast	451	e
1-13-061-MEN	Gualala Redwoods	Coast	91	e
1-13-056-MEN	Hawthorne	Coast	220	e
1-13-053-HUM	Lois Peterson	Coast	22	e
1-13-049-MEN	Hawthorne	Coast	570	e
1-13-046-MEN	North Coast Management	Coast	20	e
1-13-042-MEN	Coastal Ridges, LLC	Coast	627	e
1-13-040-HUM	Russ Ranch and Timber Company	Coast	152	e
1-13-031-MEN	Hawthorne	Coast	565	e
1-13-030-HUM	FGF-US	Coast	545	e

1-13-029-HUM	Elizabeth Marshall	Coast	310 e	
1-13-026-HUM	Arthur Stover	Coast	101 e	
1-13-023-SON	Gualala Redwoods	Coast	170 e	
1-13-014-MEN	Hawthorne	Coast	157 e	
1-13-009-MEN	Hawthorne	Coast	365 e	
1-13-007-MEN	Jackson Demonstration SF	Coast	289 e	
2-13-103-SHA	Oxbow Timber I	Northern	520 e	
2-13-093-SHA	Bascom Pacific, LLC	Northern	568 e	
2-13-091-SIS	Oxbow Timber I	Northern	563 e	
2-13-090-SIS	T.C.&I. Shasta, LLC	Northern	1122 e	
2-13-076-SIS	Fruit Growers Supply Company	Northern	619 e	
2-13-074-SIS	Oxbow Timber I	Northern	603 e	
2-13-067-SIS	Sierra-Pacific Industries	Northern	888 e	
2-13-066-SIS	Oxbow Timber I	Northern	347 e	
2-13-064-TEH	Crane Mills	Northern	1202 e	
2-13-062-SHA	Sierra-Pacific Industries	Northern	502 e	
2-13-058-TRI	Sierra-Pacific Industries	Northern	455 e	
2-13-057-SHA	Bascom Pacific, LLC	Northern	913 e	
2-13-054-SHA	Oxbow Timber I	Northern	198 e	
2-13-049-SIS	Roseburg Resources Co.	Northern	181 e	
2-13-048-SIS	Rome Creek Timber LLC	Northern	423 e	
2-13-046-SHA	Sierra-Pacific Industries	Northern	233 e	
2-13-042-SHA	Russell Reiner	Northern	640 e	
2-13-040-SIS	Jon Burke	Northern	370 e	
2-13-035-TRI	Sierra-Pacific Industries	Northern	185 e	
2-13-034-SHA	Sierra-Pacific Industries	Northern	272 e	
2-13-032-SHA	Sierra-Pacific Industries	Northern	457 e	
2-13-018-TEH	Crane Mills	Northern	865 e	
2-13-016-SIS	T.C.&I., LLC	Northern	1893 e	
2-13-015-THE	Crane Mills	Northern	876 e	
2-13-003-SIS	Lawrence W Smith Living Trust	Northern	153 e	
2-13-022-SHA	Big Bend Hot Springs Project, LLC	Northern	13 e	
				70
1-13-134-HUM	Green Diamond	Coast	206 d-HCP	
1-13-130-HUM	Humboldt Redwoods	Coast	388 d-HCP	
1-13-128-HUM	Green Diamond	Coast	130 d-HCP	
1-13-127-HUM	Green Diamond	Coast	126 d-HCP	
1-13-124-HUM	Green Diamond	Coast	122 d-HCP	
1-13-120-HUM	Green Diamond	Coast	112 d-HCP	
1-13-116-HUM	Green Diamond	Coast	69 d-HCP	
1-13-114-DEL	Green Diamond	Coast	133 d-HCP	
1-13-106-HUM	Green Diamond	Coast	109 d-HCP	
1-13-103-HUM	Green Diamond	Coast	41 d-HCP	
1-13-100-HUM	Humboldt Redwood	Coast	53 d-HCP	
1-13-092-HUM	Green Diamond	Coast	88 d-HCP	
1-13-088-HUM	Green Diamond	Coast	106 d-HCP	
1-13-085-HUM	Green Diamond	Coast	107 d-HCP	

1-13-080-HUM	Green Diamond	Coast	120	d-HCP	
1-13-073-HUM	Green Diamond	Coast	50	d-HCP	
1-13-072-HUM	Green Diamond	Coast	116	d-HCP	
1-13-071-HUM	Green Diamond	Coast	226	d-HCP	
1-13-070-HUM	Humboldt Redwood	Coast	449	d-HCP	
1-13-067-HUM	Green Diamond	Coast	102	d-HCP	
1-13-047-HUM	Humboldt Redwood	Coast	280	d-HCP	
1-13-037-HUM	Green Diamond	Coast	70	d-HCP	
1-13-110-HUM	Green Diamond	Coast	184	d-HCP	
1-13-034-HUM	Green Diamond	Coast	71	d-HCP	
1-13-033-HUM	Humboldt Redwood	Coast	372	d-HCP	
1-13-032-HUM	Green Diamond	Coast	49	d-HCP	
1-13-025-HUM	Green Diamond	Coast	61	d-HCP	
1-13-022-HUM	Green Diamond	Coast	64	d-HCP	
1-13-011-HUM	Green Diamon	Coast	53	d-HCP	
2-13-011-SIS	Fruit Growers Supply Company	Northern	266	d-HCP	
					30
1-13-132-MEN	Mendocino Redwood	Coast	465	a-SORP	
1-13-111-MEN	Mendocino Redwood	Coast	450	a-SORP	
1-13-109-MEN	Mendocino Redwood	Coast	122	a-SORP	
1-13-064-MEN	Mendocino Redwood	Coast	304	a-SORP	
1-13-060-MEN	Mendocino Redwood	Coast	163	a-SORP	
1-13-044-MEN	Mendocino Redwood	Coast	1315	a-SORP	
1-13-019-MEN	Mendocino Redwood	Coast	586	a-SORP	
1-13-001-MEN	Mendocino Redwood	Coast	438	a-SORP	
					8
					113

Attachment 2-Large Landowner NSO
Option USFWS-Alternative-e

HarvestDocument	Activity Center	PreHNR	PreF	PostNR	PostF	Poat harv tothab surplus or deficit+ or-	PreHarv >500 or 1335	e-compliant	PreHarv % Harvested	e-compliant
1-13-122-HUM	None									
1-13-061-MEN	None									
1-13-049-MEN	None									
2-13-062-SHA	None									
2-13-058-TRI	None									
2-13-049-SIS	None									
2-13-032-SHA	None									
		0	0	0	0					
1-13-135-MEN	MEN0106	247	443	244	443	187	190	Yes	2%	Yes
1-13-133-MEN	MEN0098	303	471	274	458	232	274	Yes	15%	Yes
	MEN0106	256	449	247	443	190	205	Yes	8%	Yes
1-13-129-MEN	MEN0131	294	513	294	513	307	307	Yes	0%	Yes
1-13-119-MEN	MEN0111	403	320	403	314	217	223	Yes	3%	Yes
1-13-117-MEN	MEN0067	100	759	100	722	322	359	Yes	10%	Yes
1-13-115-MEN	MEN0197	201	632	201	517	218	333	Yes	35%	No
1-13-112-HUM	HUM0567	863	25	807	28	335	388	Yes	14%	Yes
	HUM0652	897	5	774	10	284	402	Yes	27%	Yes
	HUM0652a	778	86	748	86	334	364	Yes	8%	Yes
	HUM0774	768	70	721	95	316	338	Yes	7%	Yes
	HUM0939	734	74	706	75	281	308	Yes	9%	Yes
	HUM0966	730	25	671	26	197	255	Yes	23%	Yes
1-13-101-MEN	MEN639	355	371	343	383	226	226	Yes	0%	Yes
	MEN582	785	139	747	177	424	424	Yes	0%	Yes
	MEN550	576	246	424	398	322	322	Yes	0%	Yes
	Parlin Trib	689	208	541	356	397	397	Yes	0%	Yes
1-13-097-MEN	MEN0115	275	306	272	299	71	81	Yes	7%	Yes
	MEN0116	231	408	229	408	137	139	Yes	2%	Yes
	MEN0247	356	310	333	333	166	166	Yes	0%	Yes
1-13-093-MEN	MEN0082	386	375	372	371	243	261	Yes	7%	Yes
	MEN0114	305	149	302	149	-49	-46	Yes	-7%	Yes w/TA from Call Fire Biologist
1-13-078-MEN	MEN0320	441	235	441	235	176	176	Yes	0%	Yes
	MEN0539	381	296	381	296	177	177	Yes	0%	Yes
1-13-042-MEN	MEN0197	201	632	201	576	277	333	Yes	17%	Yes
	MEN098	202	563	200	455	155	265	Yes	42%	No
1-13-031-MEN	MEN0370	649	86	643	92	235	235	Yes	0%	Yes
1-13-023-SON	SON090	463	407	451	407	358	370	Yes	3%	Yes
	SON045	713	4	686	4	190	217	Yes	12%	Yes
	SON034	613	183	580	183	263	296	Yes	11%	Yes
	SON012	680	2	667	2	169	182	Yes	7%	Yes
1-13-014-MEN	MEN0146	233	387	233	387	120	120	Yes	0%	Yes
1-13-009-MEN	MEN0122-2012	380	168	360	188	48	48	Yes	0%	Yes
	MEN0232-2012	335	348	303	384	187	183	Yes	6%	Yes
	MEN0509-2012	350	212	297	236	33	62	Yes	45%	No
1-13-007-MEN	MEN585	608	190	451	348	299	298	Yes	0%	Yes
2-13-067-SIS	SIS0319	888	1419	877	1358	900	972	Yes	7%	Yes
2-13-064-THE	TEH030	411	366	411	366	-558	-558	w/TA from USFWS	0%	Yes
	TEH072	172	1191	172	1191	28	28	Yes	0%	Yes
	TEH0087	133	329	133	329	-873	-873	w/TA from USFWS	0%	Yes
	TEH0114	493	205	493	205	-637	-637	w/TA from USFWS	0%	Yes
	TEH0117	630	243	630	243	-462	-462	w/TA from USFWS	0%	Yes
2-13-046-SHA	SHA0106	433	1782	433	1710	808	880	Yes	8%	Yes
2-13-035-TRI	TRI0019	1098	1590	1098	1555	1318	1353	Yes	3%	Yes
2-13-034-SHA	SHA0037	496	2162	494	2077	1236	1323	Yes	7%	Yes
2-13-018-THE	TE030	361	154	361	154	-820	-820	w/TA from USFWS	0%	Yes
	TE037	551	161	551	161	-623	-623	w/TA from USFWS	0%	Yes
	TE101	319	167	319	167	-849	-849	w/TA from USFWS	0%	Yes
2-13-015-THE	TE038	278	405	278	405	-652	-652	w/TA from USFWS	0%	Yes
	TE114	493	138	493	138	-704	-704	w/TA from USFWS	0%	Yes
	RP01	638	327	638	327	-370	-370	w/TA from USFWS	0%	Yes
	TE037	551	135	551	135	-649	-649	w/TA from USFWS	0%	Yes
		24726	20871	23579	20918					

Attachment 3-Small Landowner NSO
Option-USFWS -Alternative e

HarvestDocument	Activity Center	PreHNR	PreF	PostNR	PostF	tothab+ or-	opt e Consistency	Pre-harvNR&F	Avail Harv	NR/F Harvested	%ofavail Harv	e-consistent
1-13-076-HUM	HU514	192	500	192	500	192	Y	692	192.00	0.00	0%	Yes
	HU558	180	715	180	715	395	Y	895	395.00	0.00	0%	Yes
1-13-069-HUM	HUM0239	678	266	678	266	444	Y	944	444.00	0.00	0%	Yes
	HUM0622	554	200	554	200	254	Y	754	254.00	0.00	0%	Yes
1-13-030-HUM	HUM0400	379	463	304	529	333	Y	842	342.00	9.00	3%	Yes
	HUM0405	445	399	336	457	293	Y	844	344.00	51.00	15%	Yes
	HUM0791	638	328	541	375	416	Y	966	466.00	50.00	11%	Yes
	HUM0792	313	578	236	625	361	Y	891	391.00	30.00	8%	Yes
1-13-063-HUM	HUM0565	376	545	331	549	380	Y	921	421.00	41.00	10%	Yes
	HUM0948	296	619	262	649	411	Y	915	415.00	4.00	1%	Yes
	HUM0997	378	511	364	511	375	Y	889	389.00	14.00	4%	Yes
1-13-040-HUM	HUM0816-Active	399	147	383	149	32	Y	546	46.00	14.00	30%	Yes
	HUM0816-histoirc	512	122	481	122	103	Y	634	134.00	31.00	23%	Yes
1-13-029-HUM	HUM0927	179	752	179	752	431	Y	931	431.00	0.00	0%	Yes
1-13-095-HUM	HUM098	521	168	521	168	189	Y	689	189.00	0.00	0%	Yes
	HUM308	552	266	479	303	282	Y	818	318.00	36.00	11%	Yes
	HUM442	767	72	680	117	297	Y	839	339.00	42.00	12%	Yes
1-13-102-LAK	LAK0011	589	1585	588	1542	795	Y	2174	839.00	44.00	5%	Yes
	LAK0013	1327	1390	1246	1381	1292	Y	2717	1382.00	90.00	7%	Yes
	MEN0055	835	1539	812	1539	1016	Y	2374	1039.00	23.00	2%	Yes
2-13-040-SIS	Panther Rock	398	1009	398	1009	72	Y	1407	72.00	0.00	0%	Yes
	Bugle	277	1595	277	1573	515	Y	1872	537.00	22.00	4%	Yes
2-13-042-SHA	SHA0024	364	2506	364	2388	1417	Y	2870	1535.00	118.00	8%	Yes
2-13-090-SIS	SIS0492	192	2189	192	2159	1016	Y	2381	1046.00	30.00	3%	Yes
	SIS0554	644	2150	644	2150	1459	Y	2794	1459.00	0.00	0%	Yes
1-13-062-SON	SON0008	696	53	596	53	149	Y	749	249.00	100.00	40%	No
1-13-077-SON	SON0061	282	476	268	484	252	Y	758	258.00	6.00	2%	Yes
	Totals	12963	21143	12086	21265							

1-13-118-MEN	None
1-13-094-HUM	None
1-13-090-TRI	2-Activity centersnoted within 1.3 miles-No suitable habitat
1-13-089-TRI	2-Activity centersnoted within 1.3 miles-No suitable habitat
1-13-087-SON	None
1-13-053-HUM	None
1-13-046-MEN	None
1-13-026-HUM	None
2-13-103-SHA	None
2-13-093-SHA	None
2-13-091-SIS	None
2-13-074-SIS	None
2-13-066-SIS	None
2-13-057-SHA	None
2-13-054-SHA	None
2-13-048-SIS	None
2-13-003-SIS	None

Attachment 4-NTMPs-2011-2015 NSO Habitat Analysis of Conformance with Option e

HarvestDocument	NSO Option	Activity Center	PreHNR	PreF	PostNR	PostF	Total Post Harv NR/F	Post harv opt e Consistency	NR/F Avail for Harv	NR/F Harvested	%ofavail NR/F Harvested	e-consistent
1-15NTMP-005	e	HU842	448	317	446	319	765	Yes	265	0	0%	yes
1-15NTMP-004	e	HUM488	386	515	383	518	901	Yes	901	0	0%	yes
1-14NTMP-011	e-N	HUM0155	382	1974	353	1990	2343	Yes	2343	13	1%	yes
	e-N	HUM0047	1834	1096	1623	1266	2889	Yes	2889	41	1%	yes
	e-N	HUM0152	1734	1236	1613	1342	2955	Yes	2955	15	1%	yes
1-14NTMP-010	e	MEN443	733	119	733	119	852	Yes	852	0	0%	yes
	e	MEN633	510	345	510	345	855	Yes	855	0	0%	yes
1-14NTMP-008	e	HUM522	616	182	547	251	798	Yes	798	0	0%	yes
	e	HUM525	539	255	520	274	794	Yes	794	0	0%	yes
1-14NTMP-007	e	HUM0645	305	489	305	489	794	Yes	794	0	0%	yes
	e	HUM0862	396	334	396	334	730	Yes	730	0	0%	yes
1-14NTMP-006	e	HUM0162	224	518	223	519	742	Yes	742	0	0%	yes
1-14NTMP-001	e	HUM0294	664	63	658	60	718	Yes	718	9	1%	yes
	e	HUM0455	580	108	569	107	676	Yes	676	12	2%	yes
	e	HUM587	609	90	592	79	671	Yes	671	28	4%	yes
1-13NTMP-005	e	MEN545	715	160	715	160	875	Yes	875	0	0%	yes
	e	MEN627	517	82	517	82	599	Yes	599	0	0%	yes
1-13NTMP-004	e	HUM225	526	294	474	346	820	Yes	820	0	0%	yes
1-13NTMP-002	e	HU 564	293	278	261	310	571	Yes	571	0	0%	yes
	e	HRC#351	397	237	371	263	634	Yes	634	0	0%	yes
		HU563	581	123	578	126	704	Yes	704	0	0%	yes
1-12NTMP-004	e	HUM100	576	209	459	318	777	Yes	777	8	1%	yes
	e	HUM948	693	205	648	250	898	Yes	898	0	0%	yes
	e	HUM997	479	378	401	445	846	Yes	846	11	1%	yes
	e	2011AC	541	300	238	481	719	Yes	719	122	17%	yes
1-12NTMP-001	e	HUM019	288	344	288	344	632	Yes	632	0	0%	yes
	e	BC-001	496	261	201	556	757	Yes	757	0	0%	yes
	e	HUM0330	354	498	354	498	852	Yes	852	0	0%	yes
	e	HUM0441	294	426	294	426	720	Yes	720	0	0%	yes
	e	HUM0742	364	419	364	419	783	Yes	783	0	0%	yes
	e	HUM926	288	241	288	241	529	Yes	529	0	0%	yes
1-11NTMP-013	e	New	370	220	370	220	590	Yes	590	0	0%	yes
1-11NTMP-011	e	New	370	220	370	220	590	Yes	590	0	0%	yes
1-11NTMP-009	e	SON105	609	194	554	249	803	Yes	803	0	0%	yes
1-11NTMP-007	e	MEN238	238	460	238	460	698	Yes	698	0	0%	yes
	e	CG09	207	234	207	234	441	Yes	441	0	0%	yes
	e	NEW XX	324	441	324	441	765	Yes	765	0	0%	yes
1-11NTMP-006	e	SPI40	128	1074	128	1074	1202	Yes	1202	0	0%	yes
	e	HU499	457	1376	457	1376	1833	Yes	1833	0	0%	yes
	e	HU782	874	2424	874	2424	3298	Yes	3298	0	0%	yes
	e	HU892	718	2346	718	2346	3064	Yes	3064	0	0%	yes
	e	HU980	1202	2128	1202	2128	3330	Yes	3330	0	0%	yes
1-11NTMP-003	e	MEN237	787	42	787	42	829	Yes	829	0	0%	yes
1-11NTMP-001	e	MD141	213	272	213	272	485	Yes	485	0	0%	yes
	e	MD461	426	93	426	93	519	Yes	519	0	0%	yes
			24285	23620	22790	24856						
1-15NTMP-002	e	None										
1-15NTMP-001	e	None										
1-14NTMP-009	e	None										
1-14NTMP-005	e	None										
1-13NTMP-006	g	None										
1-12NTMP-002	e	None										
1-11NTMP-012	e	None										
1-11NTMP-005	e	None										
			0	0	0	0						
			24285	23620	22790	24856						

Keeping Northwest California wild since 1977

Sent via e-mail to: director@wildlife.ca.gov on date shown

April 19, 2016

Charlton H. Bonham, Director
California Department of Fish and Wildlife
1416 9th Street, 12th Floor
Sacramento, CA 95814

RE: Development of Northern Spotted Owl Stakeholder Working Group

Dear Director Bonham and Department of Fish and Wildlife:

In light of direction received by the Department from the Fish and Game Commission regarding its desires to see the creation of a Northern Spotted Owl Stakeholder Working Group commence in advance of a final determination on EPIC's petition for listing under the California Endangered Species Act (CESA), we provide the following suggestions for development of the Working Group's outline and framework. We appreciate the opportunity to provide the Department with such input at this time.

Purpose and Need for a Stakeholder Working Group

Any Stakeholder Working Group must be designed to achieve the overarching goals of protecting, enhancing, maintaining, restoring, and conserving the northern spotted owl in California, consistent with Department's mission, and the requirements of CESA. To be clear, EPIC does not believe that creation of a Stakeholder Working Group can or should be used as a basis to avoid CESA listing, or for the Department to otherwise fail to discharge its statutory duties as the trustee agency for wildlife in the State of California, otherwise.

Any Stakeholder Working Group must be construed so as to focus on the actions necessary and advisable to meet the Department's legal and statutory obligations, regardless of the interests of any individual participant or sector of participants.

It is clear that there may be benefits to the creation of a Stakeholder Working Group, insofar as it can aid in communication and coordination of management actions, scientific research, and stakeholder outreach; however, there is also a very

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real danger that a Stakeholder Working Group could do more to stymie necessary and advisable management actions through endless debate and fruitless obfuscation of the best available scientific and commercial evidence with respect to the plight of the NSO, its needs, and the activities that may be necessary to ensure its survival and recovery in the wild.

EPIC therefore cautions the Department to very clearly outline the purpose of any potential Stakeholder Working Group, and also to ensure the ends of any such group process are designed to meet the needs of the species, and not any individual, or sector of stakeholder entities.

Working Group Structure, Members, Participation, and Leadership

Regarding membership, the Stakeholder Working Group should include all interested parties, including EPIC as petitioner, bird and wildlife advocacy groups, and others such as independent scientists and researchers, not merely the regulated industry and the Department in order to be genuinely reflective of the broad array of perspectives, interests, and assets offered by the available community at-large.

Consistent with this, EPIC strongly recommends that any participation and associated information provided or gathered be contingent upon the presumption of full and complete disclosure and availability of all information to all other members of any Stakeholder Working Group.

In terms of leadership, EPIC strongly recommends that the Department lead any Stakeholder Working Group effort directly, and not contract outside mediation consultants. Our experience through the development of the California Wolf Plan through the SWG process indicates to us that outside contractors hired for the purposes of mediation are not adequately schooled or prepared for the task or political and social environment likely to be encountered in any NSO Stakeholder Working Group, and that this lack of knowledge and experience with the many entities and individuals that are likely to engage is an innate disadvantage to the overall fluency and effectiveness of the process.

Activities and Focus of the NSO Stakeholder Working Group

The Department's Status Report for the NSO (CDFW 2016), found that without CESA listing, that the continued existence of the NSO is in "serious danger," due to three factors: 1) Present or threatened modification or destruction of its habitat; 2) Competition; and 3) Other natural occurrences or human-related activities. Accordingly, any Stakeholder Working Group process must be designed to explore the aggressive and immediate implementation of management activities that will address these three categories of significant threats to the NSO in order for the group to achieve its presumed intended goal of protecting, and ultimately, recovering the NSO in the wild in California. The best available scientific and commercial information clearly indicates that all three of these threat categories must be addressed simultaneously and aggressively, and that one cannot be

addressed separately or in the absence of any other. Therefore, the Department must take the initiative and the lead to address not only threats such as competition, fire, climate change, and toxic exposure, but must also address the problem of habitat loss and destruction, which a clear and well-documented present and ongoing threat to the NSO in California.

EPIC wishes to refer the Department to its management recommendations from the NSO Status Report, as well as the management recommendations of the federal Revised Recovery Plan for the NSO (USFWS 2011), as a foundational point of discussion and consideration for activities that may be considered as part of the Stakeholder Working Group process. Again, if the Stakeholder Working Group is not to be focused on actual actions intended to conserve the NSO in the wild in California, we must seriously question its value and utility and the benefits of participation over other avenues of advocacy.

Location of Stakeholder Working Group Meetings

Finally, EPIC suggests that any Stakeholder Working Group be based in the northern regions of the state, within the geographic range of the NSO, and within the primary range of the affected landscape and multitude of stakeholders mostly work and reside. Convening the Working Group elsewhere, such as in Sacramento, will result in extensive and expensive and unreasonable burden upon all Stakeholder Working Group participants. EPIC therefore strongly recommends that any Stakeholder Working Group or associated meetings and workshops be focused in regions of the state most likely to be affected by the management actions being contemplated and implemented.

Conclusion

Creation of a Stakeholder Working Group for the NSO is not a substitute for CESA listing, but clearly has the potential to be complementary and beneficial; however such a group also has the potential to serve as a point of muddle process and paralysis to obfuscate the issues surrounding the management and conservation of the NSO, and to stall out the implementation of necessary management and recovery measures. EPIC hopes that any such group developed by the Department will be designed as an action-based entity, and not a process-based entity.

Sincerely,

Rob DiPerna
California Forest and Wildlife Advocate
Environmental Protection Information Center
145 G Street, Suite A
Arcata, California 95521
Office: (707) 822-7711
Email: rob@wildcalifornia.org

Cc: Michael Yaun, Acting Executive Director, California Fish and Game Commission

Eric Sklar, President, California Fish and Game Commission

From:	George Gentry
To:	FGC
Subject:	NSO comment
Date:	Tuesday, May 03, 2016 10:22:35 AM
Attachments:	image001.png image002.png SPIResearchNSODensityStudy.pdf Kroll_2016_stirx.pdf Diller et al 2-16-2016.pdf 160502 NSO supplement.pdf

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Attached is a comment and three new studies related to NSO. These were submitted yesterday to the Department per the Commission and Director Bonham's request. They are submitted to you as a courtesy, and to allow the Commissioners time to familiarize themselves with the material.

George "YG" Gentry
Vice President- Regulatory Affairs
California Forestry Association
P: 916.444.6592 / M: 916.584.2950

Northern Spotted Owls

Near Weaverville and Trinity Lake

In Trinity County

Within the Landscape Survey Strategy Area

(An Interim Report)

Sierra Pacific Industries
January 2016

Sierra Pacific Industries
Post Office Box 496014
Redding, California 96049-6014

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Sierra Pacific Industries

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Northern Spotted Owls near Weaverville and Trinity Lake, Trinity County
Within the Landscape Survey Strategy Area
(An Interim Report)
January 2016

Introduction

In 2003, Sierra Pacific Industries (SPI) coordinated with the US Fish and Wildlife Service (Service) to design a comprehensive multi-year survey of northern spotted owls (NSO), which we called the Landscape Survey Strategy (LSS). It was designed to survey all suspected spotted owl nesting/roosting habitat within SPI lands and extending out 0.7 mile from SPI. The total area within the LSS was 307,408 acres, of which 142,279 acres (46%) belonged to SPI. Most of the neighboring lands are under the control of the Shasta-Trinity National Forest. This strategy established 474 permanent survey points (Figure 1) that were surveyed for the five years from 2003 through 2007.

In years previous to the 1990 listing of the NSO under the U.S. Endangered Species Act, SPI surveyed much of their ownership in Trinity County to the north and south of Weaverville to determine how many NSO activity centers (ACs) were present. Surveys were done using protocols existing at the time, but may not have been comprehensive in area coverage, and negative results were not compiled. In addition, ACs in older California Natural Diversity Data Base records were included in the SPI database.

Thus, while we had a good general idea of the extent and numbers of sites on SPI lands, we knew that we did not have an accurate estimate of the number of NSO occupied ACs. During the 1990s, our approximate estimate of ACs on or near the property was 52 (Figure 2), but that estimate was subject to several sources of error, especially inclusion of older sites from over a decade earlier (some from as early as 1974). We could not estimate how many of these met the protocol definition of occupied.

In the decade following the 1990 federal listing of the NSO, the ACs recorded prior to the listing were not surveyed systematically. Instead, most surveys during that period were project based (i.e., during THP prep for the THP area only). Through the 1990s and early 2000s, all THPs were surveyed and harvested under no-take guidance, according to the Forest Practice Rules (FPR) and to whichever agency process was in place at the time. We occasionally found occupied sites in new areas, but many older sites were not revisited over a period of several years. Birds were not marked by banding, so we could only speculate as to movements.

Also during the early 1990s, the Service designated five sites as abandoned. Three of these ACs had been subject to more extensive timber harvest prior to the listing, and they had not been found to be occupied at any time since the listing of the NSO (Figure 3).

Results

The number of occupied ACs found during the 2003 - 2007 surveys was 47 (Figure 3), of which nine were not known previously. Coincidentally, nine older ACs were not occupied during this five-year survey period. Most of the new ACs established by this LSS effort were near older, unoccupied ACs.

In 2011, we began annual re-surveys of the LSS stations. During this five year effort, we found 57 occupied ACs within the original LSS area, 17 of which were in new locations (Figure 4). One activity center occupied during the 2003-2007 surveys was destroyed by wildfire prior to 2011. In addition, one occupied AC has continued to make minor movements throughout the resurvey period and has since been relocated outside the LSS boundary. Due to this bird originally being located within the LSS boundary and since it was included in the baseline and '03-07 analysis, it was included in the density calculations for this survey period even though it now falls just outside the LSS boundary.

Again, new ACs were usually near now unoccupied older ACs. Despite the single AC lost to wildfire, the estimated population density is stable to increasing. The raw density of 57 occupied ACs found on the 173,316 acre survey area results in 0.2105 occupied ACs per square mile. Up from 0.1736 in 2003-2007 based upon 47 occupied ACs and up from an estimated 0.1551 occupied ACs per sq. mi. in 1989 based upon an estimated 42 occupied ACs (80% of 52 known ACs). See table below:

Year	1989	80% (Recovery)	1989 - 2003	2003 - 2007	2011 - 2015
Occupied ACs	52 (max known 1974-1989)	42	47 (max)	47	57
Crude Density[1]	Not Applicable	0.1551[2]	0.1736[2]	0.1736	0.2105
Comment	Assumed 100% occupancy from CNDDB and SPI surveys since protocol surveys were not conducted.	Assume the population was a fully recovered population. (80% occupancy per 2008 NSO Recovery Plan)	Max estimate. Assumed all ACs occupied. (Removed 5 abandoned sites with USFWS concurrence)	Occupancy determined at all sites	Occupancy determined at all sites

[1] Note: Crude density is based upon the 173,316 acre area within .5 mile of a survey station, since the larger area inside the general survey boundary includes the town of Weaverville and a significant area that as a result of wildfires or site quality would never be considered potential habitat. See Figure 7 for the estimated effective survey area.
[2] Grey highlighted numbers are the result of assumptions not actually measured/calculated.

In both of these survey periods, some ACs were determined to not have any responses and historically would have been declared abandoned by the USFWS. Service direction changed in this time period, and the 2012 protocol no longer included a definition for abandoning sites. Thus ACs from owls that may have moved on the landscape continue to increase in number while numbers of occupied ACs and density of owls increased.

In response to the Service's revision of the survey protocol in 2011, we switched to using electronic calling devices for these surveys, and also added over 180 new calling stations, extending geographic extent of the survey effort by about 40 percent, most of which is US Forest Service land within 1.3 miles of SPI ownership. This resulted in location of still more ACs outside the original LSS area; these sites have not been included in the summary

previously mentioned (Figure 5). Also, in 2011, we began banding all NSO on the ownership, so that in the future we will be able to ascertain whether birds in new locations are residents that have relocated, or whether they are immigrants. Since 2011, we have banded 178 NSO (118 adults/sub adults and 60 juveniles).

Reproduction

During this recent 2011- 2015 effort we were able to determine that 30 of these 57 occupied ACs were reproductive, producing at least 97 fledglings (Figure 6). This represents 60 individual successful nesting attempts as many of these AC's reproduced two to four times during this five year survey.

Summary and Conclusion

In summary, the uncertainty associated with the estimate of territories extant at the time of listing precludes precise comparison of numbers over the past 26 years. However, while we have seen some change in the location of occupied ACs, we see no indication of a population decline in the LSS area during the period between the 2003 - 2007 LSS surveys and the surveys being conducted now. While we recognize that this is a very small portion of the California population and our work is not a demographic study, it is worth noting that the LSS area apparently is not showing a similar decline as reported from the NSO demographics studies. The Willow Creek Study area (referred to as NWC) is the nearest USFS demographic study area to the LSS and they have an estimated annual decline of 3.0%. The current range wide demographic average is an estimated annual decline of 3.8% (Dugger et al, 2016).

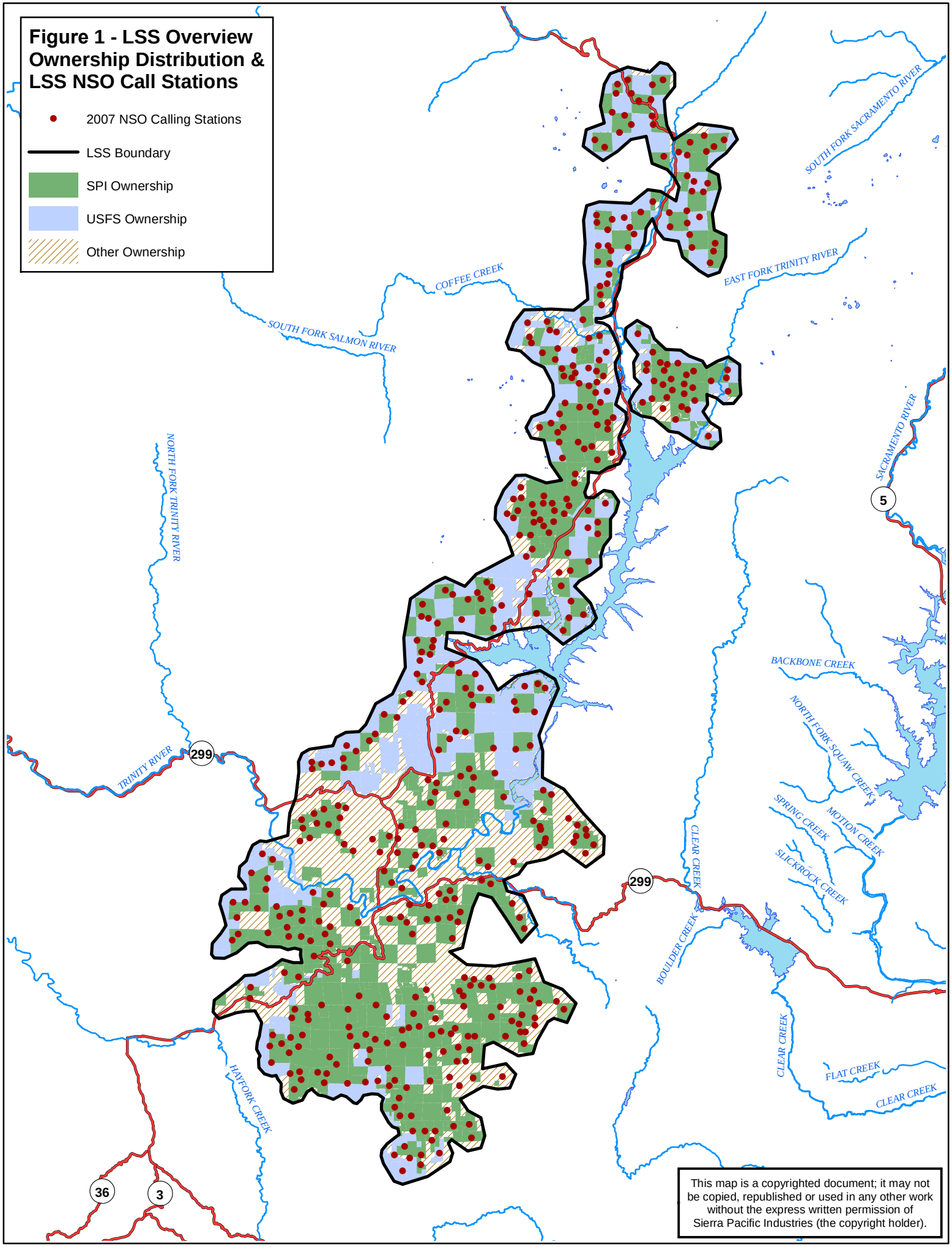
Compared to those values our numbers of occupied ACs and density of owls appears to be increasing. If our study area NSOs were following these rates and assuming that our original 1989 AC count of 52 (minus those the service declared abandoned) we would have a 1989 starting estimate of 47 ACs. Applying the NWC demographic study estimated rate of decline our study area should have experienced a reduction to only 22.1 occupied ACs and based upon the NSO range wide estimated rate we should have only 18.1 occupied ACs today. Rather than those declines our LSS study area has had a net increase of 10 ACs from that estimated starting point.

Since the listing, over the past 26 years, all THPs have been conducted under no-take guidance in effect at the time of harvest. The increased survey effort, improved protocols, and initiation of banding should improve our understanding of the owl population in this area in the future.

In conclusion, to our knowledge, our LSS effort to determine the number of occupied ACs on a fixed area of land is the only existing dataset upon which to assess potential impacts over time of FPR - guided management on NSO density. This study shows that for the period from 2003 through 2015, despite active timber harvest, there has been only an increase in population density for this portion of the range of the NSO. While our current efforts have demonstrated movement of owls around this landscape, as described above, this has resulted in an increase in the number of ACs and a misleading percent occupied estimate. This resultant increase in overall AC count obscures the fact that actual numbers of "occupied" ACs and the density of owls have increased substantially since the listing of the owl.

References

Dugger, Katie M., Eric D. Forsman, Alan B. Franklin, Raymond J. Davis, Gary C. White, Carl J. Schwarz, Kenneth P. Burnham, James D. Nichols, James E. Hines, Charles B. Yackulic, Paul F. Doherty Jr., Larissa Bailey, Darren A. Clark, Steven H. Ackers, Lawrence S. Andrews, Benjamin Augustine, Brian L. Biswell, Jennifer Blakesley, Peter C. Carlson, Matthew J. Clement, Lowell V. Diller, Elizabeth M. Glenn, Adam Green, Scott A. Gremel, Dale R. Herter, J. Mark Higley, Jeremy Hobson, Rob B. Horn, Kathryn P. Huyvaert, Christopher McCafferty, Trent McDonald, Kevin McDonnell, Gail S. Olson, Janice A. Reid, Jeremy Rockweit, Viviana Ruiz, Jessica Saenz, and Stan G. Sovern. ***The effects of habitat, climate, and Barred Owls on long-term demography of Northern Spotted Owls***, The Condor: February 2016, Vol. 118, No. 1, pp. 57-116.



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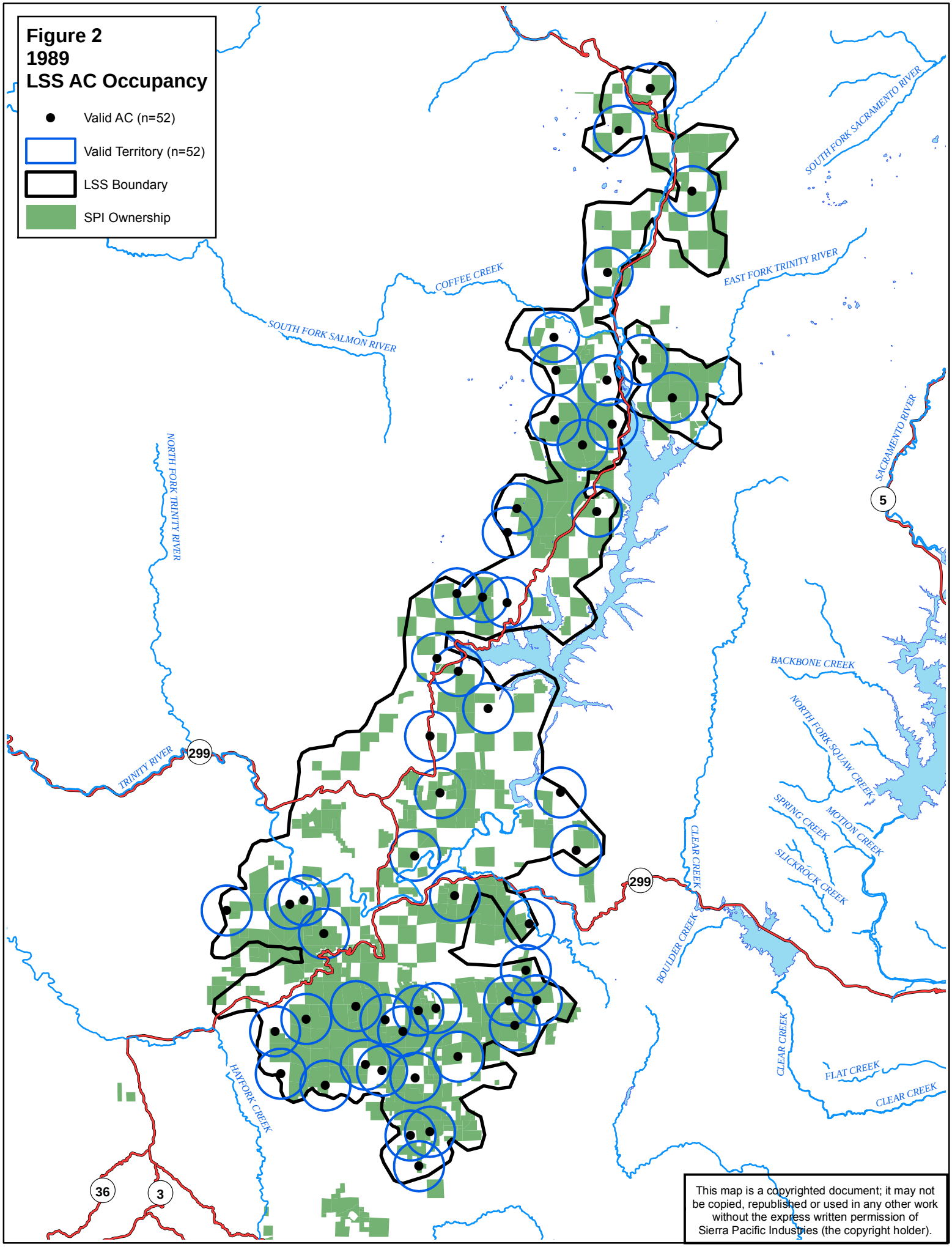

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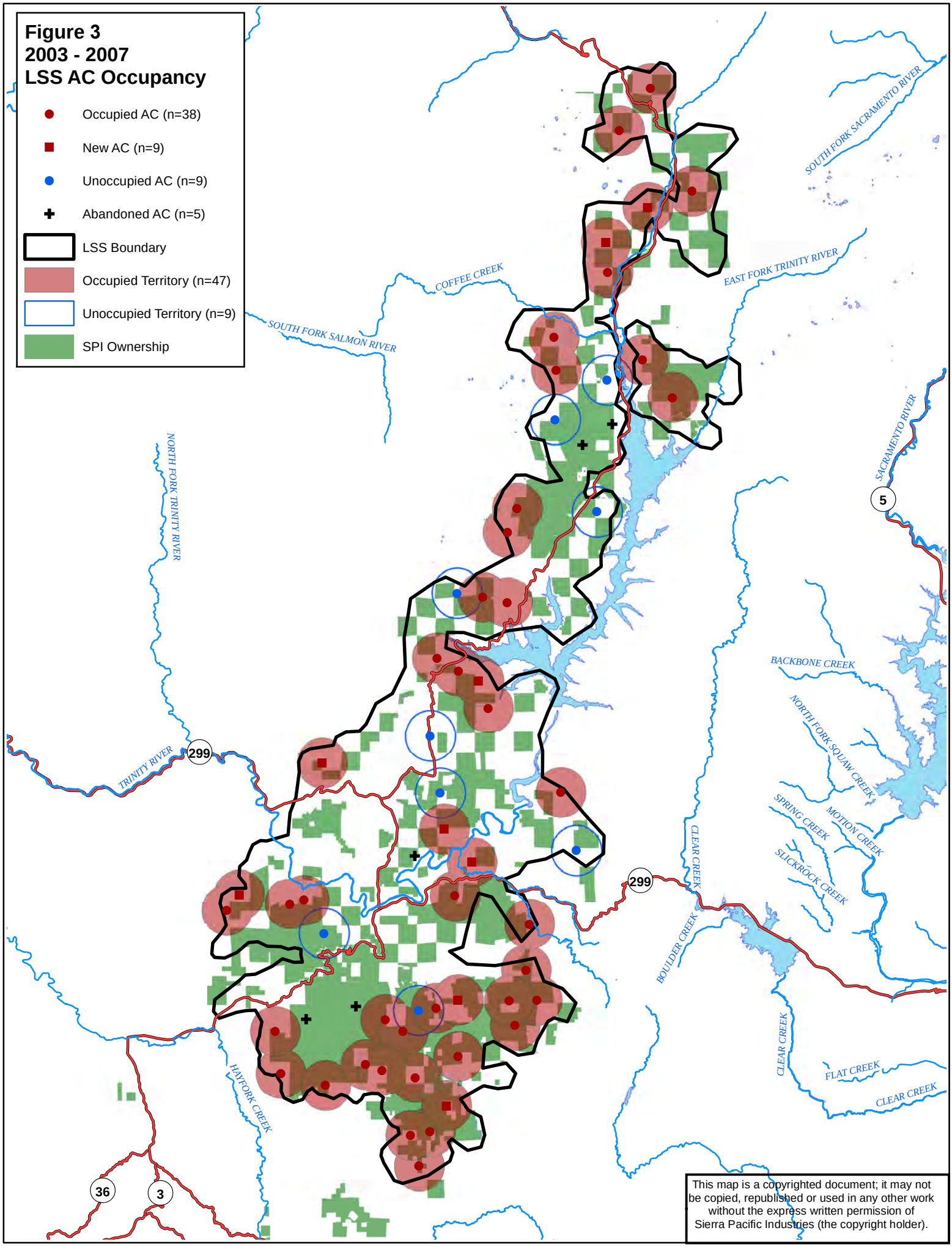
Figure 3
2003 - 2007
LSS AC Occupancy
Occupied AC (n=38)
New AC (n=9)
Unoccupied AC (n=9)
Abandoned AC (n=5)
LSS Boundary
Occupied Territory (n=47)
Unoccupied Territory (n=9)
SPI Ownership
SOUTH FORK SACRAMENTO RIVER
EAST FORK TRINITY RIVER
COFFEE CREEK
SOUTH FORK SALMON RIVER
NORTH FORK TRINITY RIVER
SACRAMENTO RIVER
5
BACKBONE CREEK
NORTH FORK SQUAW CREEK
TRINITY RIVER
299
SPRING CREEK
MOTION CREEK
SLICKROCK CREEK
CLEAR CREEK
299
BOULDER CREEK
CLEAR CREEK
FLAT CREEK
CLEAR CREEK
HAYFORK CREEK
36
3
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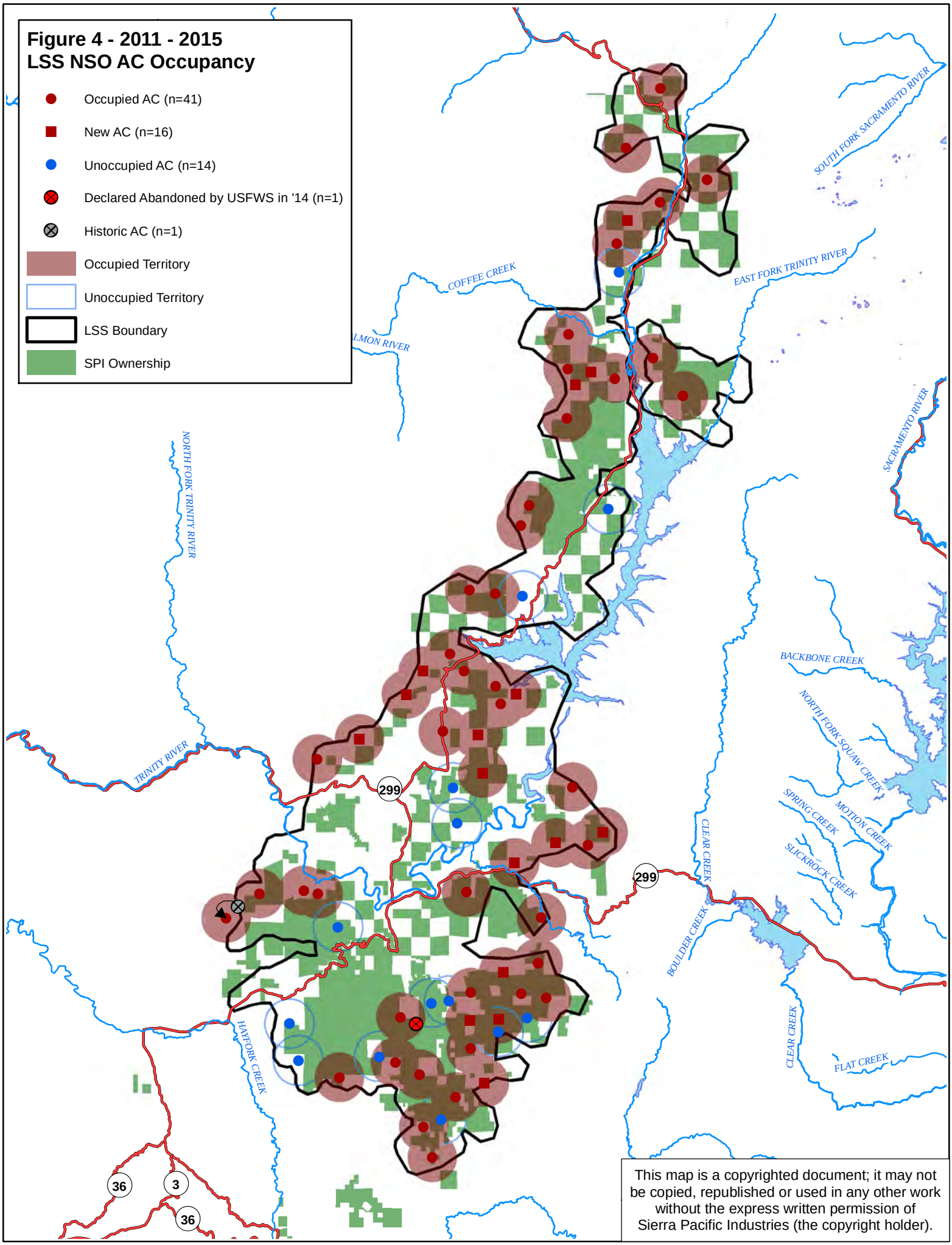
Figure 4 - 2011 - 2015
LSS NSO AC Occupancy
Occupied AC (n=41)
New AC (n=16)
Unoccupied AC (n=14)
Declared Abandoned by USFWS in '14 (n=1)
Historic AC (n=1)
Occupied Territory
Unoccupied Territory
LSS Boundary
SPI Ownership
SOUTH FORK SACRAMENTO RIVER
EAST FORK TRINITY RIVER
COFFEE CREEK
LMON RIVER
NORTH FORK TRINITY RIVER
SACRAMENTO RIVER
BACKBONE CREEK
NORTH FORK SQUAW CREEK
TRINITY RIVER
299
SPRING CREEK
MOTION CREEK
SLICKROCK CREEK
CLEAR CREEK
BOULDER CREEK
HAYFORK CREEK
FLAT CREEK
36
3
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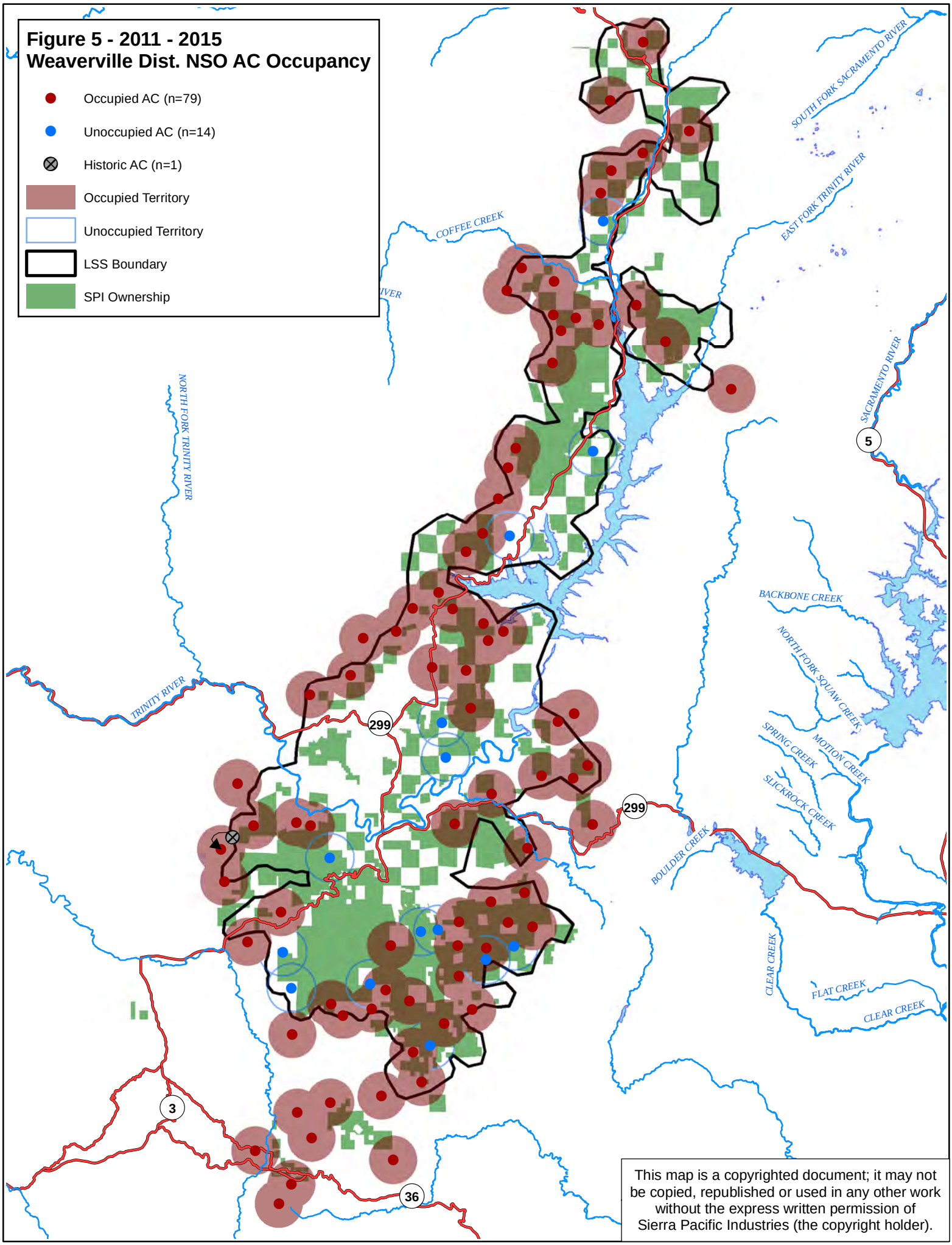

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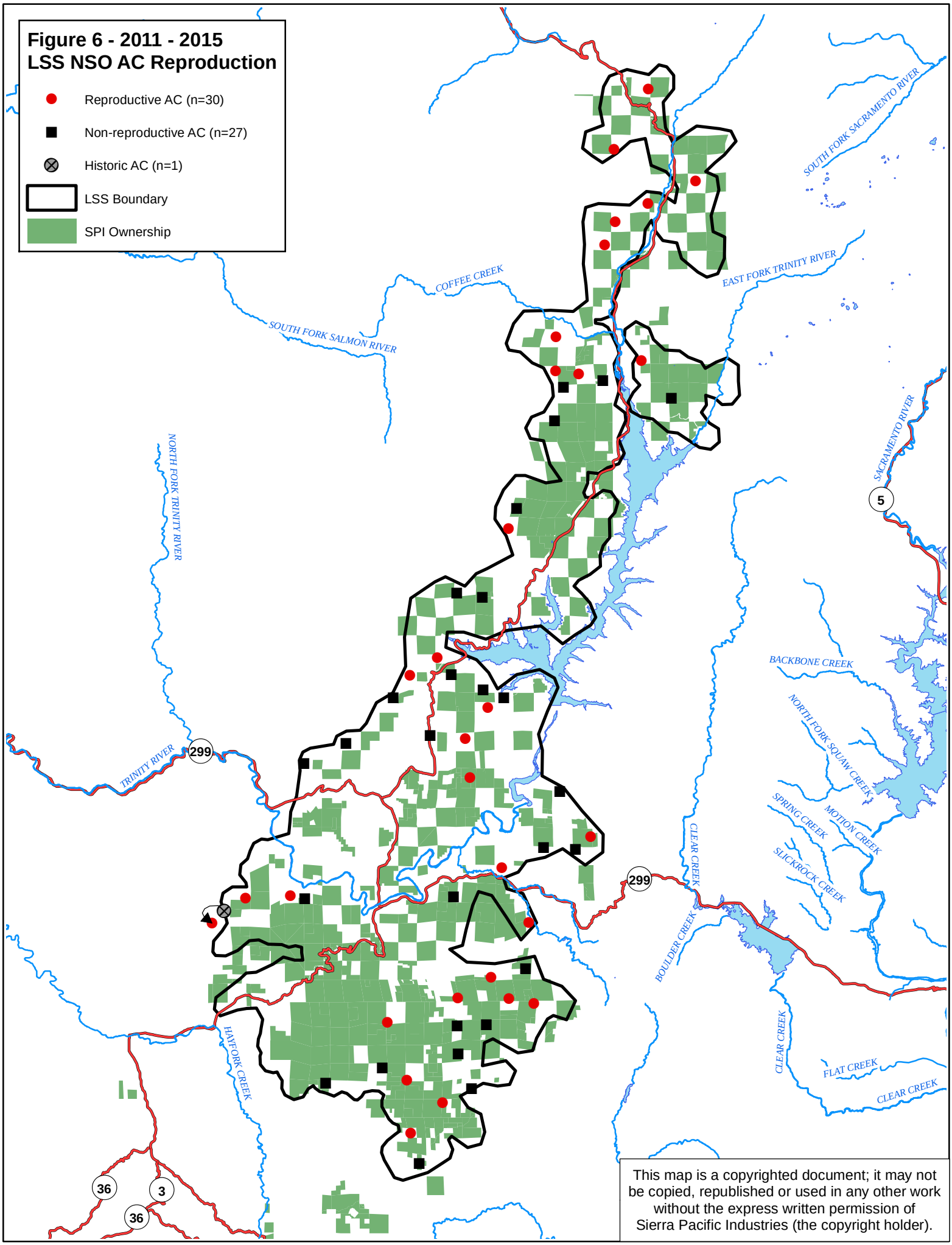

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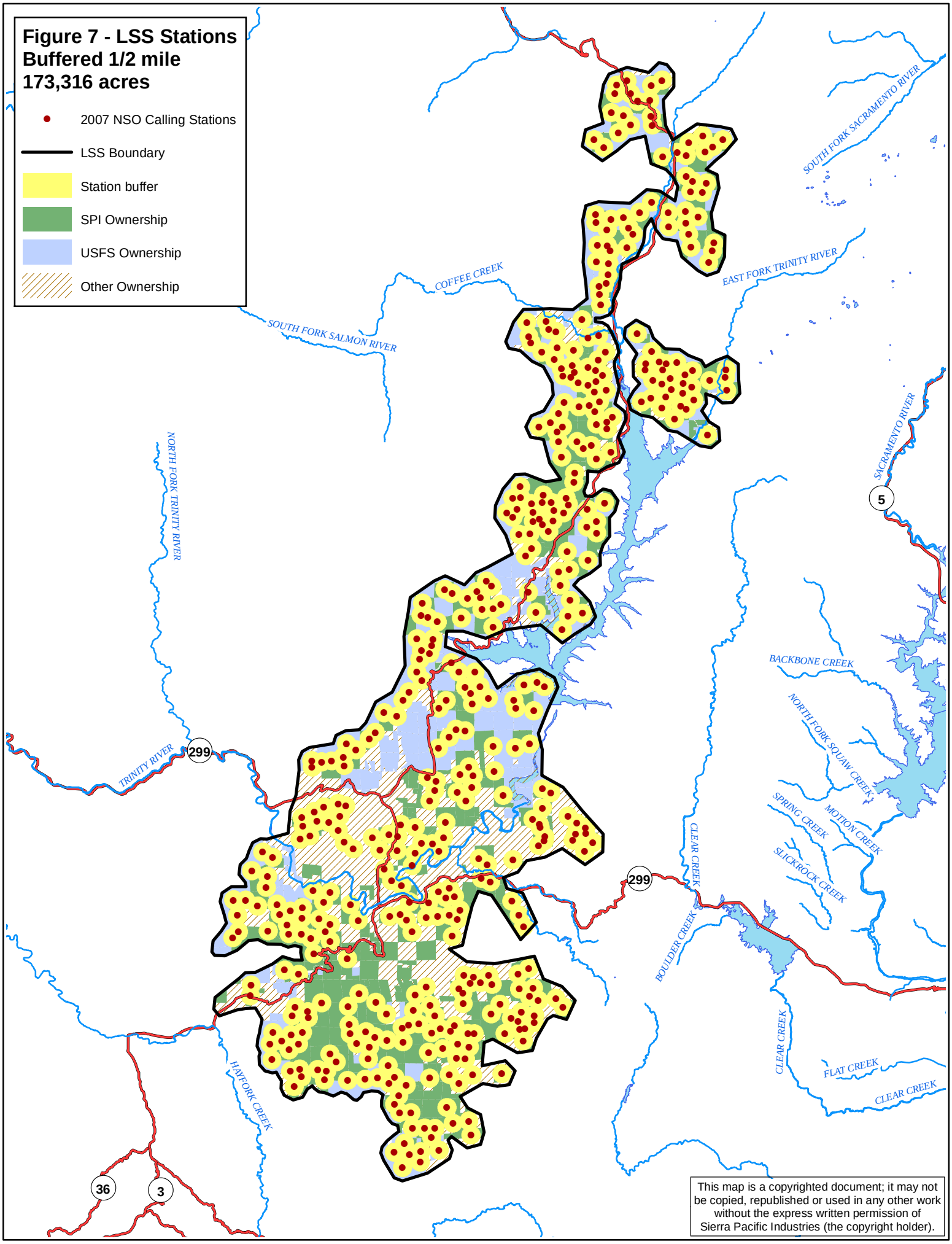
Figure 7 - LSS Stations
Buffered 1/2 mile
173,316 acres
2007 NSO Calling Stations
LSS Boundary
Station buffer
SPI Ownership
USFS Ownership
Other Ownership
SOUTH FORK SACRAMENTO RIVER
EAST FORK TRINITY RIVER
COFFEE CREEK
SOUTH FORK SALMON RIVER
NORTH FORK TRINITY RIVER
SACRAMENTO RIVER
5
BACKBONE CREEK
NORTH FORK SQUAW CREEK
TRINITY RIVER
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SPRING CREEK
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SLICKROCK CREEK
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CLEAR CREEK
HAYFORK CREEK
36
3
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RESEARCH ARTICLE

Multistate Models Reveal Long-Term Trends of Northern Spotted Owls in the Absence of a Novel Competitor

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Abstract

Quantifying spatial and temporal variability in population trends is a critical aspect of successful management of imperiled species. We evaluated territory occupancy dynamics of northern spotted owls (*Strix occidentalis caurina*), California, USA, 1990–2014. The study area possessed two unique aspects. First, timber management has occurred for over 100 years, resulting in dramatically different forest successional and structural conditions compared to other areas. Second, the barred owl (*Strix varia*), an exotic congener known to exert significant negative effects on spotted owls, has not colonized the study area. We used a Bayesian dynamic multistate model to evaluate if territory occupancy of reproductive spotted owls has declined as in other study areas. The state-space approach for dynamic multistate modeling imputes the number of territories for each nesting state and allows for the estimation of longer-term trends in occupied or reproductive territories from longitudinal studies. The multistate approach accounts for different detection probabilities by nesting state (to account for either inherent differences in detection or for the use of different survey methods for different occupancy states) and reduces bias in state assignment. Estimated linear trends in the number of reproductive territories suggested an average loss of approximately one half territory per year (-0.55, 90% CRI: -0.76, -0.33), in one management block and a loss of 0.15 per year (-0.15, 90% CRI: -0.24, -0.07), in another management block during the 25 year observation period. Estimated trends in the third management block were also negative, but substantial uncertainty existed in the estimate (-0.09, 90% CRI: -0.35, 0.17). Our results indicate that the number of territories occupied by northern spotted owl pairs remained relatively constant over a 25 year period (-0.07, 90% CRI: -0.20, 0.05; -0.01, 90% CRI: -0.19, 0.16; -0.16, 90% CRI: -0.40, 0.06). However, we cannot exclude small-to-moderate declines or increases in paired territory numbers due to uncertainty in our estimates. Collectively, we conclude spotted owl pair populations on this landscape managed for commercial timber production appear to be more stable and do not show sharp year-over-year declines seen in both managed and unmanaged landscapes with substantial barred owl colonization and persistence. Continued monitoring of reproductive territories can determine whether recent declines continue or whether trends reverse as they have on four previous occasions. Experimental investigations

salaries for authors (AK,JJ). The specific roles of these authors are articulated in the 'author contributions' section.

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to evaluate changes to spotted owl occupancy dynamics when barred owl populations are reduced or removed entirely can confirm the generality of this conclusion.

Introduction

Long-term ecological studies often investigate population dynamics as a function of habitat quality, competition, meta-population structure, and other factors. Collection of demographic data such as fecundity and survival can be challenging and costly, however, and limit their application in many instances. For long-lived species that exhibit strong site fidelity, evaluation of multiple occupancy states may be an effective alternative to support conservation and management programs. Collection of detection/non-detection data is relatively simple, and a broad array of sampling designs and statistical tools are available to analyze basic and applied questions [1, 2]. For species of particular conservation interest, utilizing these tools across multiple studies can provide strong inference about factors affecting population dynamics.

The northern spotted owl (*Strix occidentalis caurina*) is an endangered raptor which exhibits a strong association with structurally complex conifer forests in the Pacific Northwest, USA [3, 4]. The current endangered status of the spotted owl [5] results from population declines associated with reductions of preferred late-successional forest habitat due to timber harvesting. Management agencies proposed broad-scale conservation regulations under the assumption of continued declines in spotted owl populations until improved habitat conditions could support increasing populations [4]. However, recent, rapid expansion of barred owl (*Strix varia*) populations throughout much of the distribution of the spotted owl exacerbated population declines [6–9]. Although presence of this novel ecological competitor can have negative consequences for spotted owl productivity and adult survival [10, 11], Anthony et al. [10] found little support for a negative association between barred owl presence and spotted owl fecundity. Instead, barred owl presence may exert a negative effect on spotted owl territory occupancy [9, 10]. For example, recent analyses found strong associative evidence for interference competition between the two species and consequent negative effects on spotted owl territory occupancy [12, 13]. However, due to the near ubiquity of barred owls throughout the distribution of spotted owls, information is not available to evaluate the original premise that spotted owl populations would recover as habitat conditions improved and as conservation measures were implemented where active timber management continued to occur [4].

In this paper, we used a multistate occupancy model to evaluate northern spotted owl territory occupancy and reproductive dynamics in northern California, USA, 1990–2014. Our primary question was whether territory occupancy of reproducing spotted owls has declined over time, as in other populations of this species [11, 14, 15]? Our dataset and analysis are of broad interest for two reasons. First, we sampled territories in a landscape managed for timber production throughout the 25 year period of observation. Second, this portion of the spotted owl's distribution does not support breeding populations of the barred owl. Current investigations in other areas will evaluate if spotted owl occupancy dynamics change once barred owl populations are reduced or removed entirely [16]. As a result, our analysis provides unique insight into contemporary population dynamics of the spotted owl, and can complement on-going studies to inform management activities to conserve spotted owl populations.

Materials and Methods

Study Area & Management Descriptions

Our study area was located in Mendocino County, CA, USA (S1 Fig). Three generally contiguous blocks occurred from north to south: Blocks A (209 km^2), B (472 km^2), and C (107 km^2).

Elevations ranged from 0–915 m (3000 feet). The furthest inland extent of the study area was 33 km. The climate is characterized by cool, wet winters and hot, dry summers [17]. Fog is the most common source of precipitation during the summer months, particularly along the coast and in coastal valleys [17]. The study area contained a mix of Redwood, Douglas-fir, Montane Hardwood, and Montane Hardwood-Conifer forest vegetation types [18]. Dominant tree species included coast redwood (*Sequoia sempervirens*), as well as Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and western hemlock (*Tsuga heterophylla*). Tanoak (*Notholithocarpus densiflorus*), Pacific madrone (*Arbutus menziesii*), and red alder (*Alnus rubra*) were the most common hardwood species, with tanoak and madrone dominant on xeric and higher elevation sites. Common understory shrub species included ceanothus (*Ceanothus* spp.), coyotebush (*Baccharis pilularis*), huckleberry (*Vaccinium* spp.), manzanita (*Arctostaphylos* spp.), poison-oak (*Toxicodendron diversilobum*), rhododendron (*Rhododendron macrophyllum*), and salal (*Gaultheria shallon*).

Commercial timber management has occurred in the study area for more than a century and all of the forest stands were either 2nd or 3rd-growth with most stands less than 80 years old. Numerous timber management techniques have been applied over the decades, including both even- and uneven-aged silvicultural prescriptions. As a result, the study area contained a mosaic of forest stands relative to species composition, stand structure, and age distribution. Late-successional forest structures occurred on the blocks only in the form of individual trees or clumps of residual trees.

Northern Spotted Owl Surveys & Territory Monitoring

The spotted owl population in this study area has been monitored since the late 1980s when public and private landowners began implementing standardized survey protocols to determine spotted owl presence and population status on their respective ownerships [19, 20]. In order to maintain compliance with state and federal "take avoidance" requirements, spotted owl surveys in this study area have followed the survey protocol current at the time [20–22]. When spotted owls were detected during surveys, we initiated follow-up monitoring [20] and applied standard protection measures for the spotted owl territory.

In general, we conducted spotted owl surveys between March 1st and August 31st across all three blocks. The exact count of survey visits to a single territory varied each year due to the timing and type of spotted owl detection, evidence of breeding effort, and proximity to timber management activities. We used one of two methodologies for each spotted owl survey visit: nighttime point-calling surveys in areas without known spotted owl territories and daytime walk-in surveys for known territories. In this analysis, we used data only from daytime walk-in surveys. As a result, our sample includes territories known to be occupied prior to 1990 as well as territories identified (during nighttime surveys) after 1990 with unknown status prior to 1990.

We used daytime surveys to determine occupancy status (i.e., single or pair) and reproductive status. Here, we define positive reproductive status as an owl pair provisioning nestlings, consistent with prior usage [23]. Daytime surveys were conducted in the historic territory site center(s) or in areas where spotted owls were detected during nighttime surveys. We conducted daytime surveys approximately two hours before sunset. Daytime surveys consisted of using spotted owl vocalizations to elicit an owl response and searching for evidence (i.e., pellets and white-wash) of owl presence.

We fed live mice to spotted owls located during daytime surveys to determine territory status and nesting activity. For surveys conducted before May 15th, if an owl cached or ate four mice on a minimum of two visits it was considered to be 'non-nesting'; if an owl took a mouse

to a nest it was considered to be 'nesting'. We suspended surveys for non-nesting owls after May 30th, with the exception of banding visits for un-banded individuals. We concluded young were present when owls took mice to the nest (reproductive status was positive).

Our dataset consisted of 104 territories monitored from 1990–2014. Eighteen, 62, and 24 territories occurred on Blocks A, B, and C, respectively. Although surveys occurred prior to 1990, we did not include those data because the survey program was still being developed and the study area had not been surveyed thoroughly. In any given year, we surveyed all known and active spotted owl territories. We discontinued surveys at previously active territories only after completing absence surveys under the USFWS protocol [21] or declared abandoned in consultation with USFWS. At the same time, we added new territories to the survey program once identified. An individual territory was considered eligible for inclusion in the database if it had at least one survey in a season, regardless of whether or not an owl was detected. We note that 73/104 (70%) of the territories were identified and surveyed in the first 3 years of the study (1990–1992). We surveyed an average of 67 territories (SD = 16; range = 36–94) with daytime visits in each year. Individual territories were surveyed from 1–15 times in each year (median = 3 surveys per year; average = 3.5; SD = 1.8), with a median range of 71 days between first and last visits (minimum = 0, maximum = 150). On Block C, we discontinued surveys after 2006. We recorded 25 barred owl detections on 11 territories (11%) during the duration of the study. Number of detections on these 11 territories ranged from 1–5. We detected seven barred owls from 1990–1992 and five barred owls from 2012–2014.

Analytical Approach for Estimating Multistate Occupancy Dynamics

We used the MacKenzie et al. [23] dynamic multistate occupancy model to examine trends in NSO occupancy states. This methodology allowed for estimation of state probabilities and across-year state transition probabilities, while accounting for imperfect state detection. In our analysis, we considered four possible states: unoccupied (state 1), occupied by single owl (state 2), occupied by non-reproducing pair (state 3), and occupied by reproducing pair (state 4).

We followed the state-space approach described in MacKenzie et al. [23], where the true state of a territory is taken to be a random vector $\mathbf{z}$. For example, if the true state of territory i at time t was occupancy by a non-reproducing pair (state 3), this would give $\mathbf{z}_{it}$ = [0 0 1 0]. The random vector $\mathbf{z}$ is assumed to arise from a single draw of a multinomial distribution. The initial state probabilities are denoted $\boldsymbol{\phi}_{\mathbf{0}} = [\phi_0^{[1]} \;\; \phi_0^{[2]} \;\; \phi_0^{[3]} \;\; \phi_0^{[4]}]$. Under the dynamic multistate occupancy model, state probabilities for subsequent seasons t (t = 1,.., T) depend on the true state in season t-1. As such, occupancy dynamics are incorporated in the model by considering transition probabilities from one true state to another across years. We denote the probability of transitioning from state m at time t to state n at time t+1 with $\phi_t^{[m,n]}$. A transition probability matrix (TPM) defines the probability of each true state at time t+1 given the possible true states at time t. For example, a four-state transition probability matrix may be represented as follows:

$$\boldsymbol{\Phi}_{\mathbf{t}} = \begin{bmatrix} \phi_t^{[1,1]} & \phi_t^{[1,2]} & \phi_t^{[1,3]} & \phi_t^{[1,4]} \\ \phi_t^{[2,1]} & \phi_t^{[2,2]} & \phi_t^{[2,3]} & \phi_t^{[2,4]} \\ \phi_t^{[3,1]} & \phi_t^{[3,2]} & \phi_t^{[3,3]} & \phi_t^{[3,4]} \\ \phi_t^{[4,1]} & \phi_t^{[4,2]} & \phi_t^{[4,3]} & \phi_t^{[4,4]} \end{bmatrix}$$

Each row in the TPM sums to 1, and represents the state probability vector at time t+1 given the row state at time t; i.e., the transition probabilities from time t to t+1 conditional on the state at time t. In all cases the true state of a territory is assumed to remain constant within a season.

We denote the probability of observing a territory in state n during survey j of year t, given a true occupancy state m as $p_{t,j}^{m,n}$. Uncertainty in observed states is assumed to be constrained such that $p_{t,j}^{m,n} = 0$ for any $n > m$. For example, if the true state were 2, we assume that it is not possible to detect the species in either state 3 or 4, but that either state 1 or 2 could be observed. A four state detection probability matrix (DPM) may then be defined as:

		1	**2**	**3**	**4**
TrueState	**1**	1	0	0	0
	2	$1 - p_{tj}^{2,2}$	$p_{tj}^{2,2}$	0	0
	3	$1 - p_{tj}^{3,2} - p_{tj}^{3,3}$	$p_{tj}^{3,2}$	$p_{tj}^{3,3}$	0
	4	$1 - p_{tj}^{4,2} - p_{tj}^{4,3} - p_{tj}^{4,4}$	$p_{tj}^{4,2}$	$p_{tj}^{4,3}$	$p_{tj}^{4,4}$

Under the MacKenzie et al. [23] model, the observed state of a territory is taken to be a random vector **y** which, conditional on the true state **z**, is assumed to arise as a single draw from a multinomial distribution. For example, if the true state of territory i in year t was a non-reproducing pair (state 3), then the multinomial probability vector for the observed state at visit j would be $[1 - p_{tj}^{3,2} - p_{tj}^{3,3}\ p_{tj}^{3,2}\ p_{tj}^{3,3}\ 0]$, so that the probability of observing a single owl in this case would be $p_{tj}^{3,2}$.

In our analysis of the spotted owl data, we did not include any covariates in the TPM or the initial state probabilities, as none were available and our goal was to estimate the number of territories and long-term trends. For the initial state probabilities, we specified a Dirichlet prior distribution with all parameters equal to 1, equivalent to a multivariate uniform distribution. Using random effects, we allowed for the values of $\phi_t^{[m,n]}$ to vary by season, yet also allow for similarity across seasons. For example, $\phi_t^{[m,n]}$ may tend to be low across most seasons for some values of m and n, while for other values of m and n it may tend to be moderate across most seasons. Similarly, some parameters $\phi_t^{[m,n]}$ may tend to show little variation over time, while others may tend to show a larger degree of variation over time. We incorporate this added structure via random effects using the multi-logit transformation (to ensure row probabilities sum to 1). Specifically, we assumed

$$\phi_t^{[m,n]} = \Pr(z_t = n | \mathrm{z}_{t-1} = m) = \frac{\exp(\beta_{0,t}^{[m,n]})}{1 + \Sigma_{l=2}^{4} \exp(\beta_{0,t}^{[m,l]})} \text{ for } n > 1, \text{ and}$$

$$\phi_t^{[m,n]} = \Pr(z_t = 1 | \mathrm{z}_{t-1} = m) = \frac{1}{1 + \Sigma_{l=2}^{4} \exp(\beta_{0,t}^{[m,l]})},$$

where the random effects (intercept only) were assumed to arise from a normal distribution:

$$\beta_{0,t}^{[m,n]} \sim N(\mu^{[m,n]}, \sigma^{[m,n]}) \text{ for } n > 1.$$

The random effects mean and variance, $\mu^{[m,n]}$ and $\sigma^{[m,n]}$, were specified with N(0, 2) and Gamma(2, 0.5) prior distributions, respectively, for all values of m and n. We chose these priors to provide broad prior distributions for the transition probability parameters $\phi_t^{[m,n]}$. The use of random effects provides improved precision of annual estimates of the TPM.

The dates on which owl surveys were conducted varied across owl territories and across years. To allow for within-season variability in detection probabilities, we parameterized each (non-constant) element of the DPM with linear and quadratic Julian date terms. Further, we allowed the date effects to vary across seasons by incorporating random effects for the

coefficients. Specifically, we assumed for $m > 1$ that:

$$p_{itj}^{[m,n]} = \Pr(y_{itj} = n | z_{it} = m) = \frac{\exp(\alpha_{0,t}^{[m,n]} + \alpha_{1,t}^{[m,n]} \cdot \mathrm{JD}_{ij} + \alpha_{2,t}^{[m,n]} \cdot \mathrm{JD}_{ij}^2)}{1 + \Sigma_{l=2}^{m} \exp(\alpha_{0,t}^{[m,l]} + \alpha_{1,t}^{[m,l]} \cdot \mathrm{JD}_{ij} + \alpha_{2,t}^{[m,l]} \cdot \mathrm{JD}_{ij}^2)} \quad \text{for } 1 < n \leq m, \text{ and}$$

$$p_{itj}^{[m,1]} = \Pr(y_{itj} = 1 | z_{it} = m) = \frac{1}{1 + \Sigma_{l=2}^{m} \exp(\alpha_{0,t}^{[m,l]} + \alpha_{1,t}^{[m,l]} \cdot \mathrm{JD}_{ijt} + \alpha_{2,t}^{[m,l]} \cdot \mathrm{JD}_{ijt}^2)},$$

with normal random effects for the intercept, linear and quadratic terms:

$$\alpha_{0,t}^{[m,n]} \sim N\left(\mu_0^{[m,n]}, \sigma_0^{2[m,n]}\right)$$

$$\alpha_{1,t}^{[m,n]} \sim N\left(\mu_1^{[m,n]}, \sigma_1^{2[m,n]}\right)$$

$$\alpha_{2,t}^{[m,n]} \sim N\left(\mu_2^{[m,n]}, \sigma_2^{2[m,n]}\right).$$

Here, y_{itj} is the observed state for visit j, year t, territory i; z_{it} is the true state of territory i in year t; and JD_{itj} is the Julian date for territory i during visit j in year t. We specified prior distributions for the DPM random effects mean and variance as N(0,2) and Gamma(2, 0.5), respectively. We centered and scaled Julian data prior to analysis.

We collected data for this analysis on territories distributed across three management blocks, each with its own management history (D. Meekins, pers. comm.). We allowed all parameters of our model to vary by block in order to obtain block-specific estimates of quantities of interest.

Although the dynamic multistate occupancy model is parameterized in terms of an initial state probability vector and transition probabilities, estimates of state probabilities may be obtained for any given season through the recursive matrix operation:

$$\phi_t = \phi_{t-1}\phi_{t-1}$$

An advantage of the state-space approach from MacKenzie et al. [23] is that the true state of a territory is imputed for each season, allowing for summaries of territory states for a given territory or across the population sample. For example, one can obtain posterior mean estimates of the number of reproductive territories during each season t, along with posterior credible intervals. In turn, the seasonal summaries allow for the estimation of long term linear or quadratic trends across seasons using, for example, orthogonal polynomial contrasts [24]. In our study, we calculated linear trends for number of reproductive territories using the estimator:

$$\tilde{T}_L = \frac{1}{S}\Sigma_{s=1}^{S} T_L^{(s)}, \text{ where } T_L^{(s)} = \frac{\Sigma_t N_t^{(s)}(Yr_t - \overline{Yr})}{\Sigma_t (Yr_t - \overline{Yr})^2}.$$

To calculate $\tilde{T}_{L,}$ a set of s = 1, . . ., S simulations were sampled from the posterior distribution. The quantity $N_t^{(s)}$ is the s-th sample of the total number of reproductive territories imputed at time t (does not include pair or single territories), Yr_t is the year at time t, and $\overline{Yr}$ is the mean year. $T_L^{(s)}$ is calculated from the s-th sample of the posterior distribution, and we take the average over all samples to calculate an estimate of the posterior mean. Credible intervals

may be calculated in a similar manner using sample quantiles for $T_L^{(s)}$. The estimator $\tilde{T}_{L,}$ is interpreted as the expected average change in the number of reproductive territories over each one year interval. For example, a value of -1.0 would indicate an average decline of 1 reproductive territory per year over the course of the study.

We fit the model using JAGS [25] called from R [26] using package R2jags [27]. We ran three chains of length 55,000 with a burnin of 5,000 and 1/100 thinning. Convergence was assessed using the Gelman-Rubin statistic [28] and visual inspection of the chains, with results consistent with Markov chain convergence. We used posterior predictive checks to assess agreement between the fitted model and the observed data, and these checks did not indicate problems with the fitted model (steps in S1 File; results in S1 Table). R code for specifying the JAGS model is included in S2 File. Data used in analyses are in S2 Table.

Ethics Statement

We conducted this research in compliance with all California and USA laws and regulations. The United States Fish and Wildlife Service (USFWS) approved all activities involving the sampling and handling of live vertebrate animals.

Results

We found substantial annual variation in the number of territories in States 3 and 4 while the number of territories in States 1 and 2 remained relatively constant across years (Fig 1). We note that use of naïve territory counts would have over-estimated the number of territories in State 2 in Block B (Fig 1). As a result, the number of territories occupied by pairs in a given year would have been underestimated. Estimated (linear) trends in the number of reproductive territories suggest an average decline of approximately 0.15 territories every year in Block A, and one half territory per year in Block B over the 25 years of this study (1990–2014; Table 1). The estimated per-year trend (-0.09) for Block C was also negative (Table 1). However, for Block C, 90% credible intervals contained zero, indicating uncertainty as to the direction of this trend. Trends in the combined number of pair and reproductive pair territories showed no clear evidence of an increase or decrease in any of the three study blocks. Estimates from 2002–2014 indicated that both Block A and Block B may have lost reproductive pairs, with an estimated decline of approximately 0.32 and 0.97 nesting pairs per year, respectively. However, in both cases the number of pair and reproductive pairs combined showed no clear trends during the same period (Table 1). We note that the size of the estimated decline in number of reproductive pairs was greater for Blocks A and B from 2002–2014 than from 1990–2014, suggesting that the magnitude of the decline increased in the second half of the study period.

In all three management blocks, we found substantial variation in probability of reproduction, depending on prior territory state (Fig 2). Averaged across all years of the study (using hyper-prior means), probability of reproducing in a current year given reproduction in a previous year was 0.30 (90% CRI: 0.13, 0.49), 0.50 (90% CRI: 0.40, 0.60), and 0.70 (90% CRI: 0.53, 0.85) across Blocks A, B, and C, respectively. In contrast, probability of reproducing in a current year, given non-reproduction in a previous year, was 0.30 (90% CRI: 0.16, 0.46), 0.34 (90% CRI: 0.25, 0.43), and 0.37 (90% CRI: 0.14, 0.60) across Blocks A, B, and C, respectively. Estimates for all blocks indicated that probability of reproduction (State 4) was rare if a territory was occupied by a single owl (State 2) in the previous year (Fig 2). Estimates for Block B indicated that probability of reproduction (State 4) was rare if a territory was unoccupied (State 1) in the previous year. Data were insufficient to estimate reproduction when the state in the previous year was unoccupied (State 1) for Blocks A and Block C.

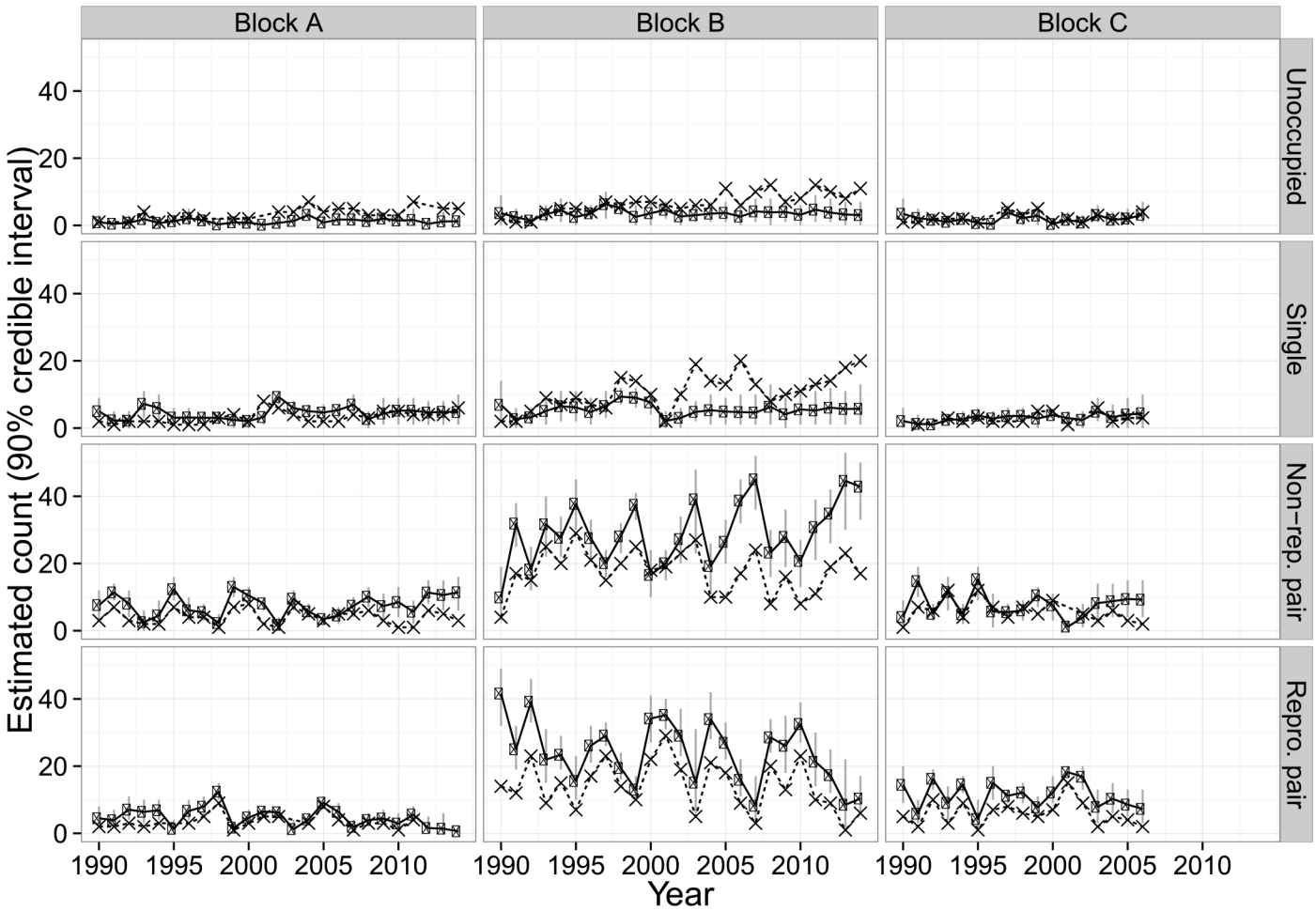

Fig 1. Estimated number of northern spotted owl territories ('•' symbol with 90% CRI) in each of four occupancy states by management block and year, Mendocino County, CA, USA, 1990–2014. Estimates shown with the '×' symbol are the naïve counts (i.e., unadjusted for imperfect detection) of territories in each occupancy state, and do not show credible intervals.

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Additionally, we found considerable variation in reproductive probability across years for owl pairs (Fig 2). For example, mean estimates of reproductive probability, with prior-year reproduction, in Block A ranged from a high of 0.76 to a low of 0.06, in Block B from 0.20 to 0.74, and in Block C from 0.25 to 0.92. Similar variability in reproductive probability was seen when the prior state was a non-reproductive pair. Although years with low reproductive probability were often followed by years with higher probability, this was not always the case; some 4–5 year spans have increasing estimates of reproduction, and other 4–5 year spans have decreasing estimates of reproduction (Fig 2).

Estimated probabilities of observing the true state were highest for reproductive pairs (State 4) and lowest for single owls (State 2; Fig 3). Similarly, the estimated probability of observing no owls was highest for single owls and lowest for reproductive pairs. The seasonal trend in detection probability was most pronounced for reproductive pairs, with the highest probability of detection occurring in the first week of August across all years. Survey-specific detection probabilities for State 2 were low ($\leq$ 0.25 for all years). However, all surveys included in this analysis occurred during the day (in order to assess reproductive status). Typical annual

Table 1. Trend estimates and 90% posterior credible intervals for the number of northern spotted owl territories occupied by reproductive pairs and pairs and reproductive pairs combined on three management blocks, Mendocino County, CA, USA, 1990–2014. We estimated contrasts from 1990–2002, 2002–2014, and 1990–2014. Block C was not surveyed after 2006. As a result, we estimated trends for Block C for 1990–2002 and 1990–2006 only. Mean estimates represent the expected change in territory count for a one year interval.

Management block	Years	State	Trend estimates (90% posterior interval)
A	1990–2002	Reproductive pairs only	0.10 (-0.12, 0.28)
B	1990–2002	Reproductive pairs only	-0.35 (-0.87, 0.17)
C	1990–2002	Reproductive pairs only	0.31 (0.01, 0.62)
A	1990–2002	Pairs and reproductive pairs	-0.02 (-0.23, 0.21)
B	1990–2002	Pairs and reproductive pairs	-0.15 (-0.48, 0.21)
C	1990–2002	Pairs and reproductive pairs	-0.06 (-0.30, 0.18)
A	2002–2014	Reproductive pairs only	-0.32 (-0.49, -0.14)
B	2002–2014	Reproductive pairs only	-0.97 (-1.6, -0.40)
C	2002–2006	Reproductive pairs only	NA
A	2002–2014	Pairs and reproductive pairs	0.24 (-0.04, 0.53)
B	2002–2014	Pairs and reproductive pairs	-0.19 (-0.61, 0.20)
C	2002–2006	Pairs and reproductive pairs	NA
A	1990–2014	Reproductive pairs only	-0.15 (-0.24, -0.07)
B	1990–2014	Reproductive pairs only	-0.55 (-0.76, -0.33)
C	1990–2006	Reproductive pairs only	-0.09 (-0.35, 0.17)
A	1990–2014	Pairs and reproductive pairs	-0.07 (-0.20, 0.05)
B	1990–2014	Pairs and reproductive pairs	-0.01 (-0.19, 0.16)
C	1990–2006	Pairs and reproductive pairs	-0.16 (-0.40, 0.06)

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surveys of NSO territories include a mix of day and night surveys and will likely be more effective at detecting both single and pairs of owls.

Discussion

Long-term datasets provide critical information about management and conservation options for imperiled species, including those affected by habitat loss and/or competition with invasive species. We did not find evidence to indicate that territory occupancy by northern spotted owl pairs declined substantially over a 25 year period on the Mendocino County, CA, study area. These results stand in marked contrast to other studies that also examined northern spotted owl occupancy dynamics over extended time frames and found evidence indicating significant declines [9, 11–15]. Although we estimated a declining trend in territory occupancy by breeding pairs, particularly over the last 12 years, we note that due to cyclical reproductive patterns long-term trends are influenced by the interval over which trends are estimated. For example, had monitoring began in either 1994 or 1995, and ended in 2010 or 2011, we would have concluded that territory occupancy by breeding pairs had remained constant or possibly increased. In addition, we note that similarly low numbers of reproductive pairs were observed in 1999, 2003, and 2007. Finally, consistent with most long-term datasets for northern spotted owls, the initial sample consisted of territories that were either occupied or had been occupied recently [11, 15], rather than a random sample from a 'population' of unoccupied and occupied northern spotted owl territories. As a result, our initial estimate of territory occupancy by breeding pairs may have been inflated compared to the background occupancy rate for this particular state.

Our study differs markedly from other long-term investigations of NSO populations in three ways: forest type, management prescriptions, and absence of barred owls. First, all three

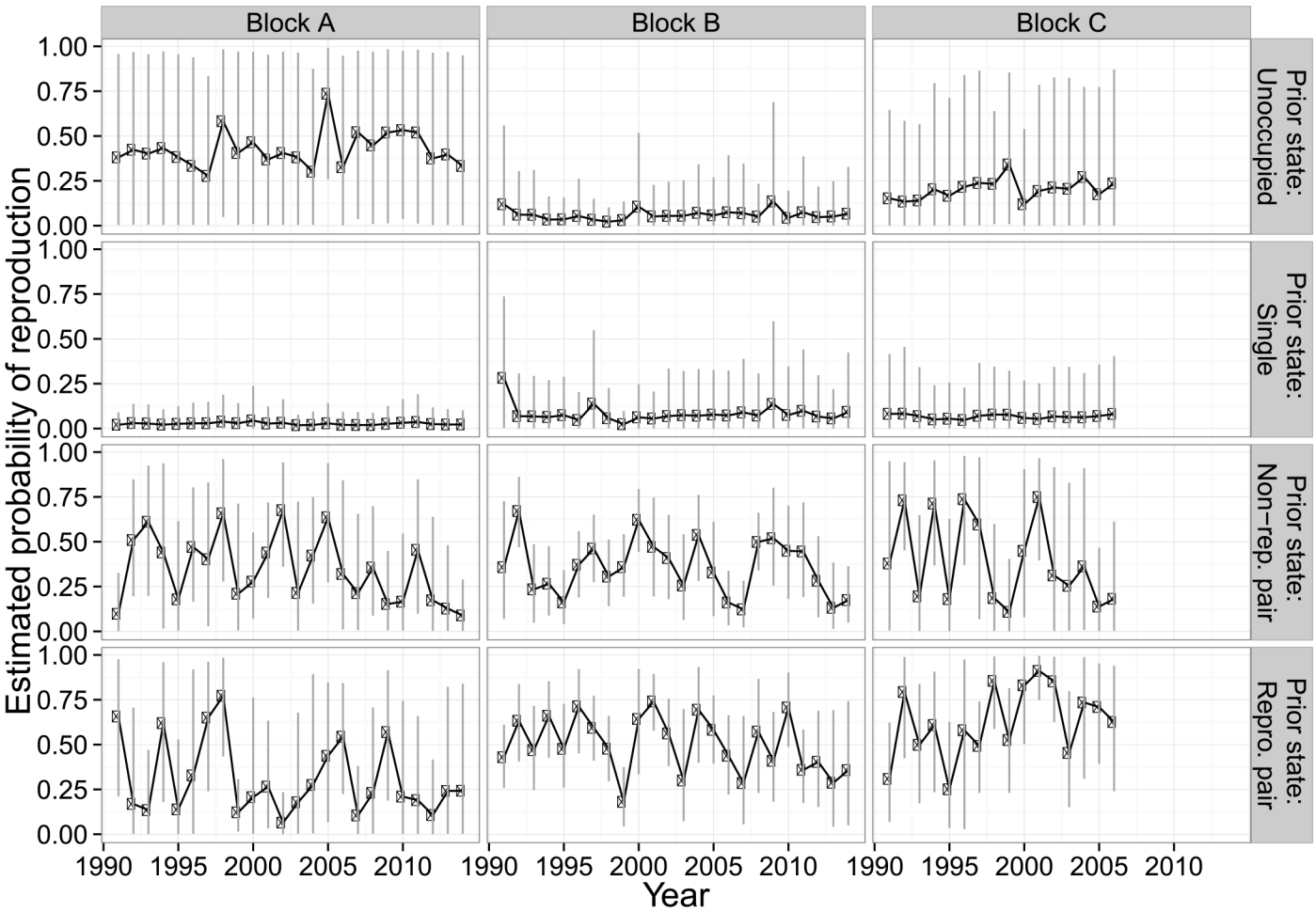

Fig 2. Estimated probability (90% CRI) of reproduction in each management block and year given the occupancy state of a territory in the previous year for northern spotted owls, Mendocino County, CA, USA, 1990–2014.

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study blocks occur in the coastal Redwood forest zone; other long-term occupancy studies have occurred in mixed conifer or western hemlock zones [29]. This forest type has different structural characteristics than other single-species dominated or mixed-conifer stands within the range of the northern spotted owl, including understory plant diversity and structure and potential to develop and retain large amounts of coarse woody debris [17, 18]. Second, stands on the three blocks have been managed intensively for timber production for over 100 years. As a result, the study area is dominated by stands less than 80 years in age. Other long-term NSO study areas are composed primarily of Federal lands managed for natural values [11, 12] and contain substantial amounts of late-successional forest, although some exceptions do exist [14]. Finally, we detected only 25 barred owls in 25 years of intensive surveys using the same methods that detect barred owls regularly throughout the range of the northern spotted owl. Given that 15 (60%) of these detections occurred from 1990–1999, when the range of the barred owl had not yet enveloped that of the northern spotted owl, we conclude that barred owls have had ample opportunity to colonize the three management blocks. We cannot determine why barred owls have not colonized our study area, although forest type, management history and contemporary practices, and climatic conditions–and interactions between all three factors–may influence this result. Similarly, we cannot preclude the possibility that barred owls

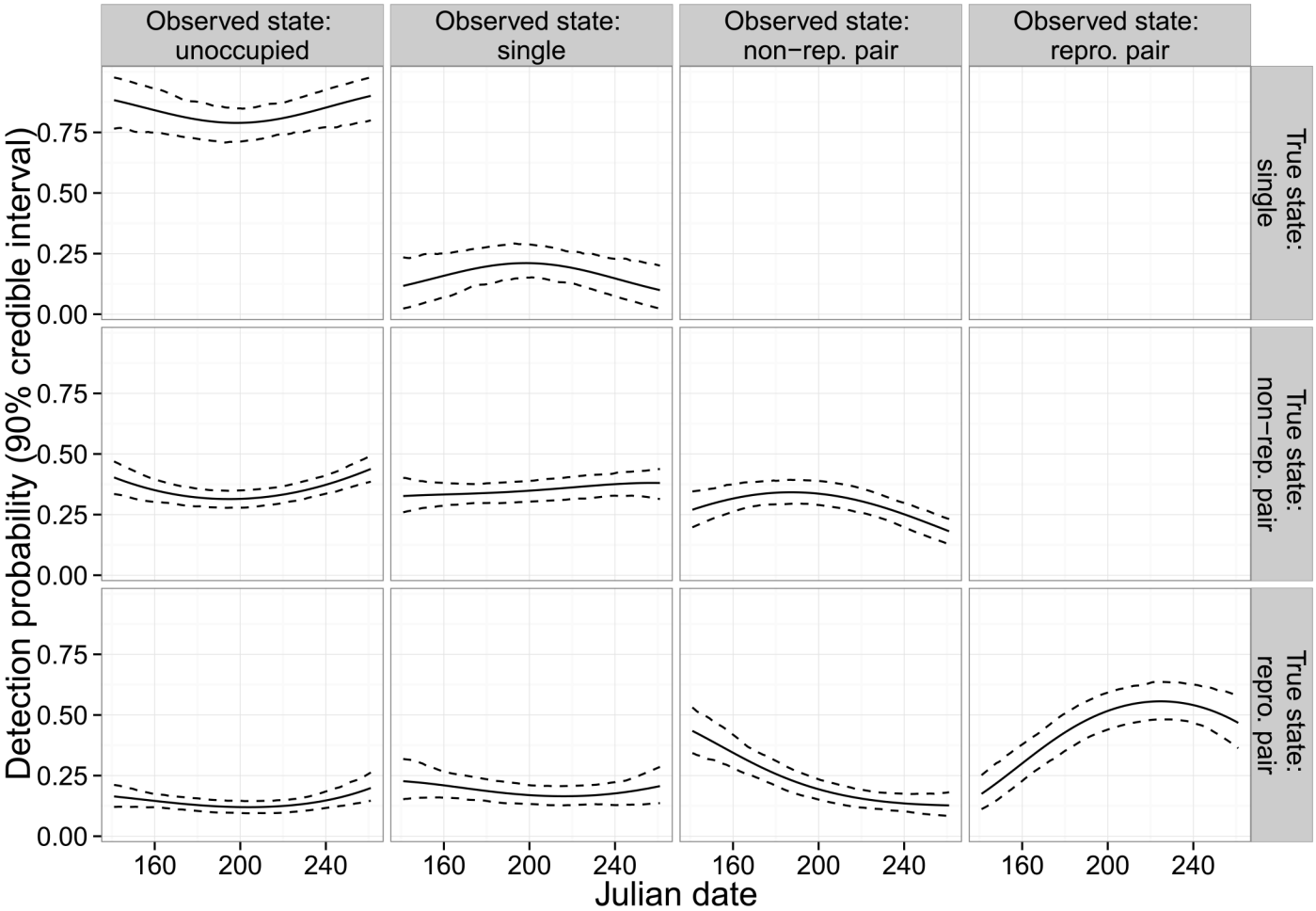

Fig 3. Estimated survey-specific detection probabilities (90% CRI) as a function of Julian date for northern spotted owls, Mendocino County, CA, USA, 1990–2014. We calculated estimates from a hierarchical model in which the quadratic parameters for Julian date varied by year using a random effects specification. The trends displayed in this graphic use the mean posterior random effects.

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will colonize some or the majority of the northern spotted owl territories in our study area in the future (as barred owls have done in other study areas).

Similar to other studies, we found a pronounced pattern in the annual reproductive activity of northern spotted owls [10, 23, 30]. In this case, the pattern was manifested as the regular transition of territories between States 3 and 4. Other studies have attributed this pattern to climatic variation early in the annual nesting cycle, usually elevated amounts of precipitation [30–32]. Given its immediate proximity to the Pacific Ocean, our study area can experience extremely variable spring precipitation [33]. Our data provide mixed support for the association between reproduction and local climatic variation. For example, occupancy of reproductive pairs was the lowest in 2003, 2007, 2013, and 2014; March precipitation in those four years was 14.9, 3.9, 8.1, and 21.5 cm, respectively, equating to 111, 29, 61, and 161% of the long-term average [34]. Annual variation in northern spotted owl reproductive effort has also been attributed to variation in prey abundance [35] and female age [30]. We did not include this covariate information in our modeling effort, but recognize that this information, as well as climatic variables, may have strong associations with occupancy states and recommend their inclusion in future analyses.

Occupancy and multi-season occupancy models [36, 37] that account for imperfect detection have become standard methods for the analysis of spotted owl data [11, 13, 15, 38]. We think that multistate occupancy modeling [23, 39] offers several advantages over other methods, and warrants serious consideration by researchers conducting spotted owl research when suitable data are available for analysis. For example, multistate modeling provides a more detailed picture of population dynamics, allowing for inference about processes such as reproductive dynamics. The state-space approach for multistate modeling imputes the number of territories for each nesting state, which in a longitudinal study allows for the estimation of longer-term trends in occupied or reproductive territories. A particular benefit of the multistate approach is the allowance for different detection probabilities by nesting state–to account for either inherent differences in detection or for the use of different survey methods for different occupancy states–as was done in this study. For example, our estimated probabilities for observing an unoccupied territory varied substantially across each of the three occupied states (Fig 3). Further, the estimated probability of observing a single-owl territory was higher for non-reproductive territories than for reproductive territories in our study. Such differences may lead to bias in studies for which multiple states are collapsed to a single level, e.g., so-called "simple" analyses [11, 15].

Although we found many benefits to the multistate approach, these models present substantial challenges. Our parameterization was relatively simple, in keeping with the goals of the analysis and the management history of the study territories. However, a researcher interested in the potential effects of multiple covariates may face difficult choices regarding how to parameterize the model. For example, in an analysis with M states, $M^*(M-1)$ free elements exist in the TPM and $M^*(M-1)/2$ free elements exist in the DPM. Each of these elements could include covariates, and the researcher must determine which covariates to include in each element as well as the functional form they would take. Another challenge relates to assessing adequacy-of-fit. We chose our approach (S1 File) to evaluate how well our model predicted observed patterns in *detected* states. Ultimately, we cannot disentangle process variation and detection probability with absolute confidence, meaning that such an approach may leave uncovered important problems with the model. Further development of adequacy-of-fit approaches and tests of closure for dynamic multistate occupancy models would help researchers undertake the important step of model checking.

Our results indicate that the number of territories occupied by northern spotted owl pairs remained relatively constant over a 25 year period in a landscape with an extensive legacy of historic, as well as contemporary, timber management. However, we cannot exclude small-to-moderate declines or increases in paired territory numbers due to uncertainty in our estimates. Given the stated close association of northern spotted owls with late-successional forest in other parts of their range [10, 40, 41], these results suggest that habitat per se may not be the only factor that determines population performance of this endangered raptor. For instance, a recent meta-analysis [9] found strong declines in northern spotted owl occupancy on study areas that contained substantial amounts of older forest as well as large populations of barred owls. Taken together, these results indicate that habitat conditions explain only some of the variation in northern spotted owl occupancy. Finally, given proposed removals of barred owls in other portions of the range of the northern spotted owl [9, 16], the Mendocino County population evaluated in this study serves as a control population. As such, it provides long-term insight into northern spotted owl occupancy states in the absence of an exotic congener known to exert significant negative effects, the barred owl.

Supporting Information

S1 Fig. Location of management blocks A, B, and C, northern spotted owl study area, Mendocino County, CA, USA, 1990–2014.
(EPS)

S1 File. Steps used to perform posterior predictive checks for model diagnostics.
(DOCX)

S2 File. R code for JAGS specification of the dynamic multistate occupancy model.
(DOCX)

S1 Table. Output from model diagnostics from simulation studies for dynamic multistate occupancy model.
(XLSX)

S2 Table. Data used in dynamic multistate occupancy model for northern spotted owls, Mendocino County, CA, USA, 1990–2014.
(XLSX)

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Author Contributions

Conceived and designed the experiments: AJK JEJ ABS DJM. Performed the experiments: AJK JEJ ABS DJM. Analyzed the data: AJK JEJ. Contributed reagents/materials/analysis tools: AJK JEJ ABS DJM. Wrote the paper: AJK JEJ ABS DJM.

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Research Article

Demographic Response of Northern Spotted Owls to Barred Owl Removal

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ABSTRACT Federally listed as threatened in 1990 primarily because of habitat loss, the northern spotted owl (*Strix occidentalis caurina*) has continued to decline despite conservation efforts resulting in forested habitat being reserved throughout its range. Recently, there is growing evidence the congeneric invasive barred owl (*Strix varia*) may be responsible for the continued decline primarily by excluding spotted owls from their preferred habitat. We used a long-term demographic study for spotted owls in coastal northern California as the basis for a pilot barred owl removal experiment. Our demography study used capture–recapture, reproductive output, and territory occupancy data collected from 1990 to 2013 to evaluate trends in vital rates and populations. We used a classic before-after-control-impact (BACI) experimental design to investigate the demographic response of northern spotted owls to the lethal removal of barred owls. According to the best 2-species dynamic occupancy model, there was no evidence of differences in barred or northern spotted owl occupancy prior to the initiation of the treatment (barred owl removal). After treatment, barred owl occupancy was lower in the treated relative to the untreated areas and spotted owl occupancy was higher relative to the untreated areas. Barred owl removal decreased spotted owl territory extinction rates but did not affect territory colonization rates. As a result, spotted owl occupancy increased in the treated area and continued to decline in the untreated areas. Prior to and after barred owl removal, there was no evidence that average fecundity differed on the 2 study areas. However, the greater number of occupied spotted owl sites on the treated areas resulted in greater productivity in the treated areas based on empirical counts of fledged young. Prior to removal, survival was declining at a rate of approximately 0.2% per year for treated and untreated areas. Following treatment, estimated survival was 0.859 for the treated areas and 0.822 for the untreated areas. Derived estimates of population change on both study areas showed the same general decline before removal with an estimated slope of −0.0036 per year. Following removal, the rate of population change on the treated areas increased to an average of 1.029 but decreased to an average of 0.870 on the untreated areas. The results from this first experiment demonstrated that lethal removal of barred owls allowed the recovery of northern spotted owl populations in the treated portions of our study area. If additional federally funded barred owl removal experiments provide similar results, this could be the foundation for development of a long-term conservation strategy for northern spotted owls. © 2016 The Wildlife Society.

KEY WORDS barred owl, competition, demography, northern spotted owl, removal experiment.

The northern spotted owl (*Strix occidentalis caurina*) is a medium-sized owl that inhabits structurally complex forests in the coastal and Cascade ranges from southwestern British Columbia to northern California. It is primarily a nocturnal forager of small mammals, has relatively large home ranges, and actively defends space around its nest and roosting area from conspecifics (Courtney et al. 2004). Extensive research on northern spotted owl habitat requirements, conducted during the past 4 decades, focused on understanding the structural characteristics and spatial requirements of nesting, roosting, and foraging habitat for this species. These studies

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have been conducted primarily in landscapes with significant amounts of mature or old forests, the principal seral stages used by this species in most areas where it has been studied (Courtney et al. 2004). The underlying ecological premise behind these habitat studies was that northern spotted owl populations were limited by the amount and distribution of habitat (Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005).

As early as 1990 when the United States Fish and Wildlife Service (USFWS) listed the northern spotted owl as a threatened species (USFWS 1990), barred owls (*Strix varia*) were recognized as a potential threat to spotted owl populations. Similar in appearance but somewhat larger in size, the barred owl is also a territorial forest owl that historically occurred east of the Great Plains in North America. Since the listing of the spotted owl, there has been ever increasing concern about the range expansion (Livezey 2009) and increasing local populations (Yackulic et al. 2012) of the closely related barred owl. The Revised Recovery Plan for the Northern Spotted Owl (USFWS 2011:vi) stated "... it is becoming more evident that securing habitat alone will not recover the spotted owl. Based on the best available scientific information, competition from the barred owl (*S. varia*) poses a significant and complex threat to the spotted owl."

Barred owls may negatively affect spotted owl detectability, site occupancy, reproduction, and survival. Barred owls decreased detectability of spotted owls (Olson et al. 2005, Crozier et al. 2006, Dugger et al. 2009, Wiens et al. 2011), and spotted owl occupancy was significantly lower in territories where barred owls were detected within 0.8 km of the territory center (Kelly et al. 2003). Other relationships between barred owl detections and reduced site occupancy by spotted owls have been reported (Pearson and Livezey 2003, Gremel 2005, Olson et al. 2005, Kroll et al. 2010, Dugger et al. 2009) and Olson et al. (2004) reported that spotted owls had lower reproductive success on sites where barred owls had been detected. A recent range-wide analysis by Forsman et al. (2011) reported that the barred owl covariate, an annual estimate of the proportion of spotted owl territories influenced by barred owls, entered the top models with a negative coefficient for survival and fecundity in some demographic study areas throughout the owl's range. Occasional hybridization between the species is also documented (Hamer et al. 1994, Kelly and Forsman 2004), but it is not considered to be a serious threat to spotted owl populations (USFWS 2011).

Barred owls are considered habitat and prey generalists (Mazur and James 2000, Hamer et al. 2001). However, they select the same habitat for roosting and nesting as spotted owls, use similar habitat for foraging, and have a high degree of dietary overlap with spotted owls (Wiens et al. 2014). Barred owls also have comparatively smaller home ranges, greater reproductive output, and occur in higher population densities in favorable habitats (Wiens et al. 2014). Because of the slightly larger size of the barred owl, their mutual territoriality (Van Lanen et al. 2011), and similar habitat use, current hypotheses and competition theory predict that barred owls may ultimately limit, and potentially extirpate, populations of spotted owls throughout their range (Gutiérrez et al. 2007, Yackulic et al. 2014).

As part of a monitoring commitment for a northern spotted owl Habitat Conservation Plan (HCP), Green Diamond Resource Company (Green Diamond) has conducted a demographic study for this species since 1990 within its approximately 1,600-km^2 ownership in northwestern California. A 2008 meta-analysis of northern spotted owl populations, including study areas from across the subspecies' range, concluded that the population on the Green Diamond study area was apparently stable or increasing until 2001, when it began to decline (Forsman et al. 2011). The 2008 meta-analysis could not determine cause and effect relationships. However, the presence of barred owls was negatively associated with fecundity and apparent survival of spotted owls. On the Green Diamond study area, the apparent decline in spotted owls coincided with an increase in barred owl numbers (Dugger et al. 2016).

Although it was the most probable hypothesis for the decline on our study area, experimental studies had not been conducted to isolate the effect of barred owls from other potential sources that may contribute to spotted owl population declines. A panel of scientists reviewed potential experimental designs and concluded that a demographic approach with a paired before-after-control-impact (BACI) experiment design where removal of barred owls was the treatment provided the greatest inference and statistical power (Johnson et al. 2008). The revised recovery plan for the northern spotted owl (USFWS 2011) expressed the need for such barred owl experimental removal experiments to be conducted.

We report the results from the first such barred owl removal experiment to address this critical research need. In 2009, the Green Diamond demographic study was partitioned into treated (barred owls lethally removed) and untreated (barred owls undisturbed) areas to estimate the impact of the treatment on spotted owl occupancy, fecundity, survival, and rate of population change. Green Diamond's demographic study has been ongoing since 1990, and they have contributed their data to the regularly conducted northern spotted owl meta-analysis since 1996 (Anthony et al. 2006, Forsman et al. 2011). Green Diamond's demographic data were also included in the most recent meta-analysis (Dugger et al., 2016) where appropriate, and where the treatment data did not compromise estimates of long-term trends. We report the specific analyses designed to test for treatment effects and integrate all of the results to draw conclusions on the effectiveness of barred owl removal for the benefit of northern spotted owls.

STUDY AREA

We conducted the study within Green Diamond's commercially managed timberlands in Humboldt and Del Norte counties, in coastal northern California. Green Diamond's lands of approximately 1,600 km^2 was composed predominantly of second- and third-growth stands of coast redwood (*Sequoia sempervirens*), Douglas-fir (*Pseudotsuga menziesii*),

and various hardwood species, including tanoak (*Lithocarpus densiflorus*), madrone (*Arbutus menziesii*), California bay (*Umbellularia californica*), and red alder (*Alnus rubra*). These forests were primarily harvested on a 50–70-year rotation. The primary silviculture was even-aged with historical incidental and current programmatic retention of mature and late seral elements. Light single tree selection harvest occurred within riparian zones and other sensitive areas that constituted close to 30% of the study area. Many forest stands occupied by spotted owls contained a substantial component of older, residual trees (Thome et al. 1999, Folliard et al. 2000). The entire study area was within 30 km of the Pacific Ocean, and elevation on the study area ranged from 5 m to 1,400 m. Additional details of the study area are included in Diller and Thome (1999).

Because we were interested in the effect of the barred owl invasion on spotted owls, we divided our study area into treated areas where barred owls were removed and untreated areas where they were not removed. To account for geographic differences in the history of timber harvesting, physiographic patterns, and density of barred and spotted owl sites, the relatively linear Green Diamond study area was divided into 3 roughly equivalently sized paired treated and untreated areas totaling 84,205 ha and 72,711 ha, respectively (Fig. 1). Given complications of lethal removal of barred owls with firearms, assignment of treated versus untreated areas was based on logistics and minimizing potential conflicts with adjacent landowners. As in virtually all field studies, it was impossible to ensure that all parameters such as mean density of spotted and barred owl territories of the treated and untreated areas were the same. However, this potential lack of complete symmetry was offset by 19 years of pre-treatment data such that post-treatment changes in trends or means of demographic parameters in the treated versus untreated areas could be reliably assigned to a treatment effect (i.e., barred owl removal).

METHODS

Field Methods

From 1990 to 2013, we monitored spotted owls by surveying the entire density study area (i.e., central contiguous areas where spotted owl population density could be estimated) with 100% survey coverage and territory-specific surveys for all the remaining peripheral owl sites in the demographic study area. The objectives of the surveys were to document occupancy status of owl territories, locate and confirm previously banded owls, band unmarked owls, and document the number of young produced by each territorial female (Lint et al. 1999, Reid et al. 1999). We conducted surveys using vocal imitations or playback of owl calls to incite the owls to defend their territories, thereby revealing their presence (Reid et al. 1999).

The number of surveys of each potential owl territory (i.e., owl site) in each study area was normally $\geq$3 per year, although fewer visits were allowed in cases where females were located that had no brood patch or showed no evidence of nesting during the period when they should have been incubating or brooding young. After we became familiar with the distribution of owl territories in our study areas, it was often possible to locate owls by simply calling quietly while visually searching for owls in their traditional roost or nest areas during the day. If these diurnal surveys were unsuccessful, we surveyed the entire territory at night by calling from survey stations distributed throughout the area according to standard survey protocol. The field methods to capture, mark, and resight individual owls and to determine number of young fledged per female was the standard protocol used in all the northern spotted owl demographic study areas (Forsman et al. 2011, Dugger et al. 2016).

The pilot barred owl removal experiment within our spotted owl demographic study area was initiated on 15 February 2009 working under a permit to California Academy of Sciences that allowed 20 barred owls to be collected. Following an evaluation by the USFWS of our removal data from this pilot study, we were authorized to continue lethal removal in 2010 of $\leq$70 barred owls over a 3-year period, with $\leq$30 individuals removed in any given year.

We detected barred owls as a consequence of standard surveys to locate spotted owls from 1990 to 2009, but because these surveys were designed for detecting spotted owls, we likely underestimated the number and location of barred owls (Wiens et al. 2011). Therefore, we began barred owl-specific surveys in 2009. Barred owl-specific surveys, with similar spacing and number of visits as spotted owl surveys, included playing recordings of barred owl calls broadcast by a commercially available, remotely controlled, high-quality digital wildlife caller (Wildlife Technologies KAS-2030ML and MA 15, Manchester, NH). To reduce the potential of initiating interspecific interactions between the 2 species, we broadcast spotted owl lure calls for 8 minutes before transitioning to the barred owl-specific survey calls. If no spotted owls responded to the initial spotted owl lure broadcasts, we broadcast barred owl lure calls for 10 minutes. Following removal of barred owls from a site, we conducted additional barred owl-specific surveys to assess recolonization by barred owls at removal sites (adapted from Forsman 1983 and Bierregaard et al. 2008).

If a barred owl was detected during any survey, we returned to the site to locate it. If that location was in a known spotted owl territory, we first broadcast spotted owl calls during these follow-up visits. If spotted owls were present, we did not attempt to lure barred owls. If spotted owls did not respond within approximately 400 m of our location, we assumed there were no spotted owls present at the local site. We then broadcast a repertoire of barred owl lure calls, generally starting with male and female 2-phrased (8-note) hoots and progressed to more agitated ascending (series) hoots, pair duets, or cackling calls (Odom and Mennill 2010). We attempted to lethally remove all barred owls continuously in treatment areas that behaved in a territorial manner except barred owls that potentially had dependent nestlings or fledglings. Territoriality was assessed by aggressive hooting, flying to the source of the lure call, stooping on the calling device, and limb crashing (i.e., landing with force on a limb such that it made a loud sound). We only removed territorial

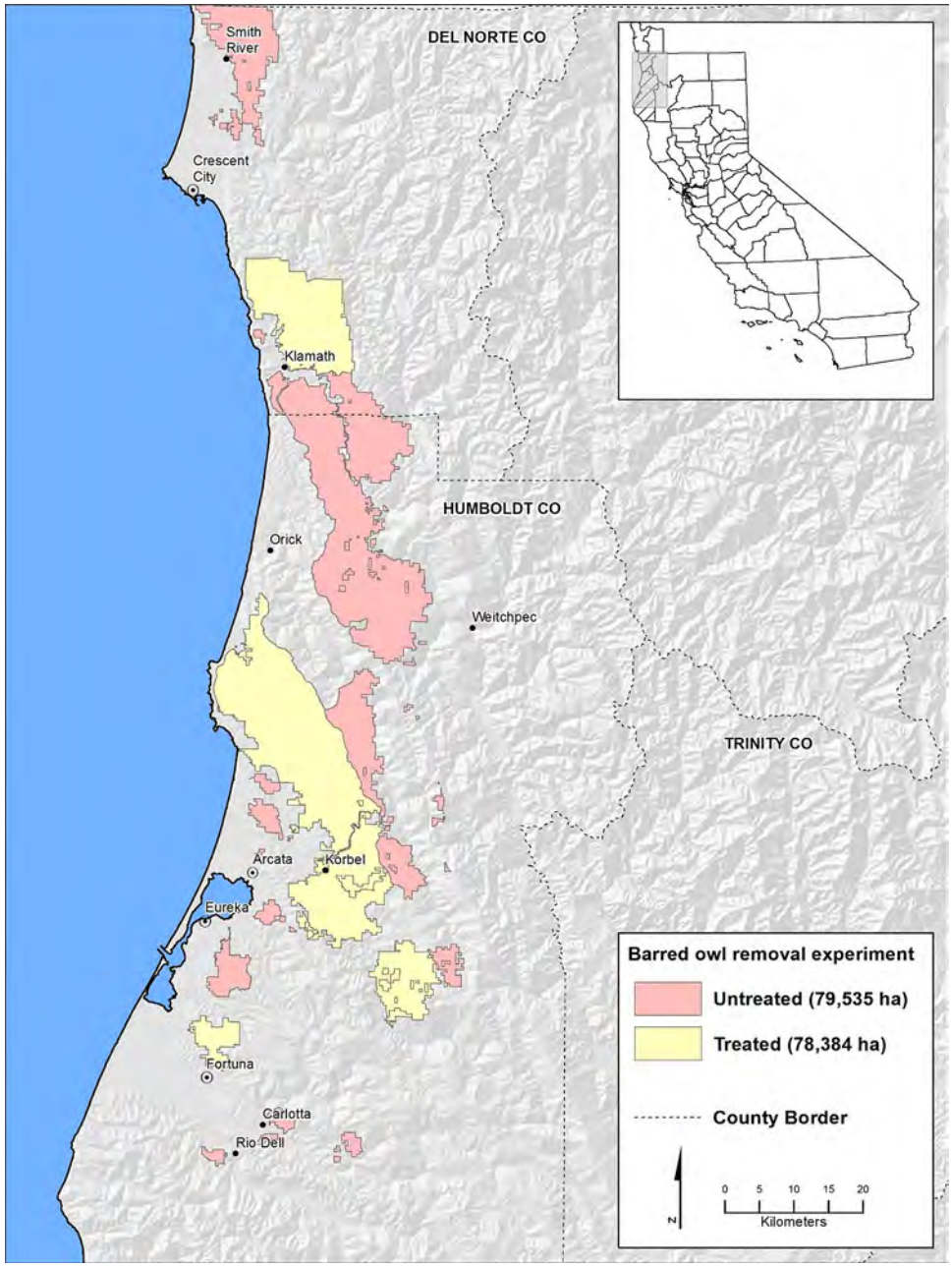

Figure 1. Treated (barred owls lethally removed) and untreated (barred owls undisturbed) areas on Green Diamond's northern spotted owl demographic study area in north coastal California, USA.

barred owls because our long-term goal was to assess impacts of territorial barred owls on spotted owls (Wiens et al. 2014) and our permits authorized a limited number of collections. We lethally removed barred owls as described in Diller et al. (2014). Lethal removal of barred owl was authorized by the following permits obtained in 2006 (USFWS permit no. MB103642-0 and California Department of Fish and Game [CDFG] permit no. SC-801126-05) issued to the California Academy of Sciences, 2009 (USFWS permit no. MB 680765-1 and CDFG permit no. SC-000687) issued to California Academy of Sciences, and 2010–2013 (USFWS no. MB 17356A-0 and CDFG Permit no. SC-000687) issued to L. V. Diller.

All territorial barred owls were continuously removed from the treated areas regardless of their proximity to known spotted owl territories. However, some barred owls occupied the same territory core, and sometimes even used the same nest site, from which the spotted owls were apparently displaced. These spotted owl sites were evaluated as case studies if the criteria were met in which a former spotted owl territory was occupied by barred owls (i.e., spotted owls no longer detected for at least a year) that inhabited the same territory center (nest or primary roost sites). In these situations, the site was surveyed at least once per month following the removal of the barred owls to determine the timing of potential re-occupancy by either barred or spotted

owls. We moused (i.e., placed a live laboratory mouse in a position to be taken by an owl; Forsman 1983) spotted owls that re-occupied (same individual owls resuming occupancy at a site that they previously occupied) or recolonized (new owls occupying a site previously occupied by different individuals) a site to determine their pair and nesting status and we captured and banded any new spotted owls.

Analytical Methods

Spatially delineated owl sites were important to the development of detection/non-detection data sets for our site occupancy analyses, and for estimation of habitat and barred owl covariates within study areas. We defined an owl site as a landscape patch that represented the cumulative area where a spotted owl or pair of spotted owls was detected. The process by which these sites were delineated using Thiessen polygons was described in Dugger et al. (2016).

Development of covariates.—We collected barred owl detection locations used in the population and site occupancy analyses incidentally during our annual northern spotted owl surveys. Barred owls were not specifically targeted during the calling surveys conducted as part of our long-term monitoring of spotted owls and detections associated with barred owl-specific surveys conducted with removal protocols were not used to develop this covariate. However, barred owls frequently responded to spotted owl calls during nocturnal surveys and, based on a calling experiment conducted by Wiens et al. (2011), we estimated that the cumulative annual detection probability of barred owls was >85% at territories in which we conducted ≥3 nocturnal surveys for spotted owls. For population (as opposed to occupancy) scale analyses, we calculated a barred owl covariate that was year-specific and reflected the proportion of spotted owl territories (i.e., Thiessen polygons) in which barred owls were detected ≥1 time per year. For occupancy analyses, we used detections at the site and survey scale to estimate barred owl detection probability and the probability of barred owl occupancy, colonization, and extinction at sites where barred owls may have been present but not detected.

We developed habitat covariates to represent the amount and distribution of northern spotted owl habitat within our study area. For population scale analyses, we calculated these covariates across the whole study area and they varied among years. For occupancy analyses, we calculated certain covariates at the scale of individual owl sites and they varied both spatially and temporally. For clarity, the covariates calculated at the population scale are capitalized and covariates calculated at the site scale are not. The covariates calculated were 1) the amount of northern spotted owl habitat (HAB for population scale; hab for individual owl site scale), 2) the change in the proportion of habitat during 3-year intervals prior to each survey year (HC/hc), 3) the proportion of the study area or owl site that contained ≥50% habitat within an 800-m-radius circle centered on each pixel in the study area (CORE/core), and 4) the total amount of edge habitat (in m; EDGE/edge), with edge as the interface between suitable owl habitat and all other cover types. Additional details on the development of the habitat covariates are in Dugger et al. (2016).

We used a variety of covariates to investigate possible effects of weather and climate on population-scale vital rates of northern spotted owls. All weather and climate covariates were time-specific and applied at the scale of the owl population on our study area. These variables included measures of seasonal and annual weather and long-term climatic conditions. Specific covariates included mean precipitation and temperature during various life-history stages, Palmer Drought Severity Index (PDSI), Southern Oscillation Index (SOI), and Pacific Decadal Oscillation (PDO; Franklin et al. 2000; Glenn et al. 2010, 2011*a*,*b*; Forsman et al. 2011). Additional details on the development of the weather and climate covariates are in Dugger et al. (2016).

Analysis of site occupancy.—Our analysis of site occupancy was based on 15 years (1999–2013) of detection data, including 10 years prior to initiation of treatment and 5 years during the treatment period. Detections occurred during surveys conducted from 1 March through 31 August within owl sites, but detection/non-detection was aggregated into 12 2-week periods. On a per survey visit basis, we defined a site as occupied by spotted owls when a mated pair was present. We considered a site unoccupied if no owls or only a single spotted owl was detected. However, we considered the site occupied by barred owls when 1 or a pair of territorial individuals were detected. The basis for this difference is that spotted owl pairs have the potential to reproduce and are the ecological sample unit of interest (i.e., sensu effective population size). However, either single or paired barred owls have the potential to negatively affect spotted owls; therefore, we estimated all territorial barred owls to fully quantify their impact. We used a multi-season 2-species occupancy model and Program MARK to generate estimates.

At the start of each breeding season, owl sites were in 1 of 4 mutually exclusive states: both species present (state 3), only northern spotted owls present (state 2), only barred owls present (state 1), and neither species present (state 0). As neither species was detected perfectly, the true state of a site was only known with certainty when both species were detected (state 3). When only a barred owl was detected (observed state 1), the site could also have been occupied by a spotted owl pair (state 3) or not (state 1). Likewise, when only a spotted owl pair was detected, the site could also have been occupied by barred owls (state 3) or not (state 2). When neither species was detected, the owl site could have been in any one of the 4 states.

We modeled the overall probability of detecting the state of a site, given its true state, using a matrix of probabilities, ρ, i, t, j, that varied by site (i), year (t), and sampling event (j). We assumed no false positives (e.g., detection of barred owl, but site is occupied by spotted owl only), reduced probabilities in the matrix, and modeled ρ as a function of 5 parameters that varied by site, year, and sampling event. Omitting subscripts for clarity, these 5 parameters were 1) detection probability of barred owls when spotted owls were not present, p^A (^{A} = barred owl), 2) detection probability of barred owls when spotted owls were present, r^A, 3) detection probability

of northern spotted owls when barred owls were not present, p^B (^{B} = northern spotted owl), 4) detection probability of northern spotted owls when barred owls were present and detected, r^{BA}, and 5) detection probability of northern spotted owls when barred owls were present but not detected, r^{Ba}. The reduced matrix was:

$$\rho = \begin{pmatrix} 1 & 0 & 0 & 0 \\ (1-p^A) & p^A & 0 & 0 \\ (1-p^B) & 0 & p^B & 0 \\ (1-r^{BA})(1-r^A) & (1-r^{Ba})r^A & r^{BA}(1-r^A) & r^{Ba}r^A \end{pmatrix}$$

where each row represents the probability of detecting a site in states 0 through 3 given that the true state is 0, 1, 2, or 3 (in descending order).

The 5 detection parameters could, theoretically, be modeled as independent of presence or absence of the other species; however, we assumed an additive effect on the logit scale of the presence or detection of the other species. In other words, if spotted owl detection probability in the absence of barred owls, p^B, is modeled as a function of a matrix of covariates, X, using a vector of betas, β, and an intercept, β_0:

$$logit(p^B) = \beta_0 + \boldsymbol{\beta X}$$

then detection probability of spotted owls when barred owls are present but not detected, r^{Ba}, is modeled as:

$$logit(r^{Ba}) = \beta_0 + \boldsymbol{\beta X} + \beta_A$$

where β_A is the additive effect of the presence of barred owls on detection of spotted owls. Previous work has suggested that spotted owls are less likely to be detected when barred owls co-occupy an area, even if barred owls are not actively responding (Yackulic et al. 2014). When barred owls do respond, the detection probability of spotted owls is expected to decline even further. This additive effect of the detection of a barred owl, β_{D^A}, in addition to the presence of a barred owl is included in the detection probability of spotted owls when barred owls are detected, r^{BA}, as follows:

$$logit(r^{BA}) = \beta_0 + \boldsymbol{\beta X} + \beta_A + \beta_{D^A}$$

For brevity, and because we only considered additive differences between detection parameters, hereafter we only refer to the betas, β_A or β_{D^A}, as opposed to the associated parameters, r^{Ba} and r^{BA}.

Hypotheses about differences before or after treatment in either the untreated or treated areas can be tested by including interactions between indicator variables and either β_A or β_{D^A}. For example, the hypothesis that detection probability of spotted owls when barred owls were present but not detected changed in the treatment area after treatment could be formulated as:

$$logit(r^{Ba}) = \beta_0 + \boldsymbol{\beta X} + \beta_A + \boldsymbol{R}\beta_{AR}$$

where $\boldsymbol{R}$ is an indicator variable determining whether a particular site was in the treatment group, and β_{AR} is the estimated difference in r^{Ba} on the logit scale associated with the treated group.

The model assumes the true state of each site did not change within breeding seasons; consequently, changes in state within a season could bias parameter estimates. In particular, removal of barred owls during the breeding season would violate this assumption. In other words, removal either changes the state from occupied by both species (state 4) to occupied by spotted owls only (state 2) or changes the state from occupied by barred owls only (state 1) to occupied by neither species (state 0). Therefore, at sites in the treated area, we considered only surveys within a breeding season that occurred prior to removal of the last barred owl to avoid biasing parameter estimates.

Between breeding seasons, sites transitioned between states according to a transition matrix, $\phi_{i,t}$, that varies depending on the covariates associated with owl site i at time t. As with detection parameters, we drop subscripts and model transition probabilities as functions of the following 8 parameters: 1) colonization probability for barred owls when barred owls were not present in the previous breeding season, γ^A, 2) colonization probability for barred owls when barred owls were present in the previous breeding season, γ^{AB}, 3) colonization probability for northern spotted owls when barred owls were not present in the previous breeding season, γ^B, 4) colonization probability for northern spotted owls when barred owls were present in the previous breeding season, γ^{BA}, 5) extinction probability for barred owls when spotted owls were not present in the previous breeding season, ε^A, 6) extinction probability for barred owls when spotted owls were present in the previous breeding season, ε^{AB}, 7) extinction probability for northern spotted owls when barred owls were not present in the previous breeding season, ε^B, and 8) extinction probability for northern spotted owls when barred owls were present in the previous breeding season, ε^{BA}. The full transition matrix, ϕ, was:

$$\begin{pmatrix} (1-\gamma^A)(1-\gamma^B) & \gamma^A(1-\gamma^B) & (1-\gamma^A)\gamma^B & \gamma^A\gamma^B \\ \varepsilon^A(1-\gamma^{BA}) & (1-\varepsilon^A)(1-\gamma^{BA}) & \varepsilon^A\gamma^{BA} & (1-\varepsilon^A)\gamma^{BA} \\ (1-\gamma^{AB})\varepsilon^B & \gamma^{AB}\varepsilon^B & (1-\gamma^{AB})(1-\varepsilon^B) & \gamma^{AB}(1-\varepsilon^B) \\ \varepsilon^{AB}\varepsilon^{BA} & (1-\varepsilon^{AB})\varepsilon^{BA} & \varepsilon^{AB}(1-\varepsilon^{BA}) & (1-\varepsilon^{AB})(1-\varepsilon^{BA}) \end{pmatrix}$$

where each row corresponds to the state at time, t, and each column corresponds to the state at time, t+1, and states in each dimension are ordered from 0 to 3.

We modeled the effects of conspecifics as additive on the logit scale. So, for example, if extinction of spotted owls in the absence of barred owls, ε^B, is modeled via an intercept, α_0, and the product of a vector of estimate coefficients, $\boldsymbol{\alpha}$, and a matrix of covariates, $\boldsymbol{X}$ according to:

$$logit(\varepsilon^B) = \alpha_0 + \boldsymbol{\alpha X}$$

then extinction probability in the presence of barred owls, ε^{BA}, would be modeled as:

$$logit(\varepsilon^{BA}) = \alpha_0 + \boldsymbol{\alpha X} + \alpha_A$$

where BA is the difference in extinction probability on the logit scale associated with barred owl occupancy. The primary hypotheses of interest regarding the effects of barred owl removal on spotted owl extinction probabilities are given below, after discussion of the background model.

Finally, the state of each owl site in the first year is modeled based on the probability of occupancy for barred owls, ψ_i^A, and spotted owls, ψ_i^B, where both probabilities vary based on site covariates, including potentially both habitat and pre-treatment groups. Although it is possible to differentiate between occupancy of spotted owls in sites where barred owls are present or absent, previous 2-species occupancy modeling of this dataset did not support this distinction, probably because of the low prevalence of barred owls at the beginning of the study period (Dugger et al. 2016).

Baseline model.—Dugger et al. (2016) analyzed data from our study area (and 10 other study areas) over the same time period but excluded sites in the treatment area after 2008. Their analysis tested a number of hypotheses about habitat covariates, interspecific interactions, and temporal trends in various parameters. We adopted their best model structure as the baseline model for all analyses presented here, and build on it to test hypotheses about the effects of barred owl removal. The baseline model identified by Dugger et al. (2016) contained the following sub-models: 1) barred owl detection probability included a linear temporal trend; 2) spotted owl detection probability included a year factor (i.e., year-specific intercepts), a within-year bi-week factor (different intercepts for each of the 12 2-week periods), a within-year survey effect (whether surveys had previously been done at the site in the same year), and differences depending on whether barred owls were present and not detected, β_A, or present and detected, β_{D^A}; 3) initial occupancy of barred owls did not vary between sites, 4) initial occupancy of spotted owls included the habitat change (hc) covariate, 5) barred owl colonization was a function of the edge covariate and a linear temporal trend, 6) spotted owl colonization was a function of the edge covariate, 7) barred owl extinction probability was a function of the hab covariate and whether spotted owls co-occupied the patch, β_B, and 8) spotted owl extinction was a function of the core covariate and whether barred owls co-occupied the patch, β_A.

Specific hypotheses tested in this analysis.—Past 2-species dynamic occupancy models for these species indicated that barred owls primarily affect northern spotted owl occupancy parameters by increasing local extinction rates in co-occupied patches (Yackulic et al. 2014, Dugger et al. 2016). Because barred owls were actively removed from sites in the treated area, we hypothesized that northern spotted owl extinction in the presence of barred owls would decline in the treated area to a level similar to northern spotted owl extinction in the absence of barred owls. Therefore, we modeled spotted owl extinction in the presence of barred owls using the following formula:

$$logit(\varepsilon^{BA}) = \alpha_0 + \boldsymbol{\alpha X} + \alpha_A + \alpha_{AR}\boldsymbol{R}$$

where X contained baseline covariates identified by Dugger et al. (2016) and hypothesized that α_{AR} would be negative with absolute magnitude approximately the same as α_A. We also hypothesized that removals would lead to an increase in barred owl extinction in the treated area regardless of whether spotted owls were present. In other words, given:

$$logit(\varepsilon^{A}) = \alpha_0 + \boldsymbol{\alpha X} + \alpha_R\boldsymbol{R}$$

$$logit(\varepsilon^{AB}) = \alpha_0 + \boldsymbol{\alpha X} + \alpha_B + \alpha_R\boldsymbol{R}$$

we hypothesized that α_R would be positive.

It was more difficult to predict the effects of barred owl removals on colonization of both species because of uncertainty regarding movement rates of both species. If movement between treated and untreated was common, we reasoned that treatment effects on colonization would be difficult to detect. In addition, barred owl occupancy was steadily increasing before treatment, and it was reasonable to assume barred owl colonization rates were increasing as well (Yackulic et al. 2012). Given these uncertainties, we tentatively hypothesized that barred owl colonization rates would be lower in the treatment area than in the untreated area but had no a priori hypothesis concerning overall trends in barred owl colonization post-treatment. In addition, we hypothesized that spotted owl colonization would increase in the treatment area.

In addition to the above hypotheses regarding the effects of treatment on different groups, we also tested for pre-existing differences between the group's initial occupancy, colonization, or extinction prior to treatment. We also considered hypotheses about how detection probability may have changed either in response to treatment or to the use of digitally broadcasted northern spotted owl calls beginning in 2009. We hypothesized that the improved quality of the broadcast calls would result in an increase in detection probabilities for barred owls. We also hypothesized that improved quality of broadcast calls might affect the probability of detecting spotted owls at sites also occupied by barred owls, but we did not have an a priori expectation concerning the sign of this effect. In addition, we hypothesized that the detection probability of northern spotted owls in previously co-occupied patches within the treated areas would increase as barred owls were removed.

Occupancy model selection.—We began by fitting a full model that included all background effects and hypotheses of interest (Table 1). We then sequentially removed effects (except those included in the baseline model) and observed changes in corrected Akaike's Information Criterion (AIC_c) values. We determined the order of potential removals a priori using the following steps: 1) determine which of the hypothesized treatment effects were supported in the detection parameters; 2) determine whether there is support for any differences between treatment groups prior to initiation of treatment in the initial occupancy, colonization, or extinction of either species; 3) determine whether parameters associated with colonization and extinction changed in the untreated area after initiation of treatment; and 4) determine if parameters associated with colonization and extinction differ between treated and untreated areas

Table 1. Unique model elements and information criterion statistics for the 2-species occupancy models fitted to data on Green Diamond's northern spotted owl demographic study area in north coastal California, 1999–2013. We modeled initial occupancy ($\hat{\psi}^B$, $\hat{\psi}^A$ [^{A} = barred owl; ^{B} = northern spotted owl]), colonization ($\hat{\gamma}^B$, $\hat{\gamma}^A$), extinction ($\hat{\varepsilon}^B$, $\hat{\varepsilon}^A$), and detection ($\hat{p}^B$, $\hat{p}^A$) for northern spotted and barred owls (BO). The full model includes parameters that allow different intercepts (β_0), effects of barred owl occupancy (β_A), effects of barred owl detections (β_{D^A}), and different trends (β_T) based on pretreatment differences (R') or changes post-treatment in either the treated (R) or untreated (U) areas. Some submodels also include hypotheses that a given parameter changed after treatment and that there was no differences between treated and untreated areas with respect to the change (U=R). We calculated differences in Akaike's Information Criterion (ΔAIC_c) both within each model set and overall and we also report the number of parameters (K) and the deviance (twice the negative log likelihood, 2NLL). All models included habitat covariates, interspecific effects, and temporal variation in various parameters already identified as important based on a previous analysis and referred to as the base model. Dash (–) indicates that no additional parameters were added from the base model. NS = model not supported; S = model supported

	Northern spotted owl					Barred owl								
	ψ_0^B	$\hat{\gamma}^B$	$\hat{\varepsilon}^B$	$\hat{p}^B$		ψ_0^A	$\hat{\gamma}^A$		$\hat{\varepsilon}^A$	$\hat{p}^A$				
Hypothesis tested	β_0	β_0	β_A	β_A	β_{D^A}	β_0	β_0	β_T	β_0	β_0	**Overall ΔAIC_c**	**Model set $\Delta AICc$**	K	**2NLL**
First model set: detection probability hypotheses														
Full model	R'	R', U, R	R', U, R	U, R	U, R	R'	R', U, R	U, R	R', U, R	U=R	17.8	5.0	67	12,620.8
$\hat{p}^A$ changes with digitally broadcasted recorders (NS).	R'	R', U, R	R', U, R	U, R	U, R	R'	R', U, R	U, R	R', U, R	—	16.4	3.6	66	12,621.5
$\hat{p}^B$ during surveys when BO are detected changes with digitally broadcasted recorders (NS).	R'	R', U, R	R', U, R	U, R	—	R'	R', U, R	U, R	R', U, R	—	12.8	0	64	12,622.1
$\hat{p}^B$ at sites where BO are present changes with treatment (S).	R'	R', U, R	R', U, R	U	—	R'	R', U, R	U, R	R', U, R	—	21.6	8.8	63	12,633.0
$\hat{p}^B$ at sites where BO are present changes with digitally broadcasted recorders (S).	R'	R', U, R	R', U, R	R	—	R'	R', U, R	U, R	R', U, R	—	15.0	2.2	63	12,626.4
Second model set: hypotheses concerning pretreatment differences between treated and untreated areas														
ψ_0^A differs between areas before treatment (NS).	R'	R', U, R	R', U, R	U, R	—	—	R', U, R	U, R	R', U, R	—	11.0	8.4	63	12,622.4
ψ_0^B differs between areas before treatment (NS).	—	R', U, R	R', U, R	U, R	—	—	R', U, R	U, R	R', U, R	—	9.7	7.1	62	12,623.2
$\hat{\gamma}^A$ differs between areas before treatment (NS).	—	R', U, R	R', U, R	U, R	—	—	U, R	U, R	R', U, R	—	8.2	5.6	61	12,623.8
$\hat{\varepsilon}^A$ differs between areas before treatment (NS).	—	R', U, R	R', U, R	U, R	—	—	U, R	U, R	U, R	—	6.5	3.9	60	12,624.2
$\hat{\gamma}^B$ differs between areas before treatment (NS).	—	U, R	R', U, R	U, R	—	—	U, R	U, R	U, R	—	4.4	1.8	59	12,624.2
$\hat{\varepsilon}^B$ at sites occupied by barred owls differs between areas before treatment (NS).	—	U, R	U, R	U, R	—	—	U, R	U, R	U, R	—	2.6	0	58	12,624.5
Third model set: hypotheses concerning changes in untreated area after treatment began														
$\hat{\gamma}^A$ intercept changes in untreated area (S).	—	U, R	U, R	U, R	—	—	R	U, R	U, R	—	11.2	9.2	57	12,635.2
$\hat{\gamma}^A$ trend changes in untreated area (S).	—	U, R	U, R	U, R	—	—	U, R	R	U, R	—	7.4	5.4	57	12,631.4
$\hat{\varepsilon}^A$ changes in untreated area (S).	—	U, R	U, R	U, R	—	—	U, R	U, R	R	—	5.8	3.8	57	12,629.8
$\hat{\gamma}^B$ changes in untreated area (NS).	—	R	U, R	U, R	—	—	U, R	U, R	U, R	—	2.5	0.5	57	12,626.4
$\hat{\varepsilon}^B$ in co-occupied sites changes in untreated area (NS).	—	R	R	U, R	—	—	U, R	U, R	U, R	—	2.0	0	56	12,628.1
Fourth model set: hypotheses concerning treatment effects on treated area														
$\hat{\gamma}^A$ intercept changes after treatment were different in treated area (S).	—	R	R	U, R	—	—	U=R	U, R	U, R	—	4.7	4.7	55	12,632.9
$\hat{\gamma}^A$ trend changes after treatment were different in treated area (NS).	—	R	R	U, R	—	—	U, R	U=R	U, R	—	0.4	0.4	55	12,628.6
$\hat{\varepsilon}^A$ changes after treatment were different in treated area (S).	—	R	R	U, R	—	—	U, R	U=R	U=R	—	11.3	11.3	54	12,641.6
$\hat{\gamma}^B$ changes in treatment area only (NS).	—	—	R	U, R	—	—	U, R	U=R	U, R	—	0	0	54	12,630.3
$\hat{\varepsilon}^B$ in co-occupied sites changes in treatment area only (S).	—	—	—	U, R	—	—	U, R	U=R	U, R	—	8.0	8.0	53	12,630.3

following initiation of treatment. Within each set, we decided a priori to always remove parameters related to barred owls before removing parameters related to northern spotted owls and we always removed parameters related to colonization before parameters related to extinction.

Analysis of fecundity.—We conducted analysis of fecundity on the number of female young produced per territorial female per year, defined as the number of young (M + F) produced per territorial female per year divided by 2 because the sex ratio of juvenile owls at hatching was assumed to be 1:1 (Fleming et al. 1996). Spotted owls are strongly territorial, with high site fidelity and detectability, even in years when they are not breeding (Franklin et al. 1996, Reid et al. 1999). Similar to other studies (Anthony et al. 2006, Forsman et al. 2011, Dugger et al. 2016), we assumed that sampling throughout the breeding season was not biased towards birds that reproduced, and that the sample of owls used in our analyses was representative of the territorial population. During 1990 to 2013 over all sites, 90% of fledged young were produced by adult females >2 years old (other age classes included 1% produced by first-year subadults (S1), 3% produced by second-year subadults (S2), and 6% produced by unknown age birds). In addition, the number of non-adult birds was low or 0 in some years, which reduced our ability to compare fecundity for these age classes. Consequently, we dropped non-adult age classes from analysis and considered only fecundity of adult females.

Similar to previous analyses (Anthony et al. 2006, Forsman et al. 2011, Dugger et al. 2016), we analyzed mean annual fecundity using standard regression based on a normal distribution. Analysis of average fecundity helped assure the homoscedastic error assumption inherent in normal models. Furthermore, the appropriate sample units for the analysis were geographical (the treated and untreated areas), not individual owls, because both experimental areas could respond annually to effects that influenced their entirety. In addition, by averaging over owl territories occupied by females and considering treatment areas as sampling units, we reduced ill-effects of autocorrelation in reproduction through time on individual owl territories (Dugger et al. 2016).

The distribution of the underlying data (no. fledglings/female; NYF) was consistent with a truncated Poisson or multinomial distribution because spotted owl pairs almost always raise 0, 1, or 2 young. However, annual fecundity averaged over territories was not Poisson (Forsman et al. 2011), and normal models are more accurate than Poisson models when data depart from Poisson (White and Bennetts 1996, McDonald and White 2010). In addition, normal models are just as accurate as multinomial models when averages are analyzed (McDonald and White 2010). Thus, we used regression models based on a normal distribution to model mean annual NYF for study area as described in Dugger et al. (2016).

Prior analysis has shown that the spatial covariance among territories tended to be small relative to temporal variance among years and other residual effects (Forsman et al. 2011). This justified disregarding spatial covariance because it would not seriously bias variance estimates. In addition, residual variation was relatively constant through time largely because residual variation was small relative to annual variation. Consistent with previous analyses (Anthony et al. 2006, Forsman et al. 2011, Dugger et al. 2016), we estimated the effect of barred owl removal and fit a large number of candidate models containing the effects of habitat, weather, climate, and various forms of interactions between study area (treated vs. untreated) and time period (pre-removal and post-removal). We determined the set of candidate models prior to estimation based on biologically plausible hypothesized effects. The full list included 574 models but we present only those models with a $\Delta AIC_c < 5$.

All models fitted here contained constraints on temporal trends pre- and post-removal that were, in fact, the primary goal of estimation. In addition to non-temporal covariates mentioned above, the models fitted here included year and treatment covariates that allowed the same, parallel, or non-parallel trends on the 2 study areas (treated and untreated) before treatment but parallel trends and differing magnitudes after treatment. If removal of barred owls on the treated area had no effect on average fecundity, the coefficient for the difference in magnitude between treated and non-treatment areas after removal would be 0. If the intercept coefficient measuring the mean difference post-treatment was not 0 (at $\alpha = 0.05$ level), we concluded the change in fecundity to be associated with removal of barred owls. That is, we concluded that fecundity on the 2 study areas was different following treatment.

Analysis of apparent survival.—We used capture–recapture (re-sighting) data to estimate capture probabilities and annual apparent survival probabilities of territorial owls using open population Cormack–Jolly–Seber models. We developed a set of models based on previous research and biological hypotheses (Dugger et al. 2016), and computed estimates of coefficients in those models using Program MARK (White and Burnham 1999). We considered both fixed and random effects models. Covariates considered in the fixed portion of the Cormack–Jolly–Seber model included sex and temporal effects. Covariates considered in the random portion of the model included reproduction, habitat, weather, climate, and generic time effects.

Based on the best-fitting fixed effects model, we included random effects to produce shrinkage estimates (Burnham and White 2002) of annual survival and standard error. Shrunk survival estimates were associated with the year of the field season that terminated the interval. For example, survival from field season 2011 to field season 2012 was associated with year 2012 for analysis. We discarded the final interval (2012–2013) because survival and capture were confounded during the final interval in time-dependent models (Forsman et al. 2011, Dugger et al. 2016).

We then tested for an effect of barred owl removal on survival. We exported the shrunk estimates of survival produced by the best fitting random effects model from MARK to R (R Foundation for Statistical Computing, Vienna, Austria) and used the estimates to test for an

association between survival and barred owl removal via the weighted linear model:

$$\varphi_{ij} = \beta_0 + \beta_1(Post_i) + \beta_2(Treated_j) + \beta_3(Post_i \times Treated_j) + \beta_4(Pre_i \times Year_i)$$

where φ_{ij} was the shrunk estimate of apparent survival between year i and (i+1) on study area j, $Post_i$ was an indicator function for all survival intervals after removal ($Post_i = 1$ for 2008–2009 through 2011–2012, 0 otherwise, with the final interval discarded as described above. $Treated_j$ was an indicator for survival estimates on the treated areas, $Year_i$ was year of the study, and Pre_i was an indicator function for years prior to barred owl removal (i.e., $Pre_i = 1$ for 1990 through 2007). Each estimate in this model was weighted by the inverses of the standard error for individual survival estimate. This model forced parallel trends on both study areas pre-removal, and no trend post-removal. The model was constrained to estimate no trend post-removal because of the small number of observations post-removal ($n = 4$ intervals post-removal). This model allowed the difference in survival on treated and untreated areas to differ pre- and post-removal, and this was considered the effect of interest.

That is, if removal of barred owls on the treated area had no effect on survival, the coefficient for $Post \times Treated$ (i.e., β_3) would be 0 because β_3 measures the difference of differences $(\bar{\varphi}_{pre,treated} - \bar{\varphi}_{pre,non}) - \left(\bar{\varphi}_{post,treated} - \bar{\varphi}_{post,non}\right)$. If β_3 differed from 0 (at $\alpha = 0.05$ level), we concluded removal of barred owls was associated with a change in survival.

Analysis of annual rate of population change.—We included all banded territorial birds (S1, S2, adults) in the analysis of finite rates of population change (λ) on our study areas, the same dataset used in the survival analysis, but we did not explicitly include age effects. We used the f-parameterization of the temporal symmetry models of Pradel implemented in Program MARK (Pradel 1996) to obtain a derived estimate of λ. The rationale for using this approach instead of Leslie matrix models was based on large natal dispersal distances of spotted owls relative to the size of our study area resulting in permanent but unknown emigration of fledglings from the population, and little ability to accurately estimate juvenile survival. We assumed this reparameterization of the Jolly–Seber capture–recapture model (λ_{RJS}) produced less biased estimates of λ compared to estimates from a Leslie matrix (Anthony et al. 2006, Forsman et al. 2011).

The Pradel (1996) method assumes that study area size does not change and that survey effort is relatively constant in each sampling interval such that owls are not gained or lost because of changes in survey effort or study area size. We used consistent, established protocols on our study area for marking and resighting spotted owls each year (Franklin et al. 1996, Lint et al. 1999) to ensure that we surveyed study areas with approximately equal effort each year. Although our study area boundary increased in 1998, we corrected for the expansion through modeling in Program MARK. Full details of how we applied the Pradel method to estimating λ in our study area are in Dugger et al. (2016).

Initial effects considered for parameters in the λ_{RJS} model were general time and sex effects on recapture rates (p), general time effects on survival (φ_t), and general time effects on recruitment (f_t). We retained the best structure on p, as evidenced by the lowest AIC_c, and estimated a constant (no effect) random effects model to produce derived estimates of annual population change λ_t. The purpose behind fitting the random effects model was to reduce the number of distinct parameters without forcing them to be equal over all years, and thus shrink derived estimates of λ_t toward their mean pre- and post-removal values on both the treated and untreated areas.

We then conducted additional analyses to test for an effect of barred owl removal on the annual rate of population change. Similar to analysis of survival, we exported shrunk estimates of λ_{ij} derived from the random effects models (Burnham and White 2002) from MARK to R and tested for evidence of association with barred owl removal. We conducted the test for association with barred owl removal by estimating the weighted linear model,

$$\lambda_{ij} = \beta_0 + \beta_1(Post_i) + \beta_2(Treated_j) + \beta_3(Post_i \times Treated_j) + \beta_4(Pre_i \times Year_i)$$

where λ_{ij} was population change between years i and ($i+1$) on study area j; $Post_i$, $Treated_j$, $Year_i$, and Pre_i were as in the previous section; and the individual estimates were weighted with the inverses of the individual estimate's standard error. This model forced parallel trends in λ on both study areas pre-removal, and estimated no trend post-removal because of the small number of observations post-removal ($n = 4$ years post-removal). Similar to the survival model, this model allowed the difference in population change on treated and untreated areas to differ pre- and post-removal, and this was considered the effect of interest.

If removal of barred owls on the treated area had no effect on λ_{ij}, the coefficient for $Post \times Treated$ (i.e., β_3) would be 0 because β_3 measured the difference of differences. If β_3 was different from 0 (at $\alpha = 0.05$ level), we concluded removal of barred owls was associated with a change in the rate of population change.

RESULTS

Site Occupancy

Based on the analysis of 281 sites (158 treated and 123 untreated) from 1999 to 2013, the best 2-species dynamic occupancy model included 8 parameters in addition to the base model (Table 1), 5 of which concerned changes in barred owl occupancy dynamics, 1 related to spotted owl extinction in sites also occupied by barred owls, and 2 related to detection of spotted owls at sites also occupied by barred owls. According to the best model, there was no evidence of differences between treated and untreated areas for any of the barred owl occupancy parameters prior to the initiation of the treatment (barred owl removal). After treatment, barred owl occupancy parameters changed as follows: 1) estimates of

occupancy rates substantially increased in the untreated areas, whereas they remained relatively constant and much lower in the treated areas (Fig. 2A); 2) colonization rates initially increased and then declined in both treated and untreated areas, but the increase was greater in the untreated areas (Fig. 2B); and 3) extinction rates increased in the treated areas but declined in the untreated areas (Fig. 2C).

Similar to barred owls, there was no evidence of different spotted owl occupancy rates between treated and untreated areas prior to the initiation of the treatment. Following treatment, there was a slow recovery in northern spotted owl occupancy in the treated areas even as occupancy continued to decline in the untreated areas (Fig. 3A). Barred owl removal decreased overall spotted owl extinction rates to levels equivalent to spotted owls sites that had never had barred owls present (Fig. 3B). The best model estimated spotted owl colonization rates at an average of 0.19 (95% CI: 0.15–0.24) and models with different spotted owl colonization rates in treated and untreated areas were not supported. Northern spotted owl detection probability at sites not occupied by barred owls varied over time but showed no differences between treatments or over time (Fig. 3C). On the other hand, spotted owl detection probability at sites also occupied by barred owls increased in the treated area to the point where detection probability was nearly the same as at sites where barred owls were not present. At the same time, spotted owl detection probability in the untreated area at sites occupied by barred owls decreased to lower levels than were found prior to treatment (Fig. 3C). In agreement with Dugger et al. (2016), barred owl detection probability was estimated to be slowly increasing over the course of the study but did not show different trends with respect to treatment.

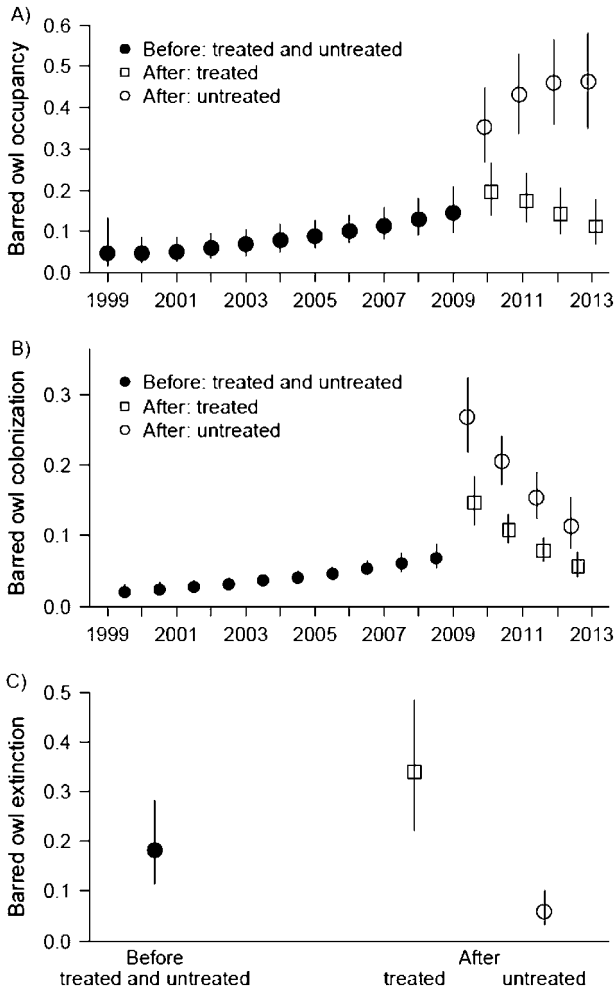

Figure 2. Changes in barred owl occupancy, colonization, and extinction on Green Diamond's northern spotted owl demographic study area in north coastal California, USA. (A) Trend in barred owl occupancy in treated and untreated areas before and after treatment (barred owl removal). (B) Trend in barred owl colonization in treated and untreated areas before and after treatment. (C) Barred owl extinction rate before treatment and after treatment in treated and untreated areas. Error bars represent 95% confidence intervals.

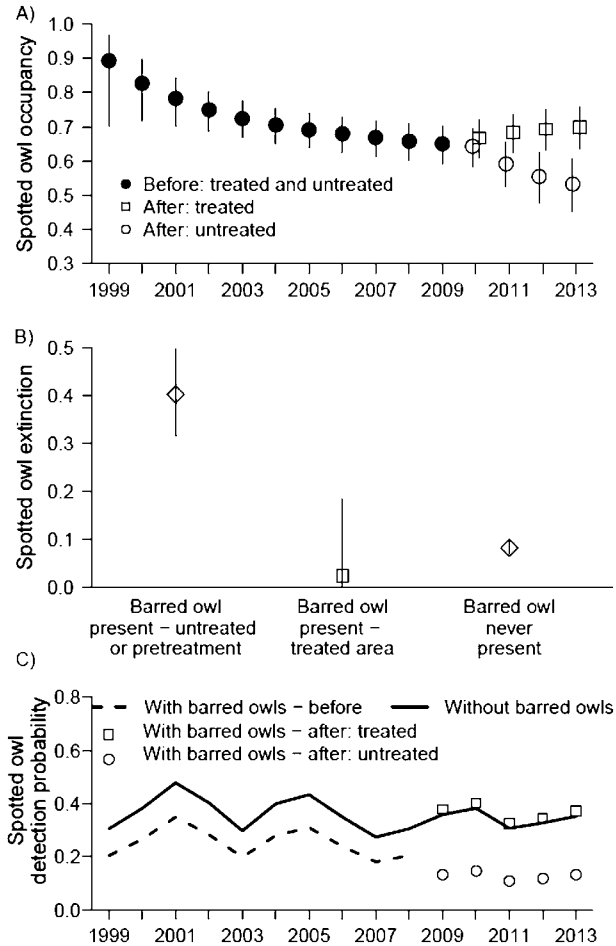

Figure 3. Changes in northern spotted owl occupancy, extinction, and detection probability on Green Diamond's demographic study area in north coastal California, USA. (A) Trend in spotted owl occupancy in treated and untreated areas before and after treatment (barred owl removal). (B) Spotted owl extinction rates when barred owls are present and not removed, barred owls are present and removed, and barred owls were never present. (C) Spotted owl detection probability with and without barred owls before treatment, without barred owls after treatment, and with barred owls after treatment in the treated and untreated areas. Error bars in panels A and B represent 95% confidence intervals.

Fecundity

Estimates of fecundity (no. of female young produced/adult female/year) from 1990 to 2013 were based on records of

964 nesting attempts by adult females on the untreated study area, and 807 nesting attempts by adult females on the treated study area, for 1,771 records.

There were 19 linear models with $\Delta AIC_c < 5$ fitted to mean annual fecundity (Table 2). The top 3 models with $\Delta AIC_c < 2$ all contained a negative effect of winter precipitation and an even-odd year effect. Two of the top 3 models contained a negative effect associated with increased winter temperatures, and another 2 contained a positive effect associated with increased amounts of edge habitat. The second and third ranked models led to the same conclusions as the top model, so we focused attention on the best-fitting model (Fig. 4). After considering the effects of habitat, climate, and even-odd year trends, prior to barred owl removal, there was evidence that fecundity decreased by an annual rate of 0.01 female young per adult female ($P = 0.021$) in both treated and untreated areas, but there was no evidence that average fecundity differed between treated and untreated areas ($P = 0.1895$). After removal of barred owls on the treated area in 2009, there continued to be no significant difference in average fecundity on the treated versus untreated areas ($P = 0.860$).

Apparent Survival

We used 4,733 encounters (captures, recaptures, and resightings, excluding multiple encounters of individuals in the same year) of 982 non-juvenile owls (162 S1, 228 S2, and 592 adults) to estimate apparent survival of spotted owls on our study areas. The weighted linear model fitted to shrunk estimates of survival showed no difference in survival pre-removal (estimated difference pre-removal = 0.0004; Fig. 5) but a marked increase in survival on the treated area relative to the untreated area post-removal ($\hat{\beta}_3 = 0.0366$, $P = 0.0162$). On both treated and untreated areas, prior to barred owl removal, survival was declining at a rate of approximately 0.2% per year ($\hat{\beta}_4 = 0.0019$, $P \leq 0.001$). Following treatment, estimated survival on the untreated area was 0.822 (95% CI = 0.801–0.844), whereas survival on the treated area was 0.859 (95% CI = 0.840–0.877).

Table 2. Models with a difference in Akaike's Information Criterion (ΔAIC_c) <5 from the 574 models fitted to fecundity data on Green Diamond's northern spotted owl demographic study area in north coastal California, 1990–2013. The covariates in the first parentheses indicate effects fitted to period before barred owl removal and the second parentheses indicate effects fitted after barred owl removal; effects outside parentheses were common to both periods. WT = mean winter temperature; WP = mean winter precipitation; EO = even-odd year effect; EDGE = proportion of edge habitat with the study area; T = linear time trend; Trt = treated area; CORE = amount of core high-use habitat in the study area; HAB = proportion of nesting and roosting habitat in the study area.

Model name	ΔAIC_c
WT+WP+EO+EDGE+(T+Trt)(Trt)	0
WT+WP+EO+(.)(Trt)	1.10
WP+EO+EDGE+(T+Trt)(Trt)	1.74
WT+WP+EO+CORE+(.)(Trt)	2.13
WP+EO+(.)(Trt)	2.45
WT+WP+EO+HAB+(.)(Trt)	2.58
WT+WP+EO+EDGE+(.)(Trt)	2.85
WT+WP+EO+(Trt)(Trt)	3.06
WT+WP+EO+CORE+(Trt)(Trt)	3.28
WT+WP+EO+(T+Trt)(Trt)	3.34
WP+EO+CORE+(.)(Trt)	3.46
WP+EO+HAB+(.)(Trt)	3.94
WT+WP+EO+HAB+(Trt)(Trt)	3.97
WP+EO+EDGE+(.)(Trt)	4.16
WP+EO+(Trt)(Trt)	4.41
WP+EO+CORE+(Trt)(Trt)	4.56
WT+WP+EO+HAB+(T+Trt)(Trt)	4.60
WT+WP+EO+EDGE+(Trt)(Trt)	4.64
WP+EO+(T+Trt)(Trt)	4.93

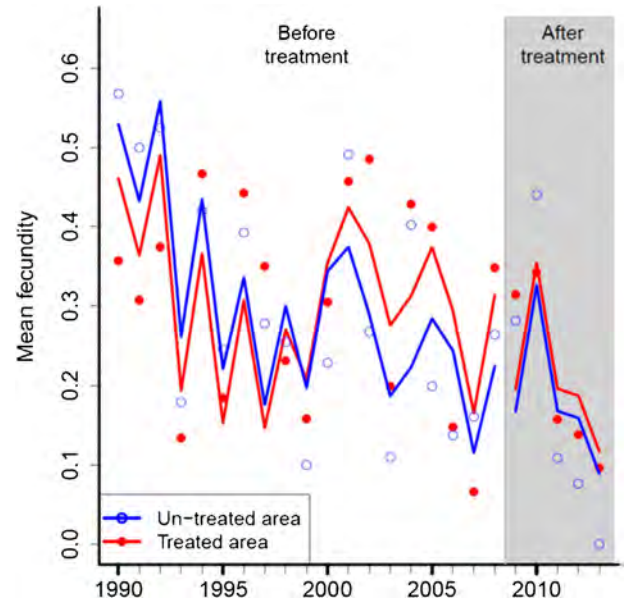

Figure 4. Observed and modeled fecundity from 1990 through 2013 on Green Diamond's northern spotted owl demographic study area in north coastal California, USA. Solid lines represent trends in fecundity estimated by the top-fitting linear model that included winter precipitation, winter temperature, an even-odd year effect, and the amount of edge habitat near the nest. An association between barred owl removal and fecundity was manifest as different lines post-treatment, but there was no evidence of an effect post-treatment ($P = 0.86$).

Annual Rate of Population Change

The best fitting λ_{RJS} model contained additive sex and time effects for capture probabilities (p), and general time effects in both survival (ϕ) and recruitment (f). Derived estimates of population change on both treated and untreated areas showed a general decline before removal of barred owls on the treated area (estimated slope pre-removal = –0.0036 per year, $P = 0.013$; Fig. 6). Following removal of barred owls on the treated areas, there was evidence that the rate of population change on the treated area increased relative to that on the untreated area (difference post-removal = 0.159, $P \leq 0.001$). Following removal of barred owls, the rate of population change averaged 1.029 (95% CI = 0.982–1.075) on the treated area, whereas the rate of population change averaged 0.870 (95% CI = 0.809–0.932) on the untreated area (Fig. 6).

Empirical Observations of Northern Spotted Owl Recolonization

We evaluated 7 known spotted owl sites that barred owls subsequently occupied for ≥1 year before removal as case

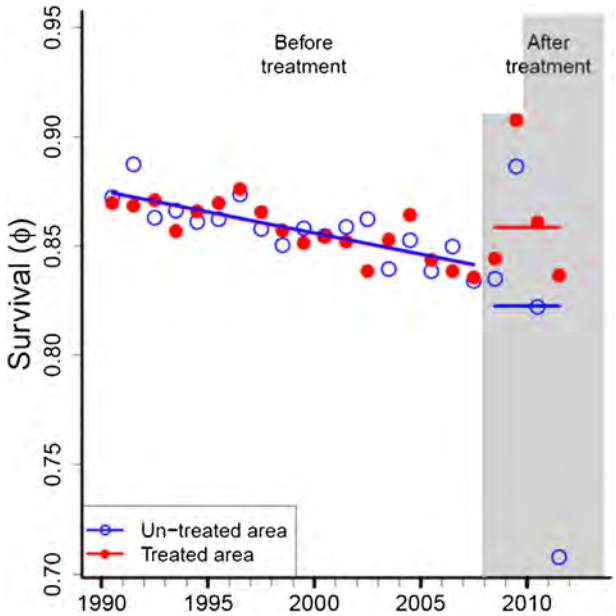

Figure 5. Shrinkage estimates of annual apparent survival from 1990 through 2013 on Green Diamond's northern spotted owl demographic study area in north coastal California, USA. Dots represent annual estimates of treated and untreated areas and trends are estimated from the weighted linear model. Survival on the treated area after removal of barred owls increased by 0.0366 (3.66%, $P = 0.016$) relative to survival on the untreated area.

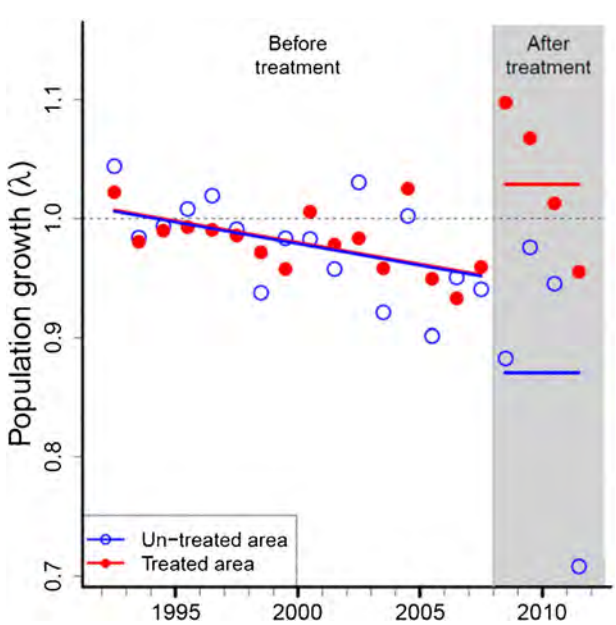

Figure 6. Shrinkage estimates of the rate of population change from 1990 through 2013 on Green Diamond's northern spotted owl demographic study area in north coastal California, USA. Shrinkage estimates are derived from the best-fitting reverse-time Cormack–Jolly–Seber model and calculated for treated and untreated areas (dots), with trends estimated from the weighted linear model. Dashed line represents a stable population, $\lambda = 1.0$. The rate of population change on the treated area increased by 0.159 ($P \leq 0.001$) after removal of barred owls relative to that on the untreated area.

studies. We documented that all were re-occupied by spotted owls with the time for re-occupation ranging from a minimum of 13 days to a maximum of 152 days after removal. Four of the sites were re-occupied by $\geq$1 of the previous resident spotted owls, including 1 female that had not been seen for 7 years. The remaining 3 sites were re-occupied by new or individuals of unknown status. Following re-occupation, the spotted owls were again displaced by barred owls at 3 sites.

There were additional barred owl removal sites that did not meet the criteria for a removal case study because the barred owls did not occupy the known spotted owl site, although they were immediately adjacent to occupied spotted owl nest sites or activity centers (i.e., the barred and spotted owl were neighbors with home ranges that likely overlapped). These neighbor case studies were more difficult to summarize, but the general pattern in all cases was for the spotted owls to either shift their territories away from the neighbor barred owls and not nest or become silent so that we had difficulty finding and determining the nesting status of the spotted owls.

DISCUSSION

The Revised Recovery Plan for the Northern Spotted Owl (USFWS 2011) noted the increasing threat of the barred owl on the northern spotted owl and called for removal experiments to quantify the impact of the invasive species on demographic parameters of spotted owls. A long-term demographic study of the spotted owl that spanned the interval when the expansion of barred owls transitioned from rare floaters on the landscape to occupying increasingly more of the available spotted owl habitat provided a unique opportunity to conduct a BACI removal experiment. However, relative to other northern spotted owl demographic study areas, the Green Diamond study area had among the lowest relative naive estimate of annual proportion of spotted owl territories with barred owl detections in Washington, Oregon, or California (Dugger et al. 2016). We hypothesized that this might reduce the magnitude of the treatment effect on all the demographic parameters, but it also facilitated the ability to remove resident barred owls from the treated areas because of their lower density compared to other areas within the range of the northern spotted owl (Diller et al. 2014).

Site Occupancy

In general, parameter estimates were consistent with our a priori hypotheses. Despite the potential for differences in physical and biological parameters, there were no differences between treated and untreated areas prior to initiation of treatment in the parameters governing either barred owl or northern spotted owl occupancy dynamics. This provides evidence that prior to treatment, the treated and untreated areas were sufficiently similar in important parameters such as occupancy, colonialization, and extinction that post-treatment differences could be assigned to the treatment effect (i.e., removal of barred owls). After the experimental removal experiment began, barred owl extinction rates

increased and barred owl occupancy rates declined in the treated areas as would be predicted given the continuous lethal removal of resident and immigrant barred owls. Occupancy of barred owls in the untreated areas continued to increase consistent with the increasing expansion of barred owls in the region (Yackulic et al. 2012, Dugger et al. 2016). The increase in barred owl colonization rates in treated and untreated areas when removal was initiated in 2009 was not expected. At the Tyee study area in Oregon, barred owl expansion proceeded slowly for many years before increasing rapidly (Yackulic et al. 2012). It is possible that treatment began just as local populations were starting to enter a similar period of rapid increases. Alternatively, environmental conditions may have been very favorable in the years prior setting the stage for a single year of high colonization. Following 2009, barred owl colonization probability declined in both treated and untreated areas. This could reflect either year-to-year variability in barred owl vital rates or could be a consequence of declines in overall regional occupancy coupled with the dependency of barred owl vitals rates on regional occupancy (Yackulic et al. 2012).

Barred owls had an impact on spotted owl territory extinction with rates approximately 4 times higher where barred owls were present at spotted owl sites compared to areas where they were never present. When barred owls were removed from sites where they co-occurred, spotted owl extinction rates became comparable to sites where barred owls were never present. This provides compelling evidence that barred owls were responsible for increases in spotted owl extinction rates and that removal efforts were effective at removing this impact. This large drop in extinction rates resulted in a slight recovery from the decline in spotted owl occupancy in the treated areas. Both the speed of any recovery in spotted owl occupancy and the expected spotted owl equilibrium occupancy are dependent on colonization rates in addition to extinction rates. Because spotted owl colonization rate did not increase in the treated area and is modest (0.19), recovery is likely to be protracted. Spotted owl colonization rates may not have increased because of low fecundity rates during this period on the study area (Fig. 4) and throughout the region (R. B. Douglas, Mendocino Redwood Company, unpublished report).

Fecundity

As observed in prior studies of northern spotted owl fecundity, we observed substantial annual variation that was primarily expressed as an even-odd year effect (Anthony et al. 2006, Forsman et al. 2011). This biennial cycle is almost certainly partly an expression of the tendency of spotted owls to be facultative nesters with most females breeding in alternate years. It is not known specifically what causes the synchronization, but the fact that winter precipitation and temperature entered the top fecundity models with a negative coefficient suggests that weather may be a major contributing factor. Weather may have also contributed to the declining trend in fecundity even in the early years of this study when the annual rate of population change was not significantly different from 1.0 and before barred owls were sufficiently abundant to affect the spotted owl population.

The lack of evidence of an effect of barred owl removal on spotted owl fecundity is likely to be at least partly caused by the high annual variation in fecundity. Furthermore, the competitive interaction between barred owls and spotted owls often results in the displacement of spotted owls (Wiens et al. 2014), and when this occurred, we were generally unable to detect the female spotted owls. This manifested itself as a reduction in occupancy in the untreated versus treated areas, but females that were not detected in a given year did not contribute to an estimate of fecundity. So although we did not find evidence of a change in the number fledged per breeding pair, the total productivity did appear to change in treated compared to untreated areas. Presumably due mostly to a reduction in the number of spotted owl sites, empirical counts of the number fledged at active (occupied at least once in the preceding 3 consecutive years) owl sites post treatment (2009–2014) indicated that only 36 fledglings were documented from an annual mean of 49.8 active owl sites in the untreated areas. In contrast, during the same period, 133 fledglings were observed from an annual mean of 104.2 active sites in the treated areas due at least partly to an increasing number of active sites following barred owl removal.

Apparent Survival

There is evidence of a pretreatment negative trend in apparent survival for spotted owls in both the treated and untreated areas. Following initiation of the removal experiment, there was evidence that survival rates recovered in the treated areas with the mean rate similar to the early years of the study when barred owls were still novel single floaters in the study area. Survival rate in the untreated areas continued to decline and was estimated at the lowest recorded level post-treatment.

The mechanism by which barred owls affect apparent survival of spotted owls is not known. Although we have observed physical attacks of barred owls on spotted owls, these attacks, although violent, did not appear to result in serious physical injury to the spotted owl. There is only one recorded case of a spotted owl purported to have been killed by a barred owl (Leskiw and Gutiérrez 1998). There is also the potential that barred owls could influence spotted owl survival through competition for mutually important prey species. Although barred owls have been shown to have substantial prey overlap with spotted owls in coastal Oregon (Wiens et al. 2014), there have been no studies of prey overlap in our study area in coastal California where spotted owls tend to specialize on dusky-footed woodrats (*Neotoma fuscipes*). Barred owls almost certainly do take some woodrats in our study area, but their more generalized food habits, relative low abundance in the study area even in the untreated areas, and the high abundance of woodrats in young managed timberlands (Hamm 1995, Hughes 2005) make it very unlikely that competition for prey could increase direct mortality or permanent emigration of spotted owls. A telemetry study of barred owls and spotted owls in coastal

Oregon indicated that interference competition for territorial space limited availability of spotted owls to their preferred habitat (Wiens et al. 2014). We also made anecdotal observations of spotted owls that no longer vocalized following occupation by barred owls at or near their territory core, but we could still observed them when they flew up to take a proffered mouse. Thus, we hypothesize that release from barred owl influence creates the appearance of increasing apparent survival by allowing displaced spotted owls in the floater population to regain a territory and become more readily detected. Our empirical observations of spotted owls recolonizing sites within as little as 13 days provides support for this hypothesis.

Annual Rate of Population Change

Because of a declining rate in both fecundity and apparent survival with apparently insufficient immigration to compensate, there was evidence of a pre-treatment negative trend in λ for spotted owls in both the treated and untreated areas. Following initiation of the removal experiment, λ significantly increased in the treated areas with the mean rate greater than 1.0, suggesting a stable or increasing population. The population continued to decline in the untreated areas and was estimated at the lowest recorded level post-treatment.

As previously noted, the Green Diamond dataset was also used in the 2013 northern spotted owl meta-analysis. One of those analyses converted estimates of λ_t to estimates of realized population change ($\widehat{\Delta}_t$). This method provided a visual portrayal of the population trajectory ($\Delta_t = N_t/N_x$) in each year of the study relative to population size in year x, the first year that λ_t was estimated. The results of that analysis for Green Diamond indicated that the treated and untreated spotted owl populations were generally stable (95% CI broadly overlapped 1) until 2005 when a sharp population decline ensued. Following initiation of the experimental removal on the treated area in 2009, the treated area started to rebound and the 95% confidence interval broadly overlapped 1, whereas the trend in the untreated area continued to decline with no overlap of the 95% confidence interval (Dugger et al. 2016)

If the sharp increase in λ seen in this study were the result of increases in fecundity and actual survival within the treated population, we would have expected a delay or lag of several years in the λ response. Instead, the immediate increase suggested that similar to the effect on survival, much of the increase was probably due to displaced spotted owls in the floater population regaining territorial status and being detected. Furthermore, creating an area free of barred owls may have increased the probability that floater spotted owls rebuffed in adjacent untreated areas could colonize the treated areas.

In other areas where barred owls have been present in large numbers for a longer period of time and the population of spotted owls has been more suppressed, the demographic response of spotted owls may be protracted or delayed. If spotted owl abundance has decreased to the extent that comparatively few individuals are available on the landscape to rapidly recolonize territories, we predict there would be a lag of several years in a positive spotted owl demographic response as survival and fecundity increases in the absence of barred owls. Furthermore, differences in habitat and climate associated with different physiographic provinces throughout the species range may play a role in the time or strength of a demographic response.

Empirical Observations of Northern Spotted Owl Recolonization

Although based on a small number of case studies ($n = 7$), these results suggested that northern spotted owls were likely to re-colonize their former territories following removal of barred owls. The very rapid re-colonization of 4 sites by the original resident spotted owls also indicated that, at least in some cases, the resident owls apparently remain in the vicinity of, or regularly investigate their former territory for years after being displaced by barred owls. These results also suggest that barred owls are not simply colonizing areas vacated by declining spotted owl populations, but rather that barred owls are actively displacing spotted owls as described by Wiens et al. (2014). The high and sometimes rapid rate of re-colonization by both original resident and new spotted owls following barred owl removal suggests that at least in some cases, barred owls were keeping the spotted owls from preferred, high quality sites. The sites that were colonized by barred owls also had high continuous occupancy by pairs of spotted owls with high reproductive success before barred owls invaded, which is further evidence that these sites were in high demand by spotted owls. For our study area, located within an intensively managed landscape where many of our spotted owls occupy young-growth sites that differed relative to other demographic study areas, the barred owls tend to occupy the sites with more classic late seral habitat elements.

MANAGEMENT IMPLICATIONS

The results from this study demonstrate that lethal removal of barred owls can allow the recovery of northern spotted owl populations. However, removal experiments may be more difficult to implement and recovery may be slower in other areas where barred owls have been present in large numbers for a longer period of time and the population of spotted owls has been more suppressed. Nevertheless, this experiment provides evidence that future management options may be developed to assist in the recovery of the northern spotted owl in at least the southern portions of its range. Unlike the substantial challenge of this removal experiment in which the objective was to continuously remove all territorial barred owls from the treated areas, long-term management options could be developed that would only require reducing barred owl population densities in selected conservation areas to allow coexistence with spotted owls. Presumably this could be done with much less cost and effort per unit area treated through an incremental decrease in adult barred owl survival or by implementing less controversial methods to decrease barred owl fecundity. At a minimum, this removal experiment provides evidence that if spotted owl populations continue to decline in the face of the barred owl threat,

refugia could be created so that extreme recovery actions like captive breeding would not be necessary while further management actions are developed and tested.

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NORTHERN SPOTTED OWL

SUPPLEMENTAL INFORMATION

Northern Spotted Owl

Barred Owl

California Department of Fish and Game

California Fish and Game Commission

May 2, 2016

May 2, 2016

Executive Summary

Attached are three new studies for your consideration:

Demographic Response of Northern Spotted Owls to Barred Owl Removal, Diller, et al, 2016

Northern Spotted Owls Near Weaverville and Trinity Lake In Trinity County, Sierra Pacific Ind., 2016

Multistate Models Reveal Long-Term Trends of Northern Spotted Owls in the Absence of a Novel Competitor, Kroll, et al, 2016

- **NSO Data**
  - Data previously submitted by Calforests (*"Northern Spotted Owl Science Compendium, 2014"*), should not have been considered unsatisfactory, solely because it was not a demographic study. Contrary to that determination, Calforests never contended that its information was a demographic study. It is, however, a robust index of long term trends covering over a quarter century of direct observation of harvest activity and NSO.

- **NSO Habitat**
  - The timber harvest threat section should include a more comprehensive analysis of timber harvest activities. It reviews acres proposed for operations, without delving into post-harvest habitat. A more comprehensive review would have provided more information about post-harvest condition, and spotted owl usage. In addition, this analysis assumes all harvest activity is negative. Harvesting can not only improve necessary edge relationships for prey base and foraging, many landowners engage in explicit harvesting activities to accelerate nesting, roosting, and foraging habitat.
  - The timber harvest threat analysis was based on a small sample of plans submitted in 2013. The analysis concluded that it was likely that habitat had been impacted. A quick review of the affected areas, however, shows that the owls associated with these harvests are thriving. Moreover, this sample, which was to be "evenly distributed" across counties was instead heavily weighted to certain areas, particularly Tehama County, which skews the results at best.

- **NSO Threats**
  - The timber harvest threat analysis does not explicitly acknowledge that plans reviewed under the auspices of the California Forest Practice Rules are not approved unless they meet "no take" standards under the federal Endangered Species Act, standards far in excess of state "no take" standards.
  - The threats section should prioritize the threats to Northern Spotted Owl. There is ample evidence in the record which shows that Barred Owl and wildfire are a far more important threat and impact to the NSO than harvest. All efforts related to NSO should be focused on these threats. This was demonstrated in a recent study by Diller, et. al. (2016). Inland, where barred owl effects are not yet realized, wildfire has accounted for the most significant impact.

Overview

After 25 years of surveying and tracking, NSO Pair Territory data for California suggests a healthy, well-distributed, dynamic yet stable NSO population on California timberlands. Over this period, in addition to the voluntary efforts of many California timberland owners that benefit NSO and their habitat, the acres of NSO habitat protected pursuant to the California Forest Practice Rules (FPR) and U.S. Fish and Wildlife Service (USFWS) guidance has increased as those Rules and Guidance have become more stringent. Between 1988 and 2012, the number of recorded NSO pair territorial sites increased from 950 to 3,061. The increase in such sites has been steady: as of 1992, 2,061 site had been recorded, and by 2003 2,699 sites had been recorded. It is too facile (and erroneous) to dismiss this territorial pair site data as simply reflecting increased survey effort and NSO pair movement in response to timber harvesting. While both of those factors are no doubt in play, an appropriate scientific and statistical analysis would recognize that this data evidences a dynamic yet stable NSO population. As explained by Dr. Kenneth P. Burnham, who is widely recognized as the pre-eminent wildlife population sampling and modeling authority in the Western Hemisphere, and as set forth more fully below:

> *"While the dramatic increase in known NSO pair territories since 1988 is likely due principally to more survey effort and more places surveyed, it is consistent with the dynamic but stable and robust NSO population evidenced by the data collected in the Compendium. Such a dynamic but stable, in the long term, and robust, population is also consistent with the long-lived character but variable reproductive success (due to weather and other environmental factors) of the species, discussed above."*

A recent meta-analysis of demographic data from 11 study areas indicates the northern spotted owl is declining at an annual rate of 3.8% over its entire range. The strength of this population decline, however, is strongest in the north and weakens southward through the range (Duggar, et al. 2016). In northwestern California, results from two of three demographic study areas show consistent pattern of declining fecundity, apparent survival, and finite rate of population change (Duggar, et al. 2016). Although the potential causes differ by study area, the only study from the redwood region indicated that declining trends in both apparent survival and fecundity were influenced by the increasing presence of barred owls (Strix varia). While the maintenance and growth of habitat is still a key aspect to spotted owl conservation (Diller et al. 2016), competition from the barred owl has been identified as the single-most pressing threat to the continued existence of the northern spotted owl throughout its entire range (USFWS 2011).

The threat in the interior of California is different, as widespread impact of barred owl has not been observed, as it has on the coast. Instead, wildfire has overrun a large number of the occupied ACs in northern California, leaving many in an undermined state.

Status Review

The Department's Status Review of the Northern Spotted Owl (*Strix occidentalis caurina*) in California (Review) discounted much of the Calforests Northern Spotted Owl Science Compendium (Compendium), for the following reasons:

> *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.

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 (pg. 56)

The draft Review, prior to peer review, included more discussion of the data, but stated:

The variability in methods used by companies, the tendency to report on counts or naïve estimates of occupancy without consideration of detection probability, the sometimes inconsistent methods used over time, along with the sometimes limited description of methods, makes it difficult to interpret the reported occupancy rates and trends for most companies. This leads to some difficulty in comparing reported rates in timber company reports to other published estimates of occupancy and does not support a strong finding that occupancy rates have been stable across these ownerships over time.

The draft Review, as seen above, already had doubts about data in the Compendium, but included some of the results, including a table. The peer reviewers had the following comments on the draft.

Two reviewers advocated for removal. Gutierrez (in a letter to the department) recommended rejecting the information because it was not "peer reviewed". Dugger stated:

"a single sentence or 2 dismissing this report is probably all that's needed. Don't waste time discussing results that in the end are unreliable (and which you then acknowledge are unreliable)."

Three reviewers (Glenn, Hunter, Diller) had no comment on the data, and did not recommend its removal. Franklin did not advocate removal, but instead commented: "Incorporating detection probability would only make the estimates similar or higher". This is consistent with Dr. Burnham's observations about the data provided in the Compendium, as noted above and as set forth more fully below. As explained below, Dr. Burnham is an expert on statistical applications in biology.

The bottom line is that neither the "best available science" requirement of the California Endangered Species Act, nor statistical modeling and estimation standards/best practices, required the exclusion of occupancy data because it was not peer-reviewed. Indeed, wildlife statistics standards/best practices, dictate just the opposite – the more holistic, yet statistically rigorous, approach to the data sets taken by Dr. Burnham.

Demography and Detection Probability

Thus, much of the Compendium data was excluded on the basis of detection probability. Detection probabilities are a statistic model/method designed to account for non-detections if you are not taking a census of the whole population. The purpose is to allow reporting of occupancy (presence/absence rates). Such probabilities take into account individuals present but not counted. This means that a

modeled estimate would be higher than a naïve estimate that the companies have provided. Welsh, et.al. (2013) stated:

> *The fact that abundance is subject to detection error and hence is not directly observable, means that we cannot tell when bias is present (or, equivalently, how large it is) and we cannot adjust for it. This implies that we cannot tell which fit is better: the fit from the occupancy model or the fit ignoring the possibility of detection error.* ***Therefore trying to adjust occupancy models for non-detection can be as misleading as ignoring non-detection completely. Ignoring non-detection can actually be better than trying to adjust for it.***

In order to be effective, companies employ a survey methodology (approved and designed by the USFWS) which has a high probability of detecting the target species so that it can be protected from direct disturbance. Two characteristics of spotted owls make them easy to conserve on working landscapes: 1) they respond readily to vocal imitation or recorded conspecific calls; and 2) they exhibit high site-fidelity to the same general area over successive years (and sometimes generations). These behavioral patterns (which are known to be dampened by Barred Owl presence), combined with knowledge about their regional biology and habitat use, allow foresters and biologists to manage a landscape so that it can support the spotted owl's life-history requirements.

The Compendium was independently reviewed prior to submission by Dr. Kenneth Burnham, an emeritus professor at Colorado State, and a retired USGS Biologist and Statistician. He is the author (with David Anderson) of the seminal treatise for wildlife population sampling and modeling: Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. He has authored numerous publications specific to the NSO, and has been a co-author of all the demographic studies based on the 11 study areas. His NSO-specific publications include, for example, Burnham, K. P., D. R. Anderson and G. C. White, *Meta-analysis of vital rates of the northern spotted owl,* Studies in Avian Biology 17:92-101 (1996); Franklin, A.B., D.R. Anderson, R.J. Gutierrez, and K.P. Burnham, *Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California,* Ecological Monographs 70:539- 590 (2000); and Forsman, Eric D., et al, *Population Demography of Northern Spotted Owls,* Studies in Avian Biology 40 (2011). In reviewing the NSO Science Compendium and its occupancy data, he stated:

> *"The NSO Science Compendium, taken as a whole, is a comprehensive collection of high quality data. Overall, the effort expended in monitoring and data collection on private timberlands as regards the NSO in California is, in my opinion, exemplary."*

And:

> *"Overall, just the quantity of evidence (call it that) is impressive, and shows that NSO occur all over their putative range in northwest CA (in a somewhat uniform manner). Assuming the 3,061 known NSO pair territories number is well-documented (and I believe it is), this is robust abundance. While the dramatic increase in known NSO pair territories since 1988 is likely due principally to more survey effort and more places surveyed, it is consistent with the dynamic but stable and robust NSO population in California evidenced by the data collected in the Compendium. Such a dynamic but stable, in the long term, and robust, population is also consistent with the long-lived*

character but variable reproductive success (due to weather and other environmental factors) of the species, discussed above."

It was not the intent of Calforests to submit a demography study, nor were we aware that such a standard was being applied to our submission. It was, however, our intent to show the data that has been collected over a quarter century of managing the Spotted Owl. That data clearly demonstrates that on managed lands, where active management and protection measures are applied, the population is stable and dynamic, except where barred owls have invaded.

Multistate Models Reveal Long-Term Trends of Northern Spotted Owls in the Absence of a Novel Competitor. Kroll, et al, 2016

A recent study evaluating Mendocino timberlands formerly owned by Hawthorne Timber Company (now Lyme) has recently offered contrary evidence to the trends noted in other demographic studies. It concluded that demographic data, while sometimes useful, are not necessary to draw inference about trends in the species:

> *"For long-lived species that exhibit strong site fidelity, evaluation of multiple occupancy states may be an effective alternative to support conservation and management programs. Collection of detection/non-detection data is relatively simple, and a broad array of sampling designs and statistical tools are available to analyze basic and applied questions**. For species of particular conservation interest, utilizing these tools across multiple studies can provide strong inference about factors affecting population dynamics**."*

Even more interesting, the study, based on 25 years of data held that population were stable, and attribute that fact to the absence of barred owl:

> *"Long-term datasets provide critical information about management and conservation options for imperiled species, including those affected by habitat loss and/or competition with invasive species. **We did not find evidence to indicate that territory occupancy by northern spotted owl pairs declined substantially over a 25 year period on the Mendocino County, CA, study area**. These results stand in marked contrast to other studies that also examined northern spotted owl occupancy dynamics over extended time frames and found evidence indicating significant declines."*
>
> *"Collectively, we conclude spotted owl pair populations on this landscape managed for commercial timber production appear to be more stable and do not show sharp year-over-year declines seen in both managed and unmanaged landscapes with substantial barred owl colonization and persistence."*

Sierra Pacific Industries (SPI) Landscape Survey Strategy Area (LSS), 2016

IN 2003, SPI and the US Fish and Wildlife Service (Service) designed a comprehensive multi-year survey of northern spotted owls (NSO), which is known as the Landscape Survey Strategy (LSS). It was designed to survey all suspected spotted owl nesting/roosting habitat within SPI lands in Trinity County and

extending out 0.7 mile from those lands. The total area within the LSS was 307,408 acres, of which 142,279 acres (46%) belonged to SPI.

Most of the neighboring lands are under the control of the Shasta-Trinity National Forest. This strategy established 474 **permanent survey points** that were surveyed for the five years from 2003 through 2007.

Prior to that time, surveys were done using USFWS mandated protocols existing at the time, but may not have been comprehensive in area coverage, and negative results were not compiled. In addition, ACs in older California Natural Diversity Data Base records were included in the SPI database. This provided a good general idea of the extent and numbers of sites on SPI lands, but could only provide an approximate estimate of ACs on or near the property, and was not a comprehensive census. Based on this information, and removing ACs that the Service considered abandoned, it was estimated that 47 valid AC's existed in the LSS, and were once occupied between 1990 and 2002. After a five year LSS survey period (2003 – 2007), SPI found the same number (47) of occupied ACs in the study area.

In 2011, SPI began annual re-surveys of the LSS stations. During this five year effort (2011-2015), SPI found 57 occupied ACs within the original LSS area. Also, in 2011, SPI began banding all NSO on the ownership so that in the future they will be able to ascertain whether birds in new locations are residents that have relocated, or whether they are immigrants. Since 2011, 178 NSO (118 adults/sub adults and 60 juveniles) have been banded. SPI has determined that 30 of these 57 occupied ACs were reproductive, producing at least 97 fledglings.

The Willow Creek Study area (referred to as NWC) is the nearest USFS demographic study area to the LSS and they have an estimated annual decline of 3.0%. The current range wide demographic average is an estimated annual decline of 3.8% (Dugger et al, 2016). If in the SPI study area NSOs were following these rates and assuming that the initial AC count of 47 ACs (as verified by the 2003-2007 surveys), by applying the NWC demographic study estimated rate of decline the study area should have experienced a reduction to only 22.1 occupied ACs and based upon the NSO range wide estimated rate there should have only 18.1 occupied ACs in the LSS area today.

It is worth noting that no statistical modeling can be as accurate as a true census, such as in the case of the LSS. This LSS study shows that for the period from 2003 through 2015, despite active timber harvest, there has been a documented increase in occupied activity centers for this portion of the range of the NSO from 47 to 57. All of the harvest conducted by SPI within the study area utilized Option G under the Forest Practice Rules, with technical assistance from the USFWS.

Analysis of NSO Occupied Activity Centers (State Wide)

Forest land managers generally survey for Northern spotted owls (NSO) on a project-by-project basis to support timber harvest plan preparation and implementation. These NSO management surveys comply with the federal Endangered Species Act and provide information necessary for the Director of Cal Fire to determine if a Timber Harvest Plan (THP) is in compliance with the California Forest Practice Rules. A THP cannot be approved without demonstrating that a federally-defined "take" of a state or federally listed species will not occur as a result of the harvest operations.

NSO management surveys that support a THP follow the most recent US Fish and Wildlife Service Survey Protocol (USFWS 2012, *Protocol for Surveying Proposed Management Activities That May Impact*

Northern Spotted Owls, January 9, 2012). The Protocol includes multiple visits over multiple years, and also defines when a site can be considered occupied in a given year and assigns a category for status of occupancy (for example, reproductive pair, pair, resident single, absent, etc.). NSO surveys from 1990 to the present have been conducted in accordance with the USFWS Protocols with review by Review Team Agencies and the USFWS, and confirmed and maintained by California Department of Fish and Wildlife (CDFW). We believe this data represents the best available yearly measurements of actual occupied ACs over the last 25 years, and should be considered as an important indicator of trends on managed lands, and not discarded because it is not a formal demographic study. As was previously stated, this information likely has a negative bias, which means the numbers are conservative (low).

It is these same survey protocols that also describe the surveying methodologies relied upon by NSO demographic study areas, including the Green Diamond and Hoopa/Willow Creek NSO demographic study areas. Within a demographic study area, spotted owls are surveyed each year, regardless of whether any harvesting will occur, to document site occupancy, locate owls, confirm colored leg bands of previously marked owls, leg band unmarked owls, and determine the number of young produced by territorial pairs. Each year, the status of birds within the study areas is reported to CDFW.

In contrast, NSO management surveys determine if NSO are present within 1.3 miles (or.7 miles for coastal lands) of a proposed harvesting operation. The USFWS 2012 Protocol is designed to provide a high probability of locating resident spotted owl territories and detecting owls that may be affected by timber harvest activity, thus minimizing the potential for unauthorized incidental take. As a result, there are multiple visits to an owl site and each is considered a survey. These management survey results on a visit-by-visit basis are also reported to the CDFW.

Since the CDFW Spotted Owl Database contains both management and demographic study area survey results, we analyzed the data for trends. We first sorted the CDFW database for only NSO data because it contains California Spotted Owl data as well. Then for each master owl ID (essentially an "activity center" (AC)) reported in the database, we followed the protocol rules to determine site occupancy on a year-by-year basis. Multiple positive detections or AC locations can occur in any one year, and these are individual records in the database. Where we had AC determination we used that year's location (latitude/longitude) reported by the surveyor. If there was no AC identified, we averaged the positive detection's latitude/longitude (indicating occupied) to establish a point to allow mapping for that year. To be clear, this methodology can only be used as an index, since different levels of survey in any given year can produce variability in the number of occupied activity centers, and there is no requirement to survey activity centers unless there was some planned activity that might affect that site. Under the assumption that over time harvest levels and activity will be approximately equal, even though each owl activity center is not surveyed or checked each year, this data can serve as an index.

Using this effort we produced a total annual occupied AC chart containing data from both federal and private lands portraying active owl sites from 1990 to 2014, on which we also plotted the reported NSO range-wide decline of -3.8% per annum. (See Total Graph attached). Again, this is an index, which assumed equal harvesting each year across the range, and stable levels of annual survey.

We know that survey levels were not similar on USFS and private ownerships because in 1993, the USFS dropped its timber harvest level in excess of 80%. This drop in timber management planning resulted in limiting the NSO survey efforts except for the demography study areas and proximate to their (many fewer) proposed projects.

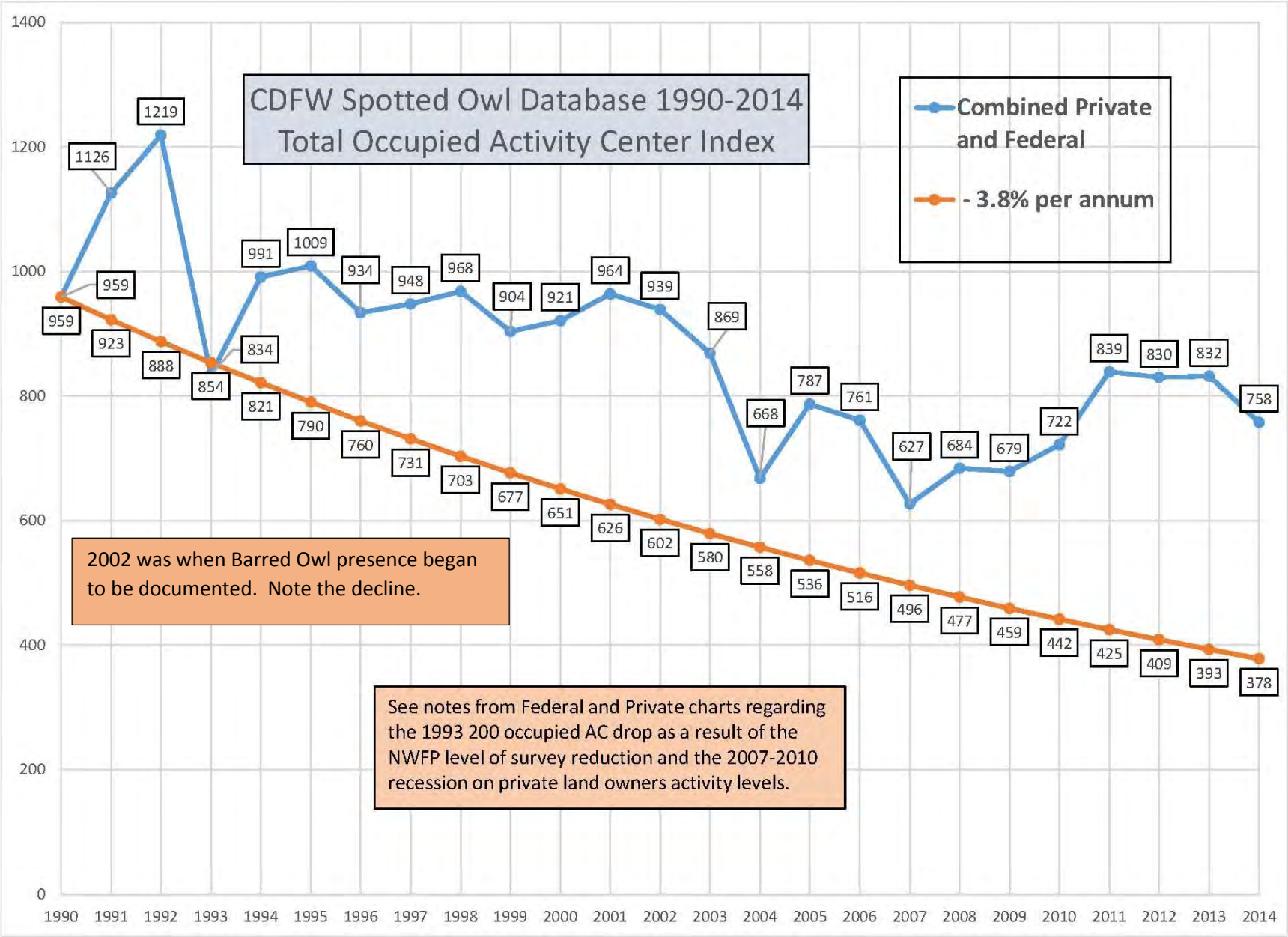
Using coordinates for occupied activity centers, we intersected them with an ownership layer to compare annually federal vs. private landowner positive NSO activity center location (essentially a minimum known occupied activity center value). This effort produced the Private (See Private Graph attached) and Federal (See Federal Graph attached) sites graphs. We then attempted to explain the fluctuations noted in the charts.

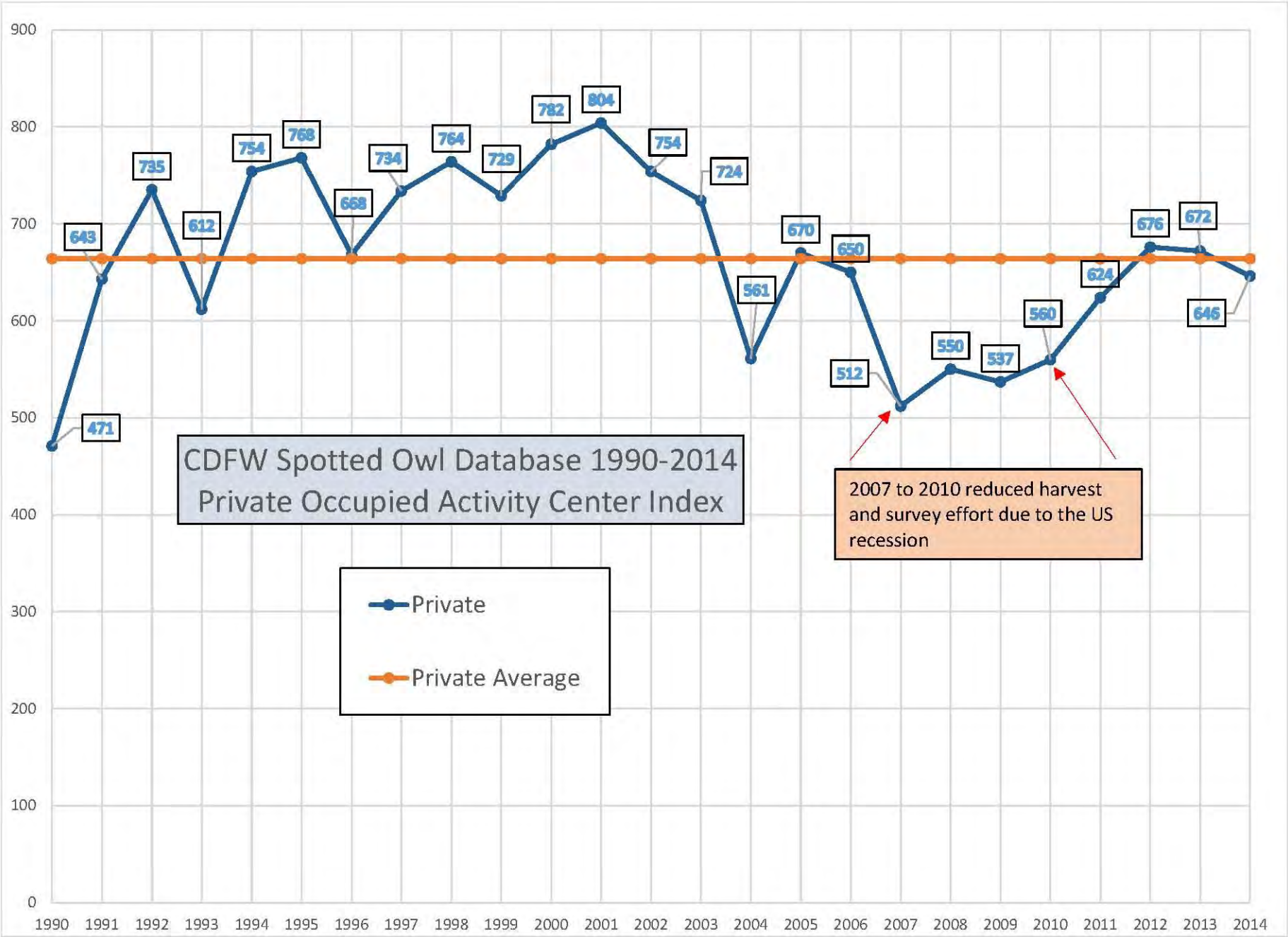
The CDFW database has not been updated for 2015 surveys, but this Private graph also shows that, as many timber company biologists reported, occupied activity centers on private lands were dynamic but stable. Since the protocol requires 3 years to determine occupancy, a particular site may be shown as occupied in one year and not occupied the next year, without an actual decline.

NSOs do not reproduce annually, but approximately once every two or three years. Because NSO are more territorial when they are nesting they also are more responsive to survey calling. The responsiveness during nesting years increases the probability of detecting NSOs in those years, which means that the detection probability of a particular activity center can fluctuate annually due to nesting status. Survey coverage will also cause the number of activity centers reported to vary. The survey coverage necessary to meet the survey protocol also varied due to the locations where THPs were being planned and implemented year to year. Logically, the variability introduced by owl nesting behavior and THP survey coverage would generally cause an annual fluctuation in occupied activity centers year over year. The Private land chart depicts such an annual fluctuation which is consistent with a dynamic yet stable number of occupied NSO activity centers from 1990 through 2014.

On the Federal lands the apparent decline of 262 occupied activity centers in 1992 to 1993 was clearly a result of a dramatic reduction in federal timber harvest and concomitant survey efforts. In fact, the variable number after 1993 reflects the work of adjoining private land owners who still needed surveys to provide required protection to owl activity centers on adjacent federal land and the ongoing surveys in the demographic study areas. The apparent decline in NSO on private land during 2007 through 2010 is reflective of the national economic recession which resulted in a steep reduction in the number of timber harvest projects on private lands that needed surveys during that period.

We conclude this analysis clearly indicates that timber harvest on private lands under the ESA and CFPR regulations is not a significant threat to the NSO. The number of occupied activity centers on private lands indicate a population that is dynamic but stable, and private lands have not experienced a 31 to 55% reduction in NSO as portrayed in the CDFW's NSO evaluation.


CDFW Spotted Owl Database 1990-2014
Total Occupied Activity Center Index
Combined Private and Federal
- 3.8% per annum
1400
1200
1000
800
600
400
200
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
959 1126 1219 854 991 1009 934 948 968 904 921 964 939 869 668 787 761 627 684 679 722 839 830 832 758
959 923 888 854 821 790 760 731 703 677 651 626 602 580 558 536 516 496 477 459 442 425 409 393 378
2002 was when Barred Owl presence began to be documented. Note the decline.
See notes from Federal and Private charts regarding the 1993 200 occupied AC drop as a result of the NWFP level of survey reduction and the 2007-2010 recession on private land owners activity levels.


CDFW Spotted Owl Database 1990-2014
Private Occupied Activity Center Index
Private
Private Average
2007 to 2010 reduced harvest and survey effort due to the US recession
471
643
735
612
754
768
668
734
764
729
782
804
754
724
561
670
650
512
550
537
560
624
676
672
646
900
800
700
600
500
400
300
200
100
0
1990
1991
1992
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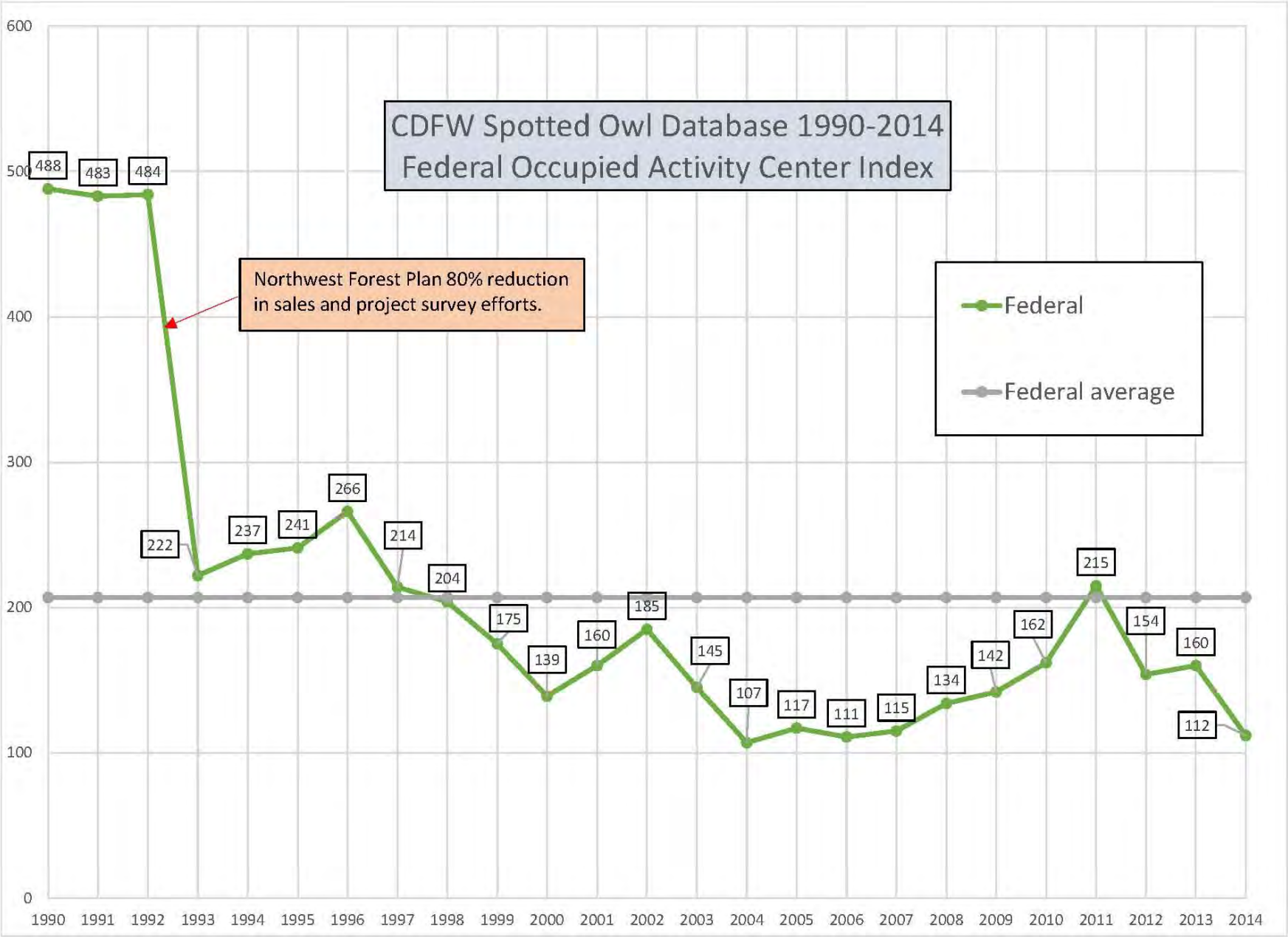
2009
2010
2011
2012
2013
2014


CDFW Spotted Owl Database 1990-2014
Federal Occupied Activity Center Index
Northwest Forest Plan 80% reduction in sales and project survey efforts.
Federal
Federal average
600
500
400
300
200
100
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
488
483
484
222
237
241
266
214
204
175
139
160
185
145
107
117
111
115
134
142
162
215
154
160
112

Timber Harvest Threat Analysis

In assessing threat from timber harvest, the Status review relies upon analysis of harvest activities around certain activity centers. The review states:

> *"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****….."(pg. 90)*

Also from the status review:

> *"…it is apparent that some activity centers have experienced extensive habitat removal or modification over time….. (pg. 92)*

The CDFW Northern Spotted Owl Status Review attempted to assess the cumulative impact of habitat *removal* at individual activity centers (AC) over time by evaluating THPs submitted between 1986 and 2013 to determine the total amount of habitat proposed for harvest around a sample of ACs at various radii typically used for habitat assessment(NSO Status Review p.90). The Status Review goes on to state that *"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."* (NSO Status Review p.92).

However, this analysis can miss important information, because the acreage of habitat proposed for harvest in a THP cannot be assumed to be *"habitat removal or modification"* that negatively impacts the NSO. In addition, the analysis is not evenly distributed across counties as claimed in the review. Nine activity centers in Tehama were chosen versus only three from Shasta and Siskiyou each.

By using simple query methods (phone and e-mail) information regarding these activity centers was readily obtained.

SIS319, 492, 554

These ACs were identified as having had timber operations that may have had impacts to the owl. Again, it is important to analyze the post-harvest habitat. 319 and 492 both exist on National Forest. They have the required 500 acre habitat in the core area, but the National Forest Land around the AC is of poor quality. Neither of these ACs has had a detection since 1993. 554, in contrast, is on private ground, with almost half the core area in higher quality habitat. It has not only had positive detections, it has produced young.

THE0037

As mentioned above, this particular AC is reported to have had 379 acres harvested in the core area (.5 miles and 500 acres) and 2.221 acres harvested between .7 and 1.3 miles (2,900 acres). What isn't

mentioned is that this AC has been in deficit habitat for a number of years prior to these harvests, and is located on poorer Site III which is slow growing. Because of this, the land owner may not reduce habitat within this area, they may only engage in harvest activities that maintain habitat. Habitat has not been reduced in this AC as a result. Owl status for THE0037 is that a nesting pair exists and fledged young in 2015. This refutes a supposition that there has been a negative impact on the owl.

HUM0622 – HRC AC 125 Habitat Review

One of the ACs sampled is HUM0622, or Humboldt Redwood Co. AC # 125. According to the Status Review, Table 15 (p.92), between 1993 and 2013 there has been a total of 798 acres of cumulative harvest within the 0.7 – mile radius of the AC.

HRC owns 363 acres of the 985 acres within the 0.7 – mile radius buffer of HUM0622. Our records of HRC THPs on the ownership from 1995 – 2013 indicate that there has been a total cumulative harvest of 465 acres. This means that there has been an overlap in THPs during that time period of 102 acres.

Prior to implementation of the HRC Habitat Conservation Plan (HCP) in 1999 all THPs were submitted with northern spotted owl 'take' avoidance measures pursuant to site-specific consultation with CDFW and/or USFWS through individual THP consultation, a Spotted Owl Management Plan, or a Spotted Owl Resource Plan. Beginning in 1999, HRC THPs implemented northern spotted owl conservation measures contained in the HRC HCP.

Regardless of the specific THP process used, AC HUM0622 was afforded a no harvest core of at least 18 acres, an additional 54 acres of roosting habitat or better surrounding the no harvest core, and retention of greater than 1,336 acres of NRF habitat within a 1.3 – mile radius of the AC. Because the balance of 622 acres of the 0.7 – mile radius buffer of HUM0622 is under other ownership, it is highly likely that the THPs or NTMPs of adjacent landowners were required to follow CDFW and/or USFWS 'take' avoidance guidelines for northern spotted owl ACs occurring within 1.3 miles of their THP or NTMP.

Table 1 illustrates the silvicultural prescriptions applied to the THPs on HRC lands in the 0.7 – mile radius buffer of HUM0622. "No harvest" comprised 100 acres or 21.5% of the area, partial harvest was 262 acres or 56.5%, and the clear cut prescription was applied to 103 acres, or 22% of the total. Thus, while the clear cut acres could be considered habitat *removal* (although the area will grow back and return to suitable habitat in ~ 30-40 years), and more than half of the acres were *modified* (although retaining roosting and foraging habitat), more than 20% of the acreage was in *no harvest buffers* in order to retain nesting/roosting habitat, and in riparian buffers.

For the entire 0.7 – mile radius buffer of HUM0622 our 2015 habitat assessment indicates that there were 96 acres of nesting, 360 acres of roosting, and 183 acres of foraging habitat, totaling 639 acres of habitat of the 985 total (Table 2).

Table 1. Harvest type by area for THPs on HRC property, 1995-2013.

Silviculture	Acres	Percent of Total
Clear Cut	103	22
Group Selection	7	1.5
No Harvest	100	21.5
Selection	53	11
Commercial Thin	199	43
WLPZ	3	1
Total	465	100

Table 2. Northern spotted owl habitat by area within the 0.7 – mile radius buffer of HUM0622 (HRC 125).

Habitat Type	Acres
Nesting	96
Roosting	360
Foraging	183
Non-habitat	346
Total	985

The HUM0622 is one example of the ACs sampled by CDFW, but it is not a good example of negative impacts. Over the 21 year period from 1996 – 2016 our monitoring efforts at this AC resulted in 100% pair occupancy: a pair of northern spotted owls occupied the site every year. There were 9 successful nesting attempts during that period, which fledged 16 juvenile northern spotted owls. The HUM0622 (HRC 125) northern spotted owl AC has been consistently occupied and reproductively successful over time.

TRI0316

Between 1997 and 2013 five THPs had operations within the home range of TRI0316. All five THPs (Granite, Stone Mule, Kay-5, Dyno and Kay-13) were conducted under a Spotted Owl Management Plan approved by the U.S. Fish and Wildlife Service (USFWS), under Technical Assistance provided by the USFWS, or under Technical Assistance from Cal Fire granted to the agency by the USFWS. The current status analysis completed by the DFW in its Status Review (Tables 13 and 14) for the operations conducted under these plans between 1997 and 2013 does not describe habitat conditions on the ground. It is important to note that an extensive analysis takes place to avoid take before operations commence.

The most recent habitat analysis for TRI0316 shows there are 2,653 acres of habitat within the 1.3-mile home range (Table 1) and 347 acres of habitat with 0.5-mile core area (Table 2). DFW states there have been 251 acres harvested within the 0.5-mile core area and 495 acres harvested within the 0.5-1.3-mile range. Further analysis of the acres harvested within these two areas showed there have actually only

been 196 acres of harvest within 0.5 miles and 555 acres harvested between 0.5 and 1.3 miles of the Activity Center (Table 3). Each THP was approved and found to avoid take prior to operations. Most importantly, the take avoidance measures outlined in the plans were successful as the TRI0316 owl site has been occupied consistently between 2004 and 2015 with a pair occupying the site in 2015.

Table 1 Pre- and Post-Harvest Habitat condition within 1.3-mile radius of TRI0316 excerpted from Kay-13 THP approved in 2013.

Habitat within 1.3 mile radius	Pre-harvest acres	Post-Harvest Acres	Net change	Compliance Requirement 1336 acres
Total Owl Habitat	2688	2653		2653
High Quality Nesting habitat[1]	0	0	0	
Nesting-roosting habitat	1098	1098	0	
Foraging habitat	352	352	0	
Low quality foraging habitat	1238	1203	-35	
Unsuitable	707	742	35	

[1] The absence of high quality nesting Roosting habitat is largely a result of the USFWS's robust definition of this habitat type that exceeds the habitat conditions of most stands, except those that would traditionally be called "old growth" or primary older forest where no management footprint exists. These stands are not common in areas where historic or past management has been engaged by either Government or private land managers.

Note: There was no harvest proposed inside the 0.5 mile radius in the Kay-13 THP, so Table 2 below is included to show the most recent typed habitat amounts as determined in this THP.

Table 2 Pre- and Post-Harvest Habitat condition within a 0.5-mile radius of TRI0316 excerpted from Kay-13 THP approved in 2013.

Are timber operation proposed in NSO habitat that meets the USFWS definition of habitat within 0.5 miles of the activity center?			If yes, provide the pre- and post-harvest habitat quantities and the net changes in habitat (acres)		
	NO	YES	Pre-harvest	Post-Harvest	Net change
High Quality Nesting habitat[1]	x		0	0	0
Nesting-roosting habitat	x		68	68	0
Foraging habitat	x		1	1	0
Low quality foraging habitat	x		278	278	0
Unsuitable	x		155	155	0
Total Owl habitat			347	347	

[1] The absence of high quality nesting Roosting habitat is largely a result of the USFWS's robust definition of this habitat type that exceeds the habitat conditions of most stands, except those that would traditionally be called "old growth" or primary older forest where no management footprint exists. These stands are not common in areas where historic or past management has been engaged by either Government or private land managers.

Table 3. Acres Harvested

Acres Harvested in TRI0316 1997-2013	
Total Acres Operated w/in 0.5 mile	Total Acres Operated between 0.5-1.3 miles
196	**555**
Acres Reported in Status Review	Acres Reported in Status Review
251	**495**

DFW's analysis does not reflect the on-the-ground conditions and only counts the proposed acres associated with the project footprint. These numbers do not take into account operating unsuitable habitat (habitat not considered to be utilized by NSO), having post operation conditions left as habitat (WLPZs), and double counting acres harvested in multiple entries.

In a hypothetical situation, say a private landowner owned 100% of the land associated with an NSO AC (3395 acres). If that land owner conducted three commercial thins on the entire home range between 1997 and 2013, essentially improving the habitat and driving the QMD towards a better nesting condition, the Department's analysis would have reported this hypothetical AC had experienced 10,185 acres of harvest within the home range, however no habitat was lost but rather improved. Simply adding total acres harvested for a given time period does not provide the basis that timber harvest is a potential threat to the species.

Unregulated Threats to NSO Populations in California

Three potential threats to NSO populations have been identified in California: Barred Owl encroachment, loss of habitat due to catastrophic wildfire, and pesticides associated with illegal marijuana plantations.

Barred Owls

In the most recent review of the condition of NSOs, the Revised Recovery Plan for the Northern Spotted Owl (Revised Recovery Plan, 2011) identified habitat loss and competition from the recently arrived barred owls as the most pressing threats to the NSO. The Recovery Plan states: "Based on the best available scientific information, competition from the barred owl (S. varia) poses a significant and complex threat to the spotted owl".

The Revised Recovery Plan continues: "Barred owls reportedly have reduced spotted owl site occupancy, reproduction, and survival. Limited experimental evidence, correlational studies, and copious anecdotal information all strongly suggest barred owls compete with spotted owls for nesting sites, roosting sites, and food, and possibly predate spotted owls. Because the abundance of barred owls continues to increase, the effectiveness in addressing this threat depends on action as soon as possible."

Barred owls are native to eastern North America, but only recently arrived in the West. They were first documented in the range of the NSO in Canada in 1959 and in western Washington in 1973. The range of the barred owl in the western United States now completely overlaps with the range of the NSO. Observations suggest that as the number of barred owls detected in historical spotted owl territories increase, the number of spotted owl responses have decreased. In the Pacific Northwest, barred owl populations developed first in Washington and spotted owl populations have declined at the greatest rate in these areas. Barred owl detections in the coastal NSO habitat of California are increasing.

Given the continuing range expansion and population growth of barred owl populations in the western United States and concurrent decline in NSO populations, the USFWS has proposed Recovery Action 29 in the Revised Recovery Plan, which involves experimental control of up to 3,600 barred owls in 11 study areas to determine if these efforts would increase spotted owl site occupancy and improve population trends. Some coastal forest owners have also initiated/proposed barred owl control research projects.

Demographic Response of Northern Spotted Owls to Barred Owl Control

Dugger, et al, 2016 states:

> *"Based on our study, the removal of Barred Owls from the Green Diamond Resources (GDR) study area had rapid, positive effects on Northern Spotted Owl survival and the rate of population change, supporting the hypothesis that, along with habitat conservation and management, Barred Owl removal may be able to slow or reverse Northern Spotted Owl population declines on at least a localized scale."*

Diller, et al, 2016 also says:

> *"Barred owl control decreased spotted owl territory extinction rates but did not affect territory colonization rates. As a result, spotted owl occupancy increased in the treated area and continued to decline in the untreated areas. Prior to and after barred owl*

control, there was no evidence that average fecundity differed on the 2 study areas. However, the greater number of occupied spotted owl sites on the treated areas resulted in greater productivity in the treated areas based on empirical counts of fledged young."

From Kroll, et al, 2016:

"Collectively, we conclude spotted owl pair populations on this landscape managed for commercial timber production appear to be more stable and do not show sharp year-over-year declines seen in both managed and unmanaged landscapes with substantial barred owl colonization and persistence."

It is abundantly clear from this recent research that habitat in coastal California is not the limiting factor. Barred owl colonization, on the other hand, is having a profound effect. Unless this issue is prioritized, habitat recruitment and maintenance will be pointless.

Loss of Habitat from Wildfire

California's forests are largely ecosystems that have adapted over time from natural fire regimes. Fire exclusion and management (or non-management) practices have resulted in significant overly-dense forest conditions ripe for unnaturally large fire events. The potential values at risk to catastrophic wildfire include the stability and viability of spotted owl habitat.

For the Northern Spotted Owl Recovery Plan, a team of experts was convened the most current threats facing the species. The range of threat scores made by the individual experts was narrowest for barred owl competition and slightly greater for habitat threats, indicating that there was more agreement about the threat from barred owls.

The experts also ranked the threats by importance in each province. Among the 12 physiographic provinces, the more fire-prone provinces (Eastern Washington Cascades and Eastern Oregon Cascades, California Cascades, Oregon and California Klamath) scored high on threats from ongoing habitat loss as a result of wildfire and the effects of fire exclusion on vegetation change. The Recovery Plan notes:

"while spotted owls can make use of some post-fire landscapes, fire also reduces the function of some habitat and likely removes some from immediate usability, particularly in areas of high-severity fire"

This is particularly important, given that fire severity and size have dramatically increased over the last decade, owing to drought, increased fuel load, and climate change. CARB projects an increase of up to 55% in wildfire acres by the end of this century due to Climate Change induced temperature and drought increases.

The Westside Fire Recovery Project, which consisted of the Happy Camp Complex, Beaver, and Whites fires destroyed or damaged large amounts of habitat. 183,000 acres burned, and of these, 81,000 acres were classified as late successional reserve, presumably all high quality NSO habitat. It is estimated that 85 ACs were involved in this incident (source: U.S. Fish and Wildlife Service (FWS) Biological Opinion (BO) Westside Fire Recovery Project).

Pesticide from illegal land-uses

There is growing recognition of the potential for a new threat resulting from possible exposure to anti-coagulant rodenticide poisoning. Both legal and illegal marijuana grows on public and private lands have been found to use often use copious amounts of rodenticide in an attempt to prevent crop damage. In turn, the rodenticides can have both primary and secondary impacts on predators such as spotted owls (Thompson, et al 2013, Douglas 2013). In the redwood region, primary prey species of NSO include the dusky-footed woodrat (*Neotoma fuscipes*) and deer mice (*Peromyscus* spp.), which are also prey species of Pacific fisher and may be responsible for exposure of fishers to rodenticides used at grow sites. Further research on this issue using the carcasses of barred owls should shed light on this potential threat in the near term.

For all three of these threats, adapting and enhancing pro-active forest management practices to address these risks is critical to stability and viability of many wildlife species.

From:	Matt Greene
To:	Wildlife Management
Subject:	Northern Spotted Owl Letter
Date:	Tuesday, May 03, 2016 12:48:34 PM
Attachments:	Fish & Game Commission NSO Listing.pdf

Dear Fish and Game Commission,

Attached is a letter about the need for some alterations to the staff report about Northern Spotted Owls on small non-industrial landowners forest lands. We were told in the commission meeting that people would be in touch with us about this issue. That has yet to occur.

Thank you for your time in this matter.

Matt Greene

--
Matt Greene Forestry & Biological Consulting
35640 Hauser Bridge Road
Cazadero CA 95421
Phone (707) 847-3761
Fax (707) 847-3905

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MATT GREENE
Forestry & Biological
CONSULTING

May 2, 2016

California Fish and Game Commission
Attn: President Sklar
P.O. Box 944209
Sacramento, CA 94244-2090

RE: The Listing of the Northern Spotted Owl

Dear President Sklar,

I would like to offer a few items for the Commission to consider ahead of the next scheduled hearing in June. As a forester, wildlife biologist, and as designated by Cal Fire and USFWS, a Spotted Owl Expert, I've spent 17 years dealing with the Northern Spotted Owl. With the development of the Status Review as put forth by the Department, I was surprised and frustrated to see that it appears only one staff member involved with the development of the Review also holds this last distinction. While others that reviewed the scientific merit of this document are SOE's, it is frustrating to see a lack of SOE's preparing this report. This designation was created for a reason and should hold some weight.

I feel a bit of history is necessary to understand why this subject may be a bit more contentious than usual. Also the Staff Status Review seemed to omit this part of history. CDFG was the Technical Service provider for this species in the 90's. Staff would issue TA's for projects (even though the species was only federally listed at the time). Following 1999 (the then) Department of Fish and CDFG abandoned the landowners of California and left them to fend for themselves in management of their lands and helping with getting technical assistance for the management of this species. Now that the Department feels that funding is available through AB1492 and other sources, they want to get back into the process. You may now understand why there were some very unhappy people that came to the last Commission Hearing. To let the Department back into this process reeks of excuses to build staffing.

The Director (roughly) stated when asked what Staff felt that listing of this species would accomplish "that the desired outcome of the listing would be increased agency interactions", not saving the species from extinction. We all know that habitat loss isn't the issue with this species, it is the barred owl. All of the scientific literature points to this issue after 25 years of managing for this species. If the Department wants to be involved in discussions on how this species should be managed, it doesn't need the species to be listed to be involved, it simply needs to show up at the meetings and participate.

<u>Small Landowner Issues</u>
The department's comments on the Staff Report that populations are declining has no scientific support across a large portion of the species range. At least 40% of the range on the Northern Spotted Owl lies on small nonindustrial landowner's forests in Northern California. Because of the current protocols (developed by the US Fish and Wildlife Service) trend analysis is not possible on these lands.

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The makeup of these lands is such that harvesting usually only occurs once every 10 to 20 years. Surveys are done one year ahead of the project and the year of the project. No post-harvest monitoring is conducted. As such, the information that is available is completely useless for looking in any scientific trend analysis. It is simply not possible to draw any conclusion from this data. This lack of trend data is significant as it represents 40% of the land base of this species. Without demographics of this critical data, there is no way that the Department can make any assertion that they know that populations are trending downward.

I would also like to draw your attention to a recently release study (Kroll, et al. 2016) which just found the following on a very large block of private lands in Mendocino County: In Summary, "We did not find evidence to indicate that territory occupancy by northern spotted owl pairs declined substantially over a 25-year period on the Mendocino County, CA, study area." [1]

The reliance of the Staff Report on just three demographic study areas is not representative of the greater range of this species. The three study sites focused on 1) an industrial landowner managing under an HCP which allows for take of NSOs, 2) a federal tribe, and 3) federal lands. None of these landowners manages their lands in the same manner as small landowners do. To lump them all together and only rely on these three studies is bad science and shows a clear misunderstanding or willful ignorance of the management that has occurred on private lands over the last 25 plus years to try and manage for this species.

Understand that there is no possible way for small landowners to be able to publish their information to meet the criteria necessary for their information to be considered by the Commission. These lofty standards may be suitable for listing other species, but in this particular case, you are unnecessarily throwing out over 25 years of data collected by forest landowners.

<u>Issues with The Staff Report</u>
There are several fundamental issues with the Staff Report that need to be pointed out and corrected.

1) Page 93 of the Staff Report states the following: *"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."*

   This is an inaccurate statement as an NTMP must address new species listings as an amendment to their plan. A point left out for obvious reasons, so that is would appear that any listing would not economically affect a landowner (See the discussion of SB617 below). This statement must be changed. 14CCR 1090.7 and 1090.14 clearly state when a NTMP must be updated, modified, or amended.

2) On page 94 of the Staff Report, the following is stated: *"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".*

   All NTMP's back to 1991 in the coast region are posted online for anyone to see at this address: ftp://thp.fire.ca.gov/THPLibrary/North_Coast_Region/NTMPs/

   All NTMP's back to 1996 in the north region are posted online for anyone to see at this address: ftp://thp.fire.ca.gov/THPLibrary/Cascade_Region/NTMPs/

   All Notices of Operations are on file and available to any member of the review team in Cal Fire's Headquarters in Santa Rosa and Redding. The statement that access to these files has been variable is false and must be stricken from this report. Staff knows these records are available and are taking the easy way out here.

[1] Kroll AJ, Jones JE, Stringer AB, Meekins DJ (2016) Multistate Models Reveal Long-Term Trends of Northern Spotted Owls in the Absence of a Novel Competitor. PLoS ONE 11(4): e0152888. doi:10.1371/journal.pone.0152888

3) Again on page 95, Staff claims the following: *"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)."*

Staff has full access to all these files. See Item 2 above.

4) The following discussion is located on page 96: *"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 first part of this statement suggest that the habitat was completely destroyed or render unusable following harvest under NTMPs, when in fact most of the harvesting done under an NTMP retains the long term habitat for the species. This misunderstanding of the management under an NTMP (since only uneven aged management which must balance growth and yield is allowed to take place) is fundamental for this discussion and really needs to be correctly addressed. The Department has really misrepresented what occurs on these lands. In general management under NTMP enhances the long-term habitat for this species which is clearly missed in this report. The habitat under an NTMP remains intact or enhanced following operations.

The second part of this statement above again claims that there is limited availability of information which is false and must be addressed by the Dept. prior to accepting this report. This information is all available.

5) The following statement suggest that harvesting is occurring under NTMP within NSO Activity Centers: *"The variability in silvicultural methods used and the lack of a detailed analysis of <u>harvest at activity centers</u> makes it difficult to draw conclusions relating to Northern Spotted Owl habitat modification or retention within NTMPs."*

NTMPs operate under the same rules as THPs. We still have to comply with the Forest Practice Rules as well as all state and federal wildlife guidance procedures. As such, no NTMPs are allowed to operate <u>at activity centers</u> as the Department suggests. This section should be addressed as it seems to imply the NTMP holders get some kind of preferential treatment for the areas surrounding Activity Centers.

6) The following statement shows the lack of time that the Department spent on this report to understand the full issues with this species: *"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."*

This is a job that the Department should have hired a Registered Professional Forester whom is capable of understandable of the practice of forestry and silviculture to help with. By not fully understanding what each NTMP proposed and leaves post harvest, it is impossible to discuss what is retained post-harvest.

7) The Department Staff have the ability to go to the Regional Cal Fire office and obtain any information that is submitted to Cal Fire by NTMP holders. The following statement about NTMP

is completely inaccurate: "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.

The Department not only has access to all NTOs, but also receives copies of them from Cal Fire.

With these 7 issues, it is impossible for the Commission to understand what is actually occurring on small non-industrial lands when the Department has completely misrepresented the facts and also have such a huge gap in information about the populations. Maybe now, it is understandable why small landowners were so unhappy with this report and with Staff at the April meeting.

Economic Analysis

The Department states the following with regard to an economic analysis of their report: "*The Department is not required to prepare an analysis of economic impacts (Fish & G. Code, § 2074.6).*"

Fish and Game Code 2074.6 states the following:

> *2074.6. (a) The department shall promptly commence a review of the status of the species concerned in the petition. Within 12 months of the date of publication of a notice of acceptance of a petition for consideration pursuant to paragraph (2) of subdivision (e) of Section 2074.2, the department shall produce and make publicly available on the department's Internet Web site a final written peer reviewed report, based upon the best scientific information available to the department, which indicates whether the petitioned action is warranted, which includes a preliminary identification of the habitat that may be essential to the continued existence of the species, and which recommends management activities and other recommendations for recovery of the species. Prior to releasing the final written report, the department shall have a draft status review report prepared and independently peer reviewed, and upon receiving the peer reviewers' input, shall evaluate and respond in writing to the independent peer review and shall amend the draft status review report as appropriate. The revised report shall be posted on the department's Internet Web site for a minimum of 30 days for public review prior to the hearing scheduled pursuant to Section 2075. The commission may grant an extension of up to six months if the director determines an extension is necessary to complete independent peer review of the report, and to provide a minimum of 30 days for public review of the peer reviewed report prior to the public hearing specified in Section 2075.*

Nowhere in this section does it state that the department is not required to prepare an economic analysis of the impacts of a listing. Furthermore, I would suggest that the Commission realize that if changes are made to this species status, there will be a considerable economic cost to the landowners of the state. 14CCR (the California Forest Practice Rules) section 1090.7(h) requires NTMPs to be amended if a new species is listed. This would suggest that all NTMP would have to be amended if this species is listed.

Furthermore, I would suggest that the Commission look at SB617. This bill requires any agency approving regulations, proposed adoption, amendment, or repeal of a regulation subject to review by the Office of Administrative Law pursuant to Article 6 (commencing with Section 11349) that will have an economic impact on California business enterprises and individuals in an amount exceeding fifty million dollars ($50,000,000), as estimated by the agency. It is my understanding that the Commission must submit any new listing for review by OAL, therefore SB617 appears to apply to the Commission. This would be further assumed because in looking at other actions by the Commission, when there is an economic cost to individuals, the Commission does do an economic analysis (for example the lead ammunition ban).

The $50,000,000 threshold will be exceeded in lost revenue in the following ways:

1) DFW Staff have stated that if listed that staff will look to redo the protocols for surveying for NSOs. This would include changing the definitions of different habitat types. This change will almost certainly require all habitat to be reviewed and changes made to over 6 million acres of habitat typing that has already occurred.

This will almost certainly reduce the habitat that is available for harvest as a broader definition of what is habitat has been expressed by Staff to be in the future plans.

2) Additionally, if the Status Report is any indication, Staff intend to restrict the use of herbicides (even though this falls under the authority of another agency) to control tanoak. This cost alone will lower growth rates on timberlands significantly and cost forest landowners far more than the $50,000,000 threshold. Because tanoak can limit the growth rate of conifer trees, a change in the common practice of using hack-n-squirt will result in loss of growth even in 1 years' time which is substantial enough to trigger this threshold on its own.

3) There is no concession in the staff report to make the findings take place as a phased in approach. Any changes will take effect immediately upon being approved by OAL. This will essentially put the entire forest industry at a standstill until a new process is figured out. If other species are any indication of this process, it could take months for the necessary meetings and procedures to be developed. Any delay in getting plans approved, working on existing plans, amending existing plans, and other possible additional actions will result in delays and losses to forest landowners economically.

I would respectfully request that before the Commission hears additional information that it makes the Department review Items 1-7 above and correct these egregious errors. This is critical for the proper information to be presented to the Commission so that you can understand what is occurring across a broad portion of the range of the Northern Spotted Owl.

Also, while I understand the need for scientifically peer reviewed information to help in decisions the Commission must make, it must be pointed out that this species is different than every other species which the Commission has reviewed or ever will. The information that has been collected on this species by landowners over the 20 plus years of management for the benefit of this species should be allowed to be considered. While it isn't demographic information in the traditional sense, it is real data that has been created to monitor this species. To not even consider this data is a slap in the face of landowners who has spent so much to protect this species over the years.

I would like to invite you out to come and take a look at our well managed forests and talk about spotted owl and other forest related wildlife species at any time. I am located in Sonoma County and happy to show you around.

Thank you for your time and consideration on this subject.

Sincerely,

Matt Greene, RPF #2747

REGISTERED PROFESSIONAL FORESTER
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29 April 2016
Mr. Eric Skylar, President
Califronia Fish and Game Commission
1416 9th St., Room 1320
Sacramento, CA 95814
fgc@fgc.ca.gov

Re: Potential State Listing of Northern Spotted Owl (NSO)

Dear Mr. Sklar:

I am a private consulting forester who has selectively harvested and sustainably managed over 25,000 acres of non-industrial forestlands. My clients are exclusively family-owned ranches and timberlands. The DFW Status Report notes these small non-industrials own 38% of the acreage in the range of the NSO. However, it is important to note that these ownerships comprise over 50% of the acreage and timber volume in the redwood region. Simply put, they own more acres and more trees in the redwood region than both the industry and government put together.

Relative to these ownerships, I would like to make three comments:

1. **High-quality NSO Habitat and Barred Owls**

My management philosophy is to both grow larger trees and increase total volume per acre. As a natural by-product of this strategy, my clients have been creating high-quality NSO habitat long before the NSO was even on people's radar. We are entering some of our stands for the 4th time; there are larger average tree diameters and more volume per acre than when we began our selective harvest programs over 40 years ago. As such, we have a number of NSO sites in our forests.

In the last 8 years, virtually every one of these NSO sites is now occupied by barred owls. Unlike the old-growth state parks, which have passively attracted barred owls, our active management goal of growing larger trees has actually done the same.

NSOs that used to answer our calls like clockwork are now rarely heard. But nonetheless, the NSOs still respond—albeit infrequently and weakly, sometimes only once every other year. Though obviously dominated by barred owls, the NSOs are still present. Since it takes time and patience to get the NSO response, it is easy to produce a "false negative" (to which the Status report references). Bottom line: my experience indicates that there are likely more NSOs present throughout the range than casual calling data alone would suggest.

2. Economic Impact of NSO Rules on Non-industrial Ownerships

The final sentence of the Status Report (page 200) notes that it was not necessary to consider economic impacts. While this may legally dismay be the case, I believe that it is neither fair nor ethical to omit these concerns.

Under current NSO Rules, a minimum of 1000' radius must be retained around an NSO site. This equals 72 acres. For a prudent landowner who has managed their timber for 10-20 years, a conservative harvest of 25% of standing inventory would easily yield around 7 mbf per acre. At today's redwood prices, this would produce around $250,000 in income (1000' radius =72 acres x 7mbf/ac x $500/mbf = $252,000).

How fair is this to the landowner who was counting on his timber investment to send a child to college, help with medical expenses, or use as retirement income? The ultimate irony is that this landowner has been managing the forest in a way which produces high-quality NSO habitat. Many non-industrial landowners are currently being punished for having done the "right thing" for NSOs.

The regulatory burden on non-industrial owners is very disproportionate. A large industrial landowner who owns 200,000 acres can easily afford to "give up" the 72 acres. But for a landowner who owns 200 acres, losing 72 acres (often, of the best timber) is devastating.

3. Comments on Status Report Recommendations

No. 30—No question, the barred owls must be reduced if NSOs are to have any chance of long-term survival.

No. 5---If any new Rules are created, they absolutely have to differentiate between industrial and non-industrial ownerships.

No. 14---Creation of NSO Habitat---Many non-industrial forests provide NSO refugia while we buy time to solve the NSO issue. Since it is obvious that more rules do not mean more NSOs, DFW needs to provide incentives to create more NSO habitat. Simple straight-forward Safe Harbor-type Agreements can provide regulatory relief while encouraging landowners to grow NSO habitat. I encourage the Commision to seek incentives "outside the box". Instead of punighing landowners, we need to start rewarding and encouraging them to grow NSO habitat.

Regards,

Craig Blencowe
Registered Professional Forester
License No. 2003

Weger Interests, Ltd
2339 Mill Creek Lane
Healdsburg, Ca 95448

RECEIVED
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April 29, 2116

Mr. Eric Sklar, President
California Fish and Game Commission
1416 9th Street, Room 1320
Sacramento, CA 95814
fgc@fgc.ca.gov

RE: Determination of whether the listing of the Northern Spotted Owl is warranted under the California Endangered Species Act, and if so, how that determination will impact Small Non-Industrial Landowners.

Dear Mr. Sklar:

I am writing to you and the other members of the Fish and Game Commission urging you to consider the impacts on small landowners before making a final decision regarding the listing of the Northern Spotted Owl (NSO) as a Threatened or Endangered Species .

Before beginning the discussion of the issue at hand, let me introduce myself. For over 130 years my family has been ranching on Orr Springs Road, fifteen miles west of Ukiah. For almost 60 years, we have owned the Ranch that is still in my family today. This property was logged at the turn of the last century and again in 1960. In 2001 we decided, after much consideration, to apply for a Non-Industrial Timber Management Plan (NTMP) to govern our timber harvesting. It took nearly a year for approval of our plan which was extensively reviewed by CALFIRE, North Coast Regional Water Quality Control Board, Department of Fish and Game, and Department of Parks & Recreation.

As I am sure you are aware, an NTMP is a framework for an extraordinarily high standard of land stewardship. Most landowners who choose to live within the confines of an NTMP are Environmentalists. I am one. We have voluntarily chosen to selectively harvest our forests on a long-term sustained-yield basis. The NTMP mandates that we grow more timber than we harvest during each ten-year cycle. This means that we cut less than 30% of the volume every ten years. At the end of each ten-year harvest cycle, our forest has more volume than it did at the beginning.

As part of the NTMP, we agree to retain and grow all-age classes of timber—this means that we have giant trees and smaller trees. If you hike through our forest it looks more like a park than

an industrial forest because harvesting is done on a selective basis. This is in contrast to most harvesting done under a typical Timber Harvest Plan (THP), which mandates neither increasing volumes through time nor retaining all-age classes of timber.

Naturally this sort of forest management is expensive. The logging costs are much higher. The current yield is much less, and the present-day profits are much lower. However, most of us who have chosen this framework have done so because we want our forests to look like forests. We protect our streams, we create a diverse habitat that benefits wildlife (including the spotted owl), and of course we positively contribute to carbon sequestration. We put those values ahead of profits.

There are several reasons that additional consideration should be given to the small landowner.

1. SMALL LANDOWNERS ROLE AS FOREST LANDOWNERS AND PROVIDERS OF OWL HABITAT WERE INADEQUATELY ADDRESSED BY THE STATUS REVIEW OF THE NORTHERN SPOTTED OWL DATED FEBRUARY 10, 2016.

Although our voices are often overshadowed by our more well funded friends in both the industrial timber industry and the paid environmental industry, as well as the well funded bureaucracy that tends to these issues, our numbers and quiet commitment to the forest are not small. Collectively we own roughly 7.9 million acres of forestland in California. We own over half of the private timberland in the north coast. There are almost 600 NTMPs which govern the management of 315,000 acres of timberland in California.

Despite our substantial ownership percentage, our contribution was summarily dismissed in the Status Report. Let me quote the summation of the contribution by small landowner: "It is likely that **some** type of habitat is retained to **some** extent through these types of silvicultural methods;, however the Department has not been able to determine the type of quality of habitat retained." Emphasis added. Page 96 NSO Status Report February 10, 2016.

Under the discussion of "Timber Harvest-Regulatory Mechanisms on Private Land" and on page 131 of the Status Report (Please note I mistakenly pointed to page 136 of the Status Report during my testimony before the Commission on April 14, 2016--my sincere apologies.) the author stated: "A similar activity center analysis was not possible for NTMPs due to lack of access to timber harvest documents, particularly older plans and with limited staff time. Considering the types of silviculture practiced in NTMPs... 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" Emphasis added.

This Status Report has been several years in the preparation and at no time did the staff take the time to meet small landowners, to conduct a field trips or to pick up the telephone and call the Registered Professional Foresters who manage the "older NTMPs" which is a matter of record and a simple phone call . I suggest that a few days of investigation would have been extremely

informative to staff. They would have discovered the sorts of forests that I have already described to you. They would have discovered this type uneven age light touch management time and time again. Frankly they would have discovered that small landowners provide large tracts of what was once considered prime NSO habitat.

2. FACTORS OTHER THAN HABITAT ARE IMPACTING THE NSO

a. We are all fully aware that the migration of the Barred owl into NSO habitat has impacted the Spotted Owl. But what the Status Report made clear is that lands that would be thought of as prime NSO habitat, for example, Redwood National Park or Montgomery Grove State Park currently do not have documented NSOs. Why?? Because what was once prime NSO habitat is currently prime Barred owl habitat.

b. The use of rodenticides in illegal marijuana grows, a rampant and deadly practice, has been devastating to many raptors and owls.

c. More compelling is the reality that no matter what a particular government agency seems to do in protecting the Spotted Owl there is no conclusive evidence that such actions have made a positive difference. The only proven means to improve NSO recovery is to eliminate Barred owls.

3 DIRECT STAFF TO PROCEED IN SUCH A MANNER AS TO INCLUDE THE VOICE AND CONCERNS OF SMALL LANDOWNERS AND EXEMPT SMALL LANDOWERS FROM OVERBURDENSOME REGULATIONS.

If the Commission decides to list the NSO as either Threatened or Endangered, I request that the Commission, in consideration of all the many factors impacting small landowners previously addressed, specifically direct Fish and Wildlife Staff to include the voice and concerns of small landowners as follows:

a. Direct staff to conduct an informal field trip to understand what is happening on lands managed with an NTMP. Further direct staff to converse with RPF's who manage lands for non industrial owners to understand what sort of management is being undertaken.

b. Recognize that a high percentage of small landowners own less than 40 acres of land so any increase of habitat setbacks only punishes those landowners both disproportionately and needlessly. This is particularly true since improved habitat only seems to help the Barred owl , as supported by the evidence in the Status Report.

c. Exempt small landowners, who can show increasing NSO habitat (as opposed to actual owl numbers) from onerous regulations imposed upon such landowners today.

d. Exempt small landowners and or NTMP holders, from the any additional burden of a California listing so long as they comply with the requirements of the US Fish and

Wildlife Service and CALFIRE. Alternatively , or perhaps additionally, create some sort of **VERY SIMPLE** means for small landowners to enter into a safe harbor agreement with CFWS which promotes habitat without burdensome habitat setbacks.

Unless the Commission specifically directs staff to the contrary, the one thing that will come from the listing of the NSO, is that small landowners will be disproportionately and unfairly burdened. To prevent this end, I urge the Commission to exempt all small landowners from any burdens of a listing. The terms of such an exemption can be negotiated between representatives of the small landowners and the Commission.

Sincerely,

Lisa Weger
Weger Ranch