From:	Stu Farber
To:	Wildlife Management
Subject:	Northern spotted owl 12-month review comments
Date:	Tuesday, March 11, 2014 12:31:23 PM
Attachments:	WBA Comments on NSO petition 3414.docx Farber and Kroll 2012.pdf Farber and Whitaker 2005.pdf Irwin et al 2012.pdf NSORP Updated 31114.pdf

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Neil,

Attached are comments and information regarding the 12-month review of the Northern spotted owl. If you have any questions or need additional information, please feel free to contact me.

Stu

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FORESTLAND
MANAGEMENT

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March 11, 2014

VIA E-MAIL

CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
Nongame Wildlife Program
Attn: Neil Clipperton
1812 9th Street
Sacramento CA 95811

Dear Mr. Clipperton;

Attached are several studies of Northern spotted owl (*Strix occidentalis caurina*) conducted on private forestlands in Siskiyou and Shasta County, California. Also attached is our Northern Spotted Owl Resource Plans (NSORP) that currently directs forest management activities on W.M. Beaty and Associates managed lands. We are providing these studies and management plans to you during your evaluation of a petition to list Northern spotted owl as a threatened or endangered species under the California Endangered Species Act.

Farber, S.L. and A.J. Kroll 2012 Site occupancy dynamics of Northern spotted owls in managed interior Douglas-fir forests, California, USA, 1995-2009. This published manuscript was based on 1,282 individual surveys and 480 spotted owl detections and 13 barred owl detections over 15 years. Average per visit detection probability (95% CL) for single and pair spotted owls was 0.93 (0.90−0.96) for informed daytime, stand-based searches and 0.47 (0.43−0.53) for nighttime, station-based surveys (estimated from the best model); the average per visit detection probability from the null model was 0.67 (0.63−0.70). Results suggest that a combination of 1 informed stand and 2 station-based operational surveys can support determinations of spotted owl site status (either a single or a pair) at desired levels of confidence. However, our information was collected in an area where barred owls were rarely detected. Surveys conducted in areas that support well-established barred owl populations are likely to be less effective for determining presence/absence of spotted owls and may require more surveys and/or different survey methods to determine site status with confidence.

Spotted owl site occupancy probability declined from 0.81 (0.59−0.93) in 1995 to 0.50 (0.36−0.63) in 2009; pair occupancy declined from 0.75 (0.49−0.91) to 0.46 (0.31−0.61). The resulting 39% decline across the 15 years of the study or approximately 2.6% annually slowed in the final 5 years of the study. However, while modeled probabilities declined 2.6% annually, the number of sites declared unoccupied or abandoned during the study period resulted in only a 9% decline across 15 years or approximately 0.6% annually. These actual site occupancy results are consistent with the reported small local-extinction and colonization probabilities which suggest relatively low turn-over at individual owl sites over 15 years.

Irwin, L.L. and D.F. Rock, S.C. Rock 2012 Habitat selection by Northern spotted owls in mixed-conifer forests. This published manuscript was based on radio-telemetry of 71 spotted owls over 5 years in 3 study areas, one in the Southern Cascades of California. Spotted owl habitat selection models were most strongly influenced by abiotic factors with negative relationships with increased distance to nest, distance to stream and positive relationship to slope. In other words, owls disproportionately used habitats within 200-300m of nest sites, closer to streams and on steeper slopes. Also, higher basal area of conifer trees with 400m of nest sites were used disproportionately. Most importantly these abiotic factors were more predictive than variables traditionally use to describe suitable owl habitat like habitat type, size or seral stage. Through adaptive management these understandings are being inserted into Spotted Owl Management Plans (SOMP), Northern Spotted Owl Resource Plans (WBA NSORP 2011), habitat conservation measures and stand-search survey strategies.

Farber, S.L. and J. Whitaker 2005 Diets of Northern spotted owls in the Southern Cascades and Klamath Provinces of interior Northern California. This unpublished study found that in both the eastern Klamath and Southern Cascades provinces Northern spotted owls consume a wide variety of prey including 16 individual species of mammals, 5 species of birds, and 1 species of insect. Based on 339 individual prey items, woodrat sp.(60.6%) followed by Northern flying squirrel (28.2%) biomass were the primary prey species for Northern spotted owls in the eastern Klamath mountains. Woodrat sp. (46.6%) followed by Northern flying squirrel (34.1%) biomass were the primary prey species in the Southern Cascades. No independent variables including tree species, size or density were significant at predicting the percent of flying squirrel biomass for an owl site. Prey species habitat associations indicate that maintaining a variety of habitats within owl sites maybe be beneficial for foraging Northern spotted owls.

W.M. Beaty and Associates, Northern Spotted Owl Resource Plan (NSORP)
This NSORP was originally approved by Cal Fire in 2011 and has subsequently been amended to update the NSORP with the current USFWS protocol, USFWS technical assistance and current scientific findings.

We hope you find the information contained in these studies and management plans interesting and informative. If you have any questions or need any additional information, please contact me at stuf@wmbeaty.com or at (530)243-2783.

Sincerely,

W. M. BEATY & ASSOCIATES, INC.

Stuart Farber
Wildlife Biologist

cc. P. Battaglia

Electronic Attachments: Farber, S.L. and A.J. Kroll, 2012.
Irwin, L.L. and D.F. Rock and S.C. Rock, 2012.
Farber, S.L. and J. Whitaker, 2005.
W.M. Beaty & Associates, NSORP 2011

The Journal of Wildlife Management 76(6):1145–1152; 2012; DOI: 10.1002/jwmg.368

Population Ecology

Site Occupancy Dynamics of Northern Spotted Owls in Managed Interior Douglas Fir Forests, California, USA, 1995–2009

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ABSTRACT Northern spotted owls (*Strix occidentalis caurina*) have received intense research and management interest since their listing as a threatened species by the United States Fish and Wildlife Service in 1990. For example, public and private forest managers in the Pacific Northwest, USA, conduct surveys to determine presence or absence of spotted owls prior to timber harvest operations. However, although recently developed statistical methods have been applied to presence–absence data collected during research surveys, the effectiveness of operational surveys for detecting spotted owls and evaluating site occupancy dynamics is not known. We used spotted owl survey data collected from 1995 to 2009 on a study area in interior northern California, USA, to evaluate competing occupancy models from Program PRESENCE using Akaike's Information Criterion (AIC). During 1,282 individual surveys, we recorded 480 spotted owl detections (37.4%) and 13 barred owl (1.0%) detections. Average per visit detection probability (85% CL) for single and paired spotted owls was 0.93 (0.90–0.96) for informed daytime, stand-based searches and 0.47 (0.43–0.51) for nighttime, station-based surveys (estimated from the best model); the average per visit detection probability from the null model was 0.67 (0.64–0.70). Average pair-only detection probabilities were 0.86 (0.81–0.90) for informed daytime, stand-based searches and 0.23 (0.18–0.29) for nighttime, station-based surveys; the average per visit detection probability from the null model was 0.63 (0.58–0.68). Site occupancy for any owl declined from 0.81 (0.59–0.93) in 1995 to 0.50 (0.39–0.60) in 2009; pair occupancy declined from 0.75 (0.56–0.87) to 0.46 (0.31–0.61). Our results suggest that a combination of 1 informed stand and 2 station-based operational surveys can support determinations of spotted owl site status (either a single or a pair) at desired levels of confidence. However, our information was collected in an area where barred owls were rarely detected. Surveys conducted in areas that support well-established barred owl populations are likely to be less effective for determining presence or absence of spotted owls and may require more surveys and/or different survey methods to determine site status with confidence.

KEY WORDS California, colonization, detection probability, local-extinction, managed forests, northern spotted owls, occupancy, operational surveys, *Strix occidentalis caurina*.

The northern spotted owl (*Strix occidentalis caurina*) has been a federally listed threatened species since 1990 and remains the focus of numerous conservation, management, and research programs in the Pacific Northwest, USA. The primary focus of research efforts for spotted owls has been demographic studies that estimate survival, productivity, and changes in population growth rate (Franklin et al. 2000, Anthony et al. 2006), although several efforts have examined site occupancy probabilities and potential sources of variation in these probabilities (Meyer et al. 1998, Swindle et al. 1999). Recent analyses used data collected on demographic monitoring areas, where the main objectives were to monitor adult survival and fecundity (Anthony et al. 2006), to examine northern spotted owl occupancy dynamics (Olson et al. 2005, Kroll et al. 2010, Dugger et al. 2011). Site occupancy probabilities can be useful metrics for monitoring how long-lived, territorial species such as the spotted owl respond to changes in environmental conditions, anthropogenic impacts, and co-occurring species.

Public and private forestland owners in California, Oregon, and Washington conduct presence–absence surveys for spotted owls prior to timber harvest operations to avoid indirect or direct impacts to spotted owls that occur within project areas. These operational surveys are planned and conducted based on widely accepted field methods and recommended United States Fish and Wildlife Service (USFWS) protocol (Forsman 1983, USFWS 1992). However, little information about the effectiveness of these operational surveys is available. For example, available spotted owl detection probabilities have been estimated from information collected in

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long-term research studies that use different methods than operational surveys (Olson et al. 2005, Anthony et al. 2006, Kroll et al. 2010).

In addition, the effectiveness of research surveys has been reduced across a wide portion of the northern spotted owl's distribution by the occurrence of barred owls (*Strix varia*), which have a negative association with spotted owl detection probabilities and may lead to misclassification of site occupancy status (Olson et al. 2005, Kroll et al. 2010). The barred owl has rapidly expanded its range in the Pacific Northwest since 1990 (Taylor and Forsman 1976, Herter and Hicks 2000, Kelly et al. 2003), and the consequences for spotted owl populations have been mostly negative (Kelly et al. 2003, Haig et al. 2004). For example, studies have found that barred owls were negatively associated with spotted owl productivity, adult survival, and occupancy (Olson et al. 2004, 2005; Anthony et al. 2006). However, the density of barred owls varies widely across the range of the northern spotted owl, and barred owls appear to be more numerous in Oregon and Washington than in California (Courtney et al. 2008). Information collected in areas where barred owls occur only infrequently would presumably provide a more accurate understanding of typical variation in detection probabilities and spotted owl population trends, and preclude the need to adjust statistical analyses to account for the influence of barred owls.

Our objectives were to evaluate annual variation and potential temporal trends in detection, local-extinction, colonization, and occupancy probabilities of northern spotted owls on a study area in interior northern California that lacks a well-established population of barred owls. In addition, we evaluated the association of pair nesting status and biological province (Klamath and Cascades) with spotted owl detection and occupancy probabilities.

STUDY AREA

The study area covered approximately 5,850 km^2 of the eastern Klamath and southern Cascade Mountains in Trinity and Siskiyou Counties, California, USA (Fig. 1). The spotted owl territories were located at elevations ranging from 1,000 m to 1,500 m. The study area was characterized by relatively steep mountainous terrain with a Mediterranean climate of warm, dry summers and cool, moist winters, with approximately 80% of the precipitation occurring from November to March. The dominant forest vegetation types in the Klamath Mountains included Klamath mixed conifer, Douglas-fir, and montane hardwood-conifer, whereas the Southern Cascades were dominated by Klamath mixed conifer, white fir, and red fir types (Mayer and Laudenslayer 1988). Coniferous forest stands were composed of Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), and white fir (*Abies concolor*), with an understory composed of Oregon white oak (*Quercus garryana*), incense cedar (*Calocedrus decurrens*), snowbrush (*Ceanothus cordulatus*), and dwarf Oregon grape (*Berberis nervosa*; Mayer and Laudenslayer 1988).

We collected data from spotted owl sites located on both private forestland and portions of the Klamath and Shasta-

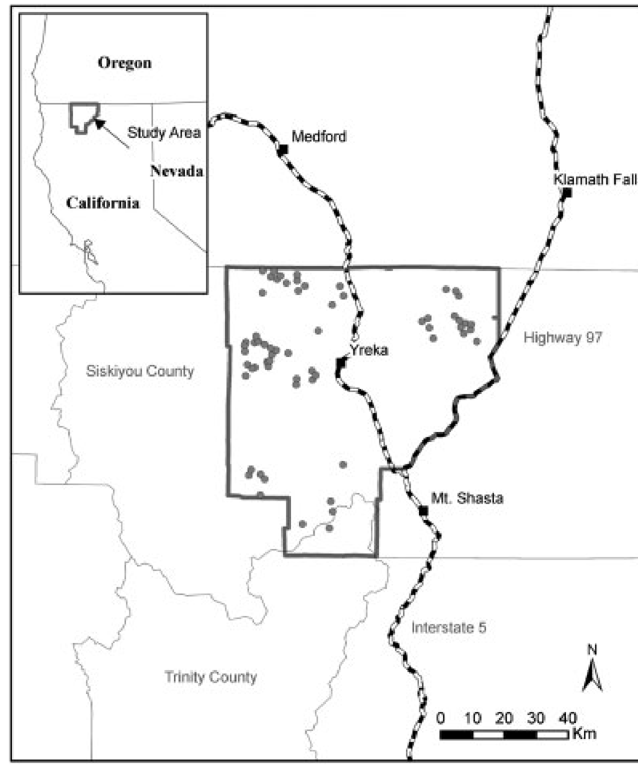

Figure 1. General outline of the northern spotted owl study area, Siskiyou and Trinity Counties, northern California, USA, 1995–2009. Gray dots reference individual northern spotted owl sites.

Trinity National Forests. Private forestland, originated from land grant railway ownership, was typically intermingled with United States Forest Service ownership in a checkerboard pattern. Forest management had occurred on the private forests for over 80 years, resulting in a forest landscape mosaic of young, intermediate, and mature forests (ranging from 80 to 120 years old). During our study period, silvicultural prescriptions on private forests included clearcut-variable retention, shelterwood removal, and commercial thinning. The clearcut-variable retention prescription retained a variety of green tree species, snags, wildlife trees, and large downed woody debris (Hansen et al. 1991, Swanson and Franklin 1992) to increase future stand complexity for species such as northern spotted owls and their prey (Thome et al. 1999, Irwin et al. 2000, Sullivan and Sullivan 2001). Prescriptions on United States Forest Service ownership were implemented to support the Northwest Forest Plan (United States Department of Agriculture 1993) and included stands that were thinned or selectively managed to reduce risk of catastrophic fire as well as late-successional reserves.

METHODS

Field Surveys and Data Preparation

Various public and private monitoring programs have surveyed northern spotted owl sites in the Klamath and Southern Cascades provinces since the late 1980s. The territorial nature of spotted owls allowed for the development of a public database of known owl sites. Our study included data from a portion of the spotted owl sites contained in the public database and we only included data from surveys that were conducted from 1995 to 2009. We did not include data for years prior to 1995 because of an unbalanced and inconsistent survey effort which could have biased our results. Although we did not include pre-1995 data in our analyses, our dataset included spotted owl sites where at least 1 owl had been detected during the March–August breeding season prior to 1995 as well as spotted owl sites where owls were first detected after 1995. We added these new sites if they were within our study area boundaries and if subsequent surveys were consistent and met our criteria described below. We conducted surveys to monitor selected known sites and to evaluate occupancy of sites prior to, and following, timber management activities. We included 63 spotted owl sites that met our criteria in our occupancy analyses. Sixteen of these sites occurred in the Southern Cascades and 47 occurred in the Klamath Mountains province.

We conducted surveys following recommended field methods (Forsman 1983, USFWS 1992). Typically, we conducted surveys (consisting of 3 visits per year) were conducted over 2 years, resulting in a minimum of 6 visits to a survey area to meet the protocol standard. One complete survey visit included a nighttime station survey (hereafter, night survey) and, if necessary, a subsequent stand search during the day to find spotted owls detected the previous night. A night survey consisted of imitating spotted owl vocalizations, by either voice or digital recording, for 10 min at each survey station located within a specific owl site. The spotted owl territory provincial radius, a circle that approximates the annual home range for spotted owls, for the Southern Cascades and Klamath Mountains is 2.1 km (USFWS 1992). For this study, we only included surveys that completely covered, at a minimum, a 1.1-km radius from the defined site center.

In addition, we often conducted an informed daytime stand search (hereafter, informed day search) prior to beginning night surveys. We conducted informed day searches, primarily within spotted owl core use areas (Blakesley et al. 1992, Bingham and Noon 1998, Zabel et al. 2003), by following routes developed by biologists using historical and current biological information gathered at the sites. Historical and current biological knowledge included 1) historic or current location of spotted owl sites; 2) suitable habitat within sites; 3) previous spotted owl detection locations; 4) previous nest and roost locations; and 5) location of abiotically favored suitable habitat (Clark 2002, Underwood et al. 2010). This information was readily available in a spatial database to biologists, survey personnel, and forest managers when planning and conducting surveys. Although we had limited information for some spotted owl sites, we had territory location and suitable habitat maps for all sites. Accordingly, we considered all of our day searches informed relative to naïve surveys (Riddle et al. 2010). In our analysis, we did not consider follow-up stand searches (e.g., conducted after a detection on the previous night) as informed day searches, as this decision would have added a positive bias to our results.

If spotted owls were detected during either the night surveys or informed day searches, we summarized the results into 1 of 4 status categories: single, pair, nesting pair, or reproductive pair (following recommendations in Forsman 1983 and USFWS 1992). We designated detections as single when only an individual spotted owl was detected and made a pair designation when both a male and female were detected within the site. We made a nesting pair designation when, after 15 April, a female spotted owl was observed on a nest or a male owl was observed taking a prey item to a female on a nest. We made a reproductive pair designation when a nesting pair had confirmed fledglings outside the nest structure. We typically conducted surveys prior to forest management operations to determine the occupancy and reproductive status of spotted owls; consequently, surveys did not always determine final nest fate or total number of young fledged. Finally, we did not attempt to detect barred owls using barred owl vocalizations. As a result, we detected barred owls opportunistically during spotted owl surveys.

Spotted owl sites are maintained by either a mated pair or a resident single bird (often a male). To reflect this distinction, we created 2 data sets: 1 data set contained detections of single birds (either M or F) and pairs (simple detections) and the second data set contained detections of pairs only (Olson et al. 2005, Kroll et al. 2010). Occupancy probabilities that we estimated from the former data set are likely to be greater and represent an upper bound of site occupancy. We refer to the analyses based on these 2 data sets as simple and pair, respectively.

Detection and Site Occupancy Modeling and Parameter Estimation

We based our analysis of site occupancy models on methods designed for open populations and described by MacKenzie et al. (2003, 2006) and employed specifically to analyze spotted owl data by Olson et al. (2005), Kroll et al. (2010), and Dugger et al. (2011). The primary sampling occasions were years and the secondary sampling occasions were the 3 individual visits that occurred during the spotted owl nesting season (Mar–Aug) to site-centers (i.e., known nest-sites or areas of concentrated use) or call stations distributed throughout owl territories.

We employed a 2-step process to estimate occupancy parameters. First, we modeled those covariates that we thought would influence detection probabilities. In the second step, we used the best detection model and evaluated combinations of time effects (., T, and TT). We then added a province (either the Klamath or Cascades) or a nesting status covariate (for pairs only) as an additive effect on local-extinction (probability that an occupied site became unoccupied in the following year) and colonization (probability that an unoccupied site became occupied in the following year) to time trend models with the lowest Akaike's Information Criterion with small sample correction (AIC_c) and models with $\Delta AIC_c < 2.0$ (Burnham and Anderson 2002). We calculated year-specific (denoted as t) site occupancy probabilities based on estimated local-extinction and colonization probabilities (following MacKenzie et al. 2003). We conducted analyses with Program PRESENCE (PRESENCE Version 3.0 beta, www.mbr-pwrc.usgs.gov/software/doc/presence/presence.html, accessed 1 Apr 2010). We used AIC_c for model selection and considered models with $\Delta AIC_c < 2.0$ as being substantially supported (Burnham and Anderson 2002). We used the logit link function for all models so that parameter estimates and 85% confidence intervals would be constrained to the interval 0–1.

We modeled several temporal structures for within-season detection probabilities, including constant (denoted as [.]), a linear trend (T), a quadratic trend (TT), and an unconstrained model (t). Within-season linear and quadratic time trends are equivalent to evaluating an effect of Julian date. Also, we evaluated year-specific, linear, and quadratic temporal trends across years. We did not consider unspecified within season and annual temporal models simultaneously, as they would have required too many parameters (i.e., a different parameter for each of the 45 visits across the study period).

We did not monitor all spotted owl site centers each year, resulting in different sample sizes in each year. As a result, we used only 3 temporal covariates (., T, and TT) to evaluate models of local-extinction and colonization (i.e., we did not model unspecified annual variation, t). We used the initial occupancy (probability that a site was occupied in 1995) parameterization in PRESENCE but we did not consider any spatial variation in initial occupancy. We added the province and nesting status covariates to the models with the most support (smallest AIC_c and $\Delta AIC_c \leq 2$). We evaluated the nesting status covariate in local-extinction models only. We evaluated whether nesting status in year i might be associated with spotted owl local-extinction in the interval between year i and year $i + 1$. Unlike other studies that investigated occupancy dynamics of spotted owls (Kroll et al. 2010, Dugger et al. 2011), we did not evaluate a barred owl covariate because barred owls were transient and rarely detected during our study. We evaluated effect sizes for covariates by examining parameter estimates and associated 85% confidence intervals; if effect sizes were large and 85% confidence intervals did not include zero, we considered the association to have support from the analysis (Arnold 2010). Finally, we note that spotted owl territories chosen for monitoring were located opportunistically over time, similar to other studies (Olson et al. 2005, Kroll et al. 2010, Dugger et al. 2011). As a result, inference from our study is restricted to spotted owl territories that are either currently occupied or were occupied at some point in the past, rather than all potential spotted owl territories in our study area.

RESULTS

Of the 63 spotted owl sites that met our criteria, 54 were known in a public database prior to 1995 and 9 spotted owl sites were discovered during the study. Sixteen (25%) and 47 (75%) spotted owl sites occurred in the Southern Cascades and Klamath Mountains, respectively. The number of spotted owl detections per site ranged from 0 to 30 ($\bar{x} = 7.6$; 95% CI = 5.5–9.7) from 1995 to 2009; 10 sites had 0 detections during our study period.

Table 1. Regression coefficients and 85% confidence intervals from the top ranked simple and pair spotted owl detection models, northern California, USA, 1995–2009. Night indicates the effect of conducting a nighttime, station-based survey; the intercept includes the effect of conducting a daytime, stand-based search.

Occupancy level	Model term	$\hat{\beta}$	SE	85% CL
Simple	Intercept	2.60	0.259	2.22 to 2.97
	Night	−2.71	0.282	−3.12 to −2.29
Pair	Intercept	1.90	0.223	1.58 to 2.22
	Time	−0.47	0.151	−0.69 to −0.25
	Night	−3.15	0.271	−3.54 to −2.76

One thousand thirty-three of 1,282 surveys (81%) occurred at night. A total of 480 (37.4%) spotted owl detections and 13 (1.0%) barred owl detections occurred during the 1,282 surveys. Barred owls were detected in 6 of 16 sites (38%) in the Southern Cascades and 2 of 47 sites (4%) in the Klamath Mountains province. During our study period, we did not detect barred owls in 1995 and 1996; however, we detected 4 barred owls from 1997 to 2004, 8 barred owls in 2005 and 2006, and 1 barred owl from 2007 to 2009. We detected a barred owl in multiple years on 1 spotted owl site; for the remaining 7 sites, we detected a barred owl in ≤1 year.

Detection Probabilities

The best model for detection probability in the simple analysis contained an effect for search type (informed day search or night survey; Table 1). Survey-specific simple detection probabilities were 0.93 (85% CI = 0.90–0.96) and 0.47 (85% CI = 0.43–0.51) for informed day searches and night surveys, respectively. The best model for detection probability in the pair analysis contained a negative linear annual trend and an effect for search type (Table 1 and Fig. 2). The average pair detection probabilities across all years were 0.86 (85% CI = 0.81–0.90) and 0.23 (85% CI = 0.18–0.29) for informed day searches and night surveys, respectively. Average detection probabilities (for all surveys combined) were 0.67 (85% CI = 0.64–0.70) and

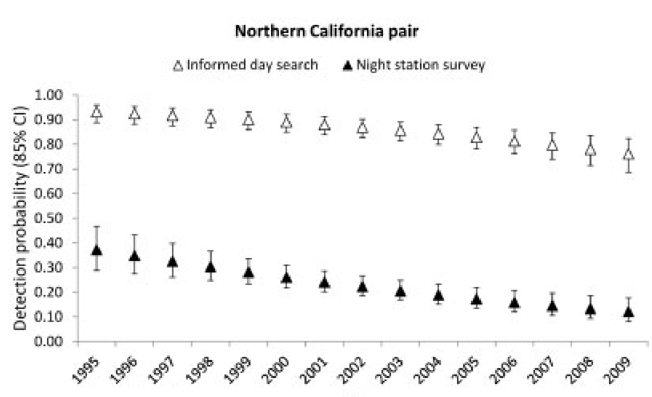

Figure 2. Estimated year-specific northern spotted owl pair detection probabilities and 85% confidence intervals, northern California, USA, 1995–2009. Open and filled diamonds represent estimates for surveys conducted during the day and night, respectively.

0.63 (85% CI = 0.58–0.68) for the simple and pair analyses, respectively (estimated with the null model). We did not find support for a difference in detection probabilities between the Southern Cascades and Klamath Mountains province.

Local-Extinction and Colonization Probabilities

Initial occupancy probabilities were 0.81 (85% CI = 0.59–0.93) and 0.75 (85% CI = 0.56–0.87) for the simple and pair analyses, respectively. The most supported model in the simple analysis included a negative linear trend in colonization probabilities; a model where colonization probability did not change during the study was the most supported in the pair analysis (Table 2). A constant local-extinction model received the most support in both the simple and pair analyses (Tables 2 and 3). Although the model weight indicated support for an effect of province on local-extinction probability in the simple analysis, the 85% confidence interval overlapped 0, suggesting uncertainty about the effect. The same was true for other covariates in both the simple (e.g., a linear trend in local-extinction) and the pair (e.g., an effect of nesting status on local-extinction and an effect of province on colonization) analyses (Table 2).

Local-extinction probabilities (from the best model) were constant across the study period for both the simple (0.09, 85% CI = 0.06–0.12) and pair (0.09, 85% CI = 0.06–0.13) analyses (Table 3). Colonization probabilities declined across the study in the simple analysis (Fig. 3 and Table 3) and remained constant in the pair analysis (0.06, 85% CI = 0.04–0.12).

Site Occupancy Probabilities

We present derived parameter estimates for simple and pair annual site occupancy probabilities for spotted owls based on best model estimates of initial occupancy, local-extinction, and colonization in our study area (Fig. 3). Site occupancy for any owl declined from 0.81 (85% CI = 0.59–0.93) in 1995 to 0.50 (85% CI = 0.39–0.60) in 2009; pair occupancy declined from 0.75 (85% CI = 0.56–0.87) to 0.46 (85% CI = 0.31–0.61). However, the rate of decline slowed for pair occupancy probabilities in the final 5 years of the study.

Table 3. Estimates and 85% confidence intervals for colonization and local-extinction coefficients from the top ranked simple and pair spotted owl occupancy models, northern California, USA, 1995–2009.

Occupancy level	Model term	$\hat{\beta}$	SE	85% CL
Simple	$\text{Intercept}_{\text{Colonization}}$	−2.15	0.33	−2.63 to −1.67
	$\text{Time}_{\text{Colonization}}$	−0.66	0.43	−1.29 to −0.03
	$\text{Intercept}_{\text{Extinction}}$	−2.34	0.24	−2.69 to −1.99
Pair	$\text{Intercept}_{\text{Colonization}}$	−2.59	0.43	−3.21 to −1.96
	$\text{Intercept}_{\text{Extinction}}$	−2.31	0.31	−2.76 to −1.86

DISCUSSION

We found that simple and pair spotted owl occupancy probabilities declined approximately 39% across the 15 years of our study, although the decline in pair occupancy probabilities appeared to slow in the final 5 years of the study. Observed pair declines in our study area were less than those reported for the Wenatchee study area in Washington, which demonstrated declines of 15% and 50% in simple and pair occupancy (Kroll et al. 2010), but greater than those for 3 study areas in western Oregon, only 1 of which demonstrated a decline of >10% (Olson et al. 2005). These declines in site occupancy are consistent with the trend in realized population change for the northwestern California demographic study area, which has been declining since 1992 (Anthony et al. 2006).

We found evidence that changes in simple occupancy probabilities were likely the result of declining colonization probabilities. Kroll et al. (2010) found that simple and pair

Table 2. Best ranked northern spotted owl site occupancy models (cumulative weight ≥0.85), northern California, USA, 1995–2009. For simple occupancy models, the detection probability model was $P_{\text{Day or Night}}$ (detection was a function of either day stand search or night station survey; 2 parameters); for pair occupancy models, the detection probability model was $P_{\text{T, Day or Night}}$ (detection was a function of a linear trend across years and day stand search or night station survey; 3 parameters). Model parameters include ψ (occupancy), γ (colonization), and ε (local-extinction); covariates include linear (T) and quadratic (TT) effects of time, Province (Klamath or Cascades), and Nesting status (whether a pair was nesting during the survey year).

Occupancy level	Model	K[a]	AIC_c	ΔAIC_c	w_i	Deviance
Simple	ψ(.)γ(T),ε(.)	6	1,153.0	0	0.20	1,141.0
	ψ(.)γ(.),ε(.)	5	1,153.1	0.1	0.19	1,143.1
	ψ(.)γ(.),ε(Province)	6	1,153.1	0.1	0.19	1,141.1
	ψ(.)γ(.),ε(T)	6	1,154.5	1.5	0.09	1,142.5
	ψ(.)γ(T),ε(T)	7	1,155.0	1.9	0.07	1,141.0
	ψ(.)γ(TT),ε(.)	7	1,155.0	2.0	0.07	1,141.0
	ψ(.)γ(Province),ε(.)	6	1,155.1	2.1	0.07	1,143.1
	ψ(.)γ(T),ε(.)	6	1,153.0	3.4	0.04	1,141.0
Pair	ψ(.)γ(.),ε(.)	6	842.5	0	0.21	830.5
	ψ(.)γ(.),ε(Nesting status)	7	843.4	0.9	0.13	829.4
	ψ(.)γ(Province),ε(.)	7	843.7	1.2	0.12	829.7
	ψ(.)γ(T),ε(.)	7	844.0	1.5	0.10	830.0
	ψ(.)γ(.),ε(Province)	7	844.5	2.0	0.08	830.5
	ψ(.)γ(.),ε(T)	7	844.5	2.0	0.08	830.5
	ψ(.)γ(Nesting status),ε(.)	7	844.5	2.0	0.08	830.5
	ψ(.)γ(TT),ε(T)	9	845.3	2.8	0.05	827.3

[a] K = the number of parameters in the model; AIC_c = Akaike's Information Criterion adjusted for small sample sizes; ΔAIC_c = difference in AIC_c between top model and each subsequent model; w_i = Akaike weight; deviance = residual sum of squares.

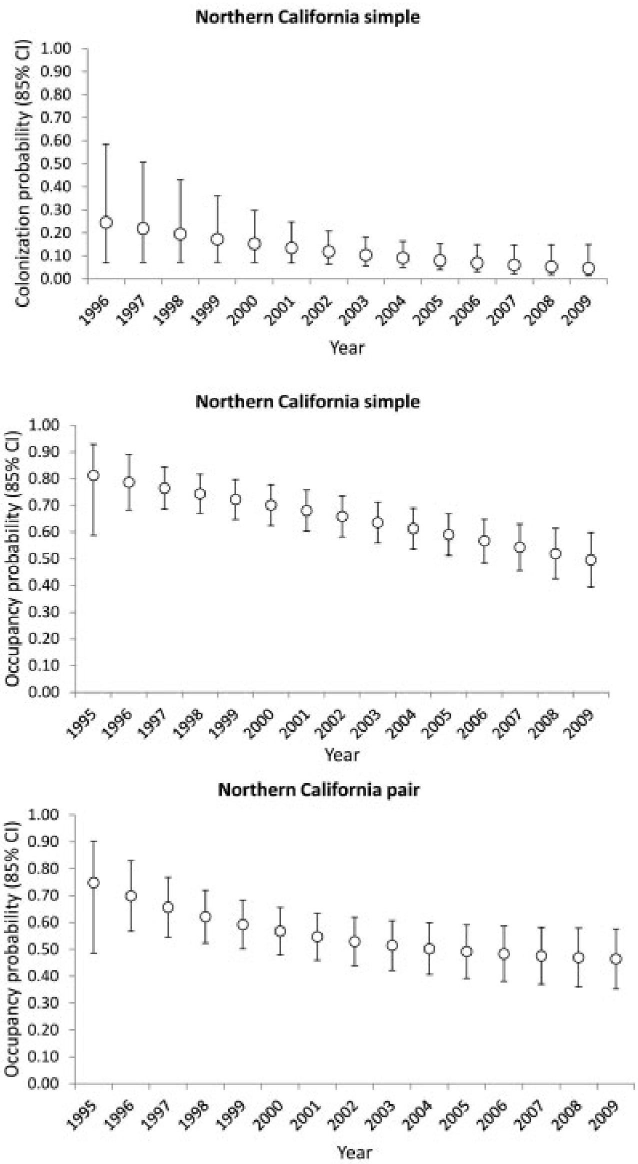

Figure 3. Estimated year-specific simple colonization probabilities and simple and pair occupancy probabilities with 85% confidence intervals for northern spotted owls, northern California, USA, 1995–2009. We calculated occupancy probabilities from the most supported models of initial occupancy, local-extinction, and colonization and using formulae from MacKenzie et al. (2003).

colonization probabilities declined during the 14 years included in their study; in contrast, Olson et al. (2005) found a consistent decline in simple colonization probabilities for only 1 of 3 study areas in Oregon; the other 2 simple colonization probabilities either increased or remained constant through time, while 1 pair colonization probability remained constant through time and 2 declined from initial levels before increasing during the last 6 years of the study. Simple colonization probabilities may have declined in our study area because recruitment declined during the study; as a result, the pool of floaters (individuals prospecting for territories) declined. We did not measure juvenile survival or emigration, so we cannot address this hypothesis. In addition, the estimated probabilities of local-extinction and colonization for both simple and pair spotted owls were small, suggesting relatively low turn-over at individual spotted owl sites.

Barred owls appeared to have occurred only as transients in our study area, suggesting that other factors were responsible for observed declines in site occupancy and corresponding differences in site occupancy estimates between our study area in northern California and results reported for Oregon and Washington (Olson et al. 2005, Kroll et al. 2010, Dugger et al. 2011). Differences in habitat types (dominant tree species and understory vegetation) and disturbance regimes (size and frequency of fires, differences in harvesting practices) are 2 primary sources of spatial variation that we were unable to model in our analysis. Specifically, we were unable to evaluate how much the amount of older forest within each spotted owl site may have influenced site occupancy dynamics. Olson et al. (2005) hypothesized that greater occupancy probabilities on 1 of their 3 study areas was a result of sites on that study area containing a greater proportion of older forest than the other 2 sites. Dugger et al. (2011) found that local-extinction probability was negatively associated with the percentage of old forest ($\geq$100 years of age) in the spotted owl site core (167-ha circle centered on the nest site). We also did not evaluate how the range of management intensity in our study area may have been associated with site occupancy dynamics. Spotted owl sites occurred on federal and private ownerships, portions of which were managed passively or actively. However, we did not have annual habitat data for all of the spotted owl sites that would allow us to model habitat-based variation in local-extinction and colonization probabilities. Collection of detailed habitat data over an extensive period, and with a resolution that accurately quantifies spotted owl habitat characteristics, poses a challenge to managers and researchers, but these attributes are probably critically important for explaining and managing spotted owl occupancy dynamics (Carey et al. 1992, Franklin et al. 2000).

In general, detection probabilities for spotted owls were $<$1.0 and variable, a result that agrees with other analyses using the same methods (Olson et al. 2005, Kroll et al. 2010). Average detection probabilities (across all years) were similar to detection probabilities reported by Reid et al. (1999) and Olson et al. (2005) as well as some of the years presented by Kroll et al. (2010). We did not find strong associations between province and simple and pair detection probabilities, although low sample sizes in the Cascades ($n = 16$) may have limited our ability to detect differences. Also, we did not find an association between nesting status and pair detection probabilities.

Detection probabilities of spotted owls in both the simple and pair analyses were strongly associated with survey type. Specifically, during night surveys, spotted owl calls were broadcasted from established survey stations; during informed day searches, the best abiotic locations of suitable habitat within territory core areas was surveyed, resulting in greater average detection probabilities compared to night surveys. Varying amounts of information about individual territories could lead to variation in detection probabilities resulting from informed day searches. However, by including only spotted owl sites that received consistent survey effort informed by comparable amounts of site-specific knowledge in our dataset, we attempted to limit this source of variation. We suggest that other landowners consider gathering information on a site-specific basis, as this information can be used to increase survey-specific detection probabilities, thereby limiting the amount of resources dedicated to spotted owl survey programs. For example, because of the high detection probabilities associated with informed day searches (0.93 and 0.86 for simple and pair detections, respectively), including even 1 informed day search per season greatly increases confidence in the determination of spotted owl site occupancy status.

MANAGEMENT IMPLICATIONS

Site occupancy probabilities for spotted owl pairs appeared to have stabilized in the final 5 years of our study, although the continuing decline in simple occupancy probabilities, because of reduced colonization, merits further monitoring attention. In addition, we expect that occupancy probabilities will decline in the future if barred owls become as prevalent in the study area as they have in other portions of the spotted owl's geographic distribution or if habitat quality changes significantly (e.g., after a large wildfire). Based on the large differences in detection probabilities between informed day searches and station-based night surveys, we recommend that survey programs in our study area include at least 1 informed day search, directed by informed knowledge of site conditions, in each survey season to increase confidence in occupancy status. Conducting 1 informed day search along with a 2 visit annual night survey protocol will meet the USFWS standard for confidence in site status for simple spotted owls in the Klamath Mountains and Southern Cascades biogeographic provinces. We did not find support for a relationship between detection probabilities and survey date and suggest that informed day searches can be conducted throughout the survey season (although we recommend that surveys be conducted early in the breeding season to identify both breeding and non-breeding spotted owls). To increase confidence in determination of site occupancy status for spotted owl pairs, given the lower and declining pair detection probabilities, managers should include 2 informed day searches along with a 3 visit annual night survey protocol.

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Diets of Northern spotted owls (*Strix occidentallis caurina*) in the Southern Cascades and Klamath Provinces of interior Northern California.

PREPARED FOR :
The U.S. Fish & Wildlife Service
for the review of the Spotted Owl Management Plan

PREPARED BY :
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February 2, 2005

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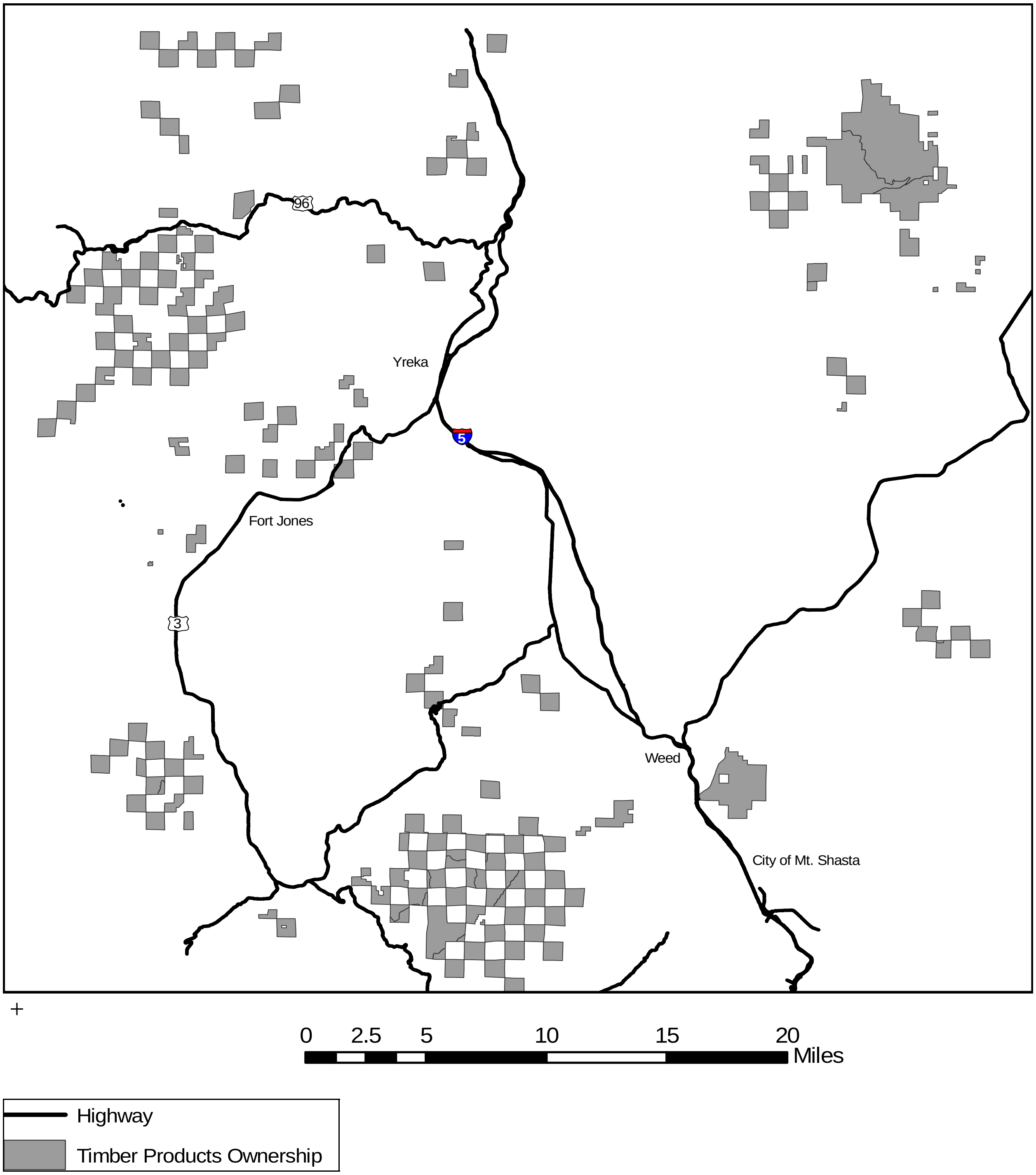
1.0 Introduction

Timber Products Company (Company) is a privately owned company whose primary objective is the long-term management of its forest resources while maintaining, protecting, and enhancing wildlife and fisheries resources. Timber Products owns and manages approximately 125,000 acres of forestland in interior Northern California (Figure 1). Since the majority of forestlands originate from railway land grants the “checkerboard” pattern ownership is typically intermingled with federal agencies supporting the Northwest Forest Plan. The four national forests adjacent to company ownership area the Klamath, Shasta-Trinity, Six Rivers, and Rogue River National Forests.

Over 80 Northern spotted owl (*Strix occidentallis caurina*) activity centers are located on or within 1.3 miles of Company forestlands. Long-term management of Company forest resources includes understanding how these forestlands provide suitable habitat for spotted owls. Accordingly, this study is part of monitoring the Company Spotted Owl Management Plan (2001) which uses new scientific information in an adaptive management process to develop future forest management plans.

Research has indicated that Northern spotted owl diets vary among regions and forest types (Forsman *et al*., 1984). Many studies have hypothesized that primary prey species and abundance are influences on home range size (Zabel *et al.*, 1995) and on habitat use (Carey *et al*., 1992). Spotted owls regurgitate the less-digestible portions of their prey, such as bones and hair, which can then be used to identify the species of prey. To better understand the foraging preferences of spotted owls in the interior northern California region, pellets were collected between 1996 and 2004 from 20 different Northern spotted owl activity centers on and adjacent to Company forestland.

Figure 1 **Location of Company forestland in interior Northern California.**



2.0 Study Areas

To better understand potential variability of spotted owl diets among ecological provinces and habitat types, pellets were collected from both the Klamath mountains and Southern Cascades provinces of California. Vegetation, parent geology and climate are the main ecological factors which separate these two distinct provinces (FEMAT 1993). The Klamath mountains province is located from the Oregon border south to the northern Sacramento valley and from Interstate 5 west to the redwood coast range. The Southern Cascades in California are located east of Interstate 5 from the Oregon border south to northern Sacramento valley (FEMAT 1993) (Figure 2).

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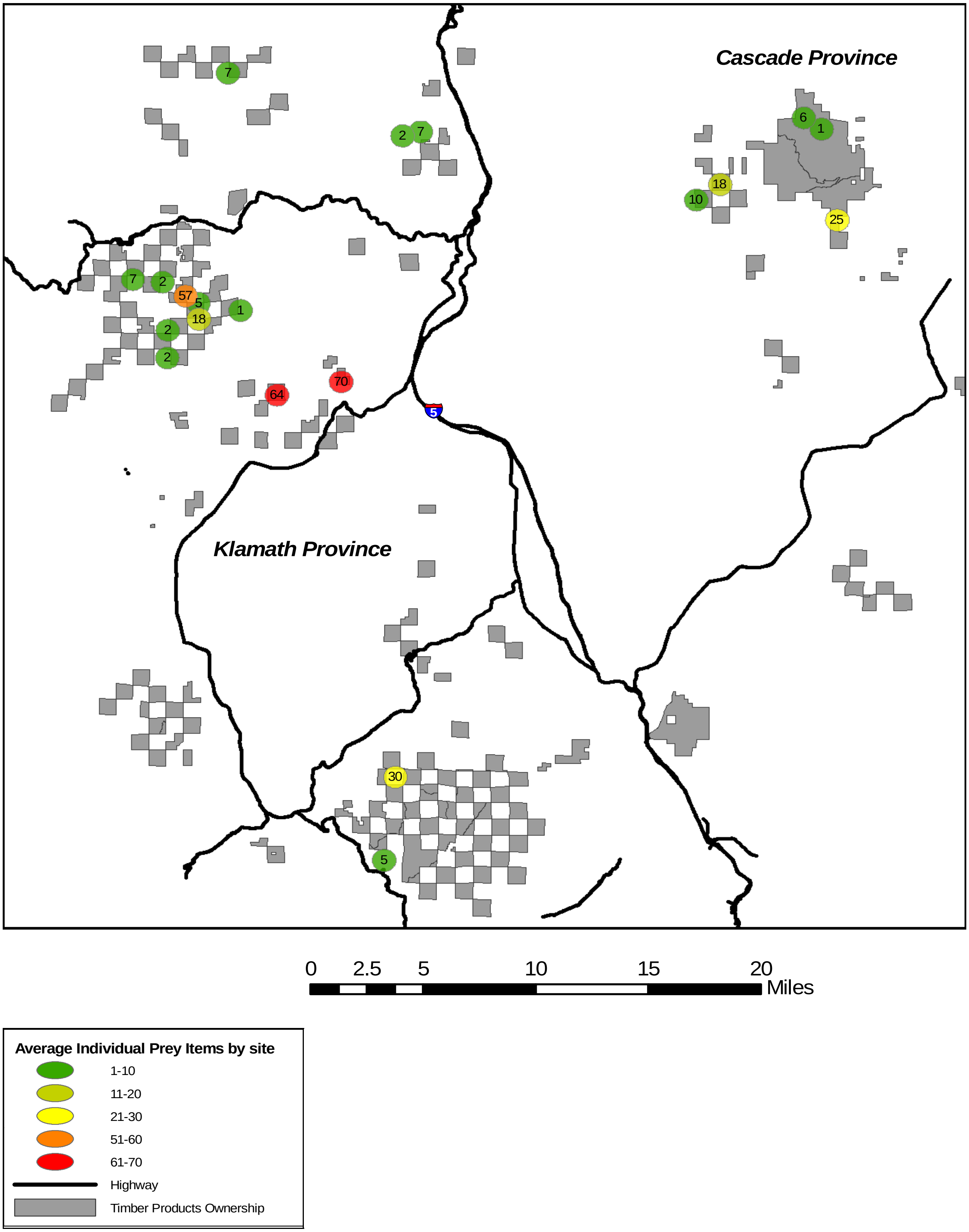
The climatic conditions within the Klamath province are characterized normally by cool, moist winters and warm, dry summers. Generally, precipitation falls as rain below 4,000 feet. Elevations of the spotted owl activity centers within this province, where pellets were collected, range from approximately 3,300ft to 5,100ft (1,000m to 1,550m). Vegetation types surrounding activity centers are dominated by Klamath Mixed Conifer, Ponderosa Pine, Douglas-fir, Montane Hardwood-Conifer, Montane Hardwood and Mixed Chaparral (Mayer and Laudenslayer 1988).

Within the Cascade Province, precipitation generally falls as rain below 4,000 feet, but it can rain during warm winter storms to as high as 7,000 feet. Snow can occur down to 1,000 feet, but generally accumulates above 4,000 feet. The spotted owl activity centers within this province range in elevation from 4,400ft to 5,300ft (1,340m – 1,615m). A wide variety of tree dominated forest types occur on Company forestlands including Klamath Mixed Conifer, Douglas-fir, White Fir, Red Fir, Ponderosa Pine, Montane Hardwood-Conifer, Juniper, Montane Hardwood and Mixed Chaparral (Mayer and Laundenslayer 1988).

Figure 2 Distribution of Northern Spotted Owl Activity Centers
Number of Individual Prey Items Collected by Site



3.0 Methods

From 1996 through 2004 northern spotted owl pellets were collected opportunistically as a part of USFWS protocol surveys and owl banding efforts. Pellets were collected below roosts and nests during the breeding season from March 1 to August 15. Only one pellet in the analysis was from outside the breeding season (September 29th, Cascade Province). For each pellet date, owl site number, location of pellet (nest, roost, or unknown) and sex of the owl (male, female or unknown) were recorded. Pellets were not collected systematically or with an even distribution between sites and years.

Individual prey items were identified to species, when possible, in each pellet and counted separately. Prey item identification and keying was completed under contract by Ms. Rita Claremont, Corvallis, Oregon. Thomomys (bottae or mazama), woodrat (cinerea or fiscipes) and some Microtus species could not be keyed to species because the pellets lacked an intact skull necessary for identification. Because each prey item was counted separately the prey count may be overestimated as larger prey items can be contained in more than one pellet. Other studies (Forsman *et al.*, 2004) have combined pellets collected under the same roost or nest tree on the same day so as to decrease the likelihood of over counting prey items. During our collection of pellets we did not distinguish between pellets that were collected under the same roost or nest so prey items were not combined.

An analysis of pellets was completed using biomass of species, which is the count of individual prey items times the mean weight (grams). Mean weights were obtained from “Diets and Foraging behavior of Northern Spotted Owls in Oregon” (Forsman *et al.*, 2004). Weights for Lagomorph (rabbit) species were estimated because this prey item was represented in our samples by juveniles and sub-adults and biomass may have been overestimated using mean weight. Some prey items that could not be keyed to species (Microtus, Bird, and Muridae) had a large range of mean weights within each species so weight was also estimated for these.

4.0 Results

A total of 224 pellets were collected at 20 spotted owl activity centers between 1996 and 2004. There were 339 individual prey items identified or 1.5 prey items in each pellet (Table 1). Since pellets were collected non-systematically the distribution within this sample varies significantly between sites (Table 1) (Figure 2). As an example, a total of 7 owl activity centers account for 282 prey items or 83% of the entire sample.

The 339 individual prey items consisted of 330 mammals, 8 birds and 1 insect. There were 16 individual species of mammals, 5 species of birds, and 1 species of insect (Table 2). The mean weight of prey items was 163.0 grams (SE +/- 5.8 grams). Major prey species with greater than 1% of the total biomass included: woodrat sp. (58.3%), Northern flying squirrel (29.2%), broad-footed mole (3.9%), rabbit (3.9%) and gopher (1.4%) (Figure 3).

Woodrat sp. and Northern flying squirrels made up the majority of the total individual prey items and of the total biomass. Of the individual prey items Northern flying squirrel accounted for 36.6% and woodrat sp. 33.3%. Based on the biomass of each species the Northern flying squirrel accounted for 29.2% of the biomass and woodrat sp. 58.3% (Table 2). In total, woodrat sp. and Northern flying squirrels accounted for 70% of the individual prey items and 88% of the total biomass (Figure 3).

Figure 3 **Percent Biomass by Individual Prey Species for Total Population**
n = 339

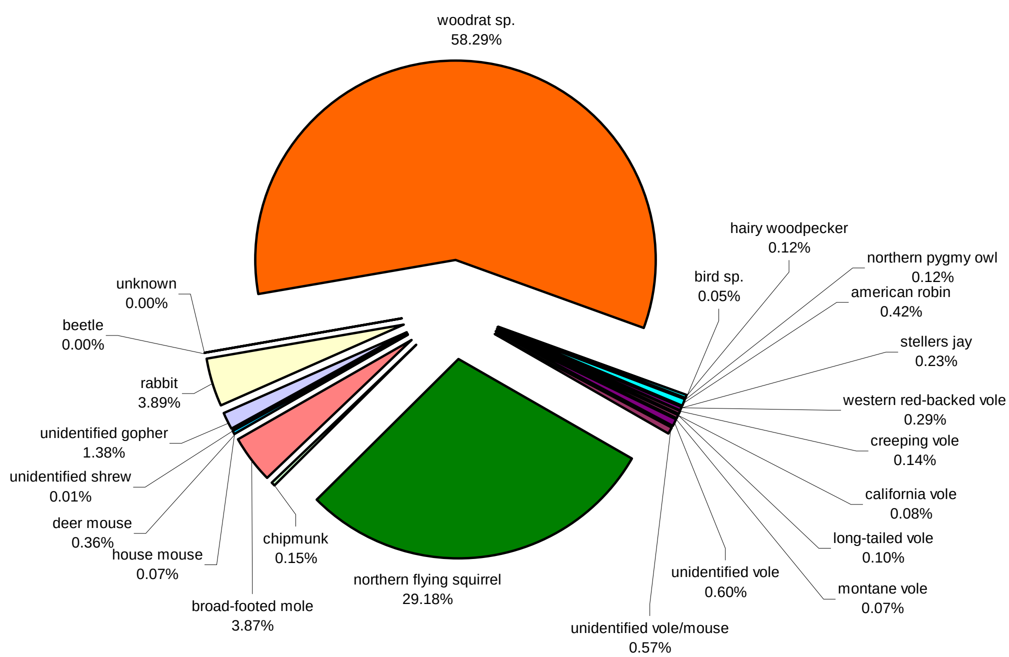


Table 1 Number of Pellets and Individual Prey items identified by site

Site Number	Site Name	Number of Pellets	Number of Individual Prey Items	Percent of Prey Items (%)
SK012	KC Mine	1	2	0.6
SK048	Collins Creek	6	7	2.1
SK051	Gumboot	13	18	5.3
SK052	Coats Creek	1	2	0.6
SK056	Kangaroo Creek	16	30	8.8
SK063	Singleton Creek	1	2	0.6
SK152	Stove Springs	1	1	0.3
SK302	Ikes Creek	20	25	7.4
SK310	Upper Bear Creek	6	7	2.1
SK340	Mckinney Creek	2	5	1.5
SK364	N. Fk. Ditch Creek	4	7	2.1
SK391	Deadwood	41	64	18.9
SK467	Ditch Creek	2	2	0.6
SK493	Negro Creek	5	6	1.8
SK541	Hells Canyon	8	18	5.3
SK542	Steep Trail	6	10	2.9
SK549	Golden Age Mine	38	57	16.8
SK553	Greenhorn/Mill	49	70	20.6
SK556	Barkhouse	1	1	0.3
TR061	Dan Rice Creek	3	5	1.5
	TOTAL	**224**	**339**	**100**

Table 2. Individual Prey Count and Biomass for the Total Population

Common Name	Total count of individual species	Mean mass of species (grams)	Total biomass (grams)	Percent Biomass (%)
American robin	3	77	231	0.42
Beetle sp	1	2	2	0.00
Bird sp	1	10	10	0.02
Bird sp	1	20	20	0.04
Broad-footed mole	31	69	2139	3.87
California vole	1	43	43	0.08
Chipmunk	1	83	83	0.15
Creeping vole	4	20	80	0.14
Deer mouse	9	22	198	0.36
Hairy woodpecker	1	66	66	0.12
House mouse	2	20	40	0.07
Long-tailed vole	1	56	56	0.10
Montane vole	1	40	40	0.07
Northern flying squirrel	124	130	16120	29.18
Northern pygmy owl	1	68	68	0.12
Rabbit	1	350	350	0.63
Rabbit	2	500	1000	1.81
Rabbit	1	800	800	1.45
Stellers jay	1	128	128	0.23
Unidentified gopher	8	95	760	1.38
Unidentified shrew	1	7	7	0.01
Unidentified vole	3	30	90	0.16
Unidentified vole	6	40	240	0.43
Unidentified vole/mouse	2	20	40	0.07
Unidentified vole/mouse	11	25	275	0.50
Western red-backed vole	7	23	161	0.29
Woodrat sp	113	285	32205	58.29
Unknown mammal	1	0	0	0
Total	**339**	**--**	**55252**	**100**

*Individual prey items in which mean weights were estimated are separated by weights in the table.

Twelve other mammal prey species represented 27% of the prey items and only 11% of the total biomass. These prey species included voles (Clethrionomys californicus, Microtus oregoni, Microtus sp, Muridae sp, Microtus montanus, Microtus longicaudus), mice (Mus musculus, Peromyscus maniculatus, Muridae sp), moles (Scapanus latimanus), gophers (Thomomys sp), and rabbit (lagomorph sp). Apparently minor prey species including two mammals, five birds species and one insect species represented 3% of the prey items and only 1% of the total biomass (Figure 3).

Further analysis of prey items by year to determine any annual variations in prey species was not completed. Pellets were not collected systematically with an even distribution between sites or years. Annual variation in the number individual prey items identified ranged from 1996 (n=1), 1997 (n=12), 1998 (n=57), 1999 (n=7), 2000 (n=12), 2001 (n=11), 2002 (n=6), 2003 (n=74) and 2004 (n=159). To complete an analysis of annual variation, similar owl diet studies have recommended having a minimum of 20 prey items each year for each site for 2 or more years (Forsman *et al*, 2004). Our relatively small sample size does not meet this criteria.

4.1 Differences between Klamath and Southern Cascades Provinces

Sample size in each province may influence any comparisons between provinces. A total of 184 pellets in the sample were collected from the Klamath mountains, which had 279 individual prey items identified (Table 3). Forty pellets were collected from the Southern Cascade with a total of 60 individual prey items (Table 3)(Figure 4)(Figure 5). The difference between pellet counts is primarily due to survey intensity as well as total number of spotted owl activity centers within each province. The Klamath Mountains has 66 total activity centers on or adjacent to Timber Products Company Land, while there are only 16 in the Southern Cascades.

TABLE 3. Number of Pellets and Individual Prey Items Identified by Province

Province Name	Number of Spotted owl Territories	Number of Pellets	Number of Individual Prey Items	Percent of Prey Items (%)
Klamath mountains	15	184	279	82
Southern Cascades	5	40	60	18
Total	**20**	**224**	**339**	**100**

Figure 4 **Percent Biomass by Individual Prey Species for the Klamath Province**
n = 279

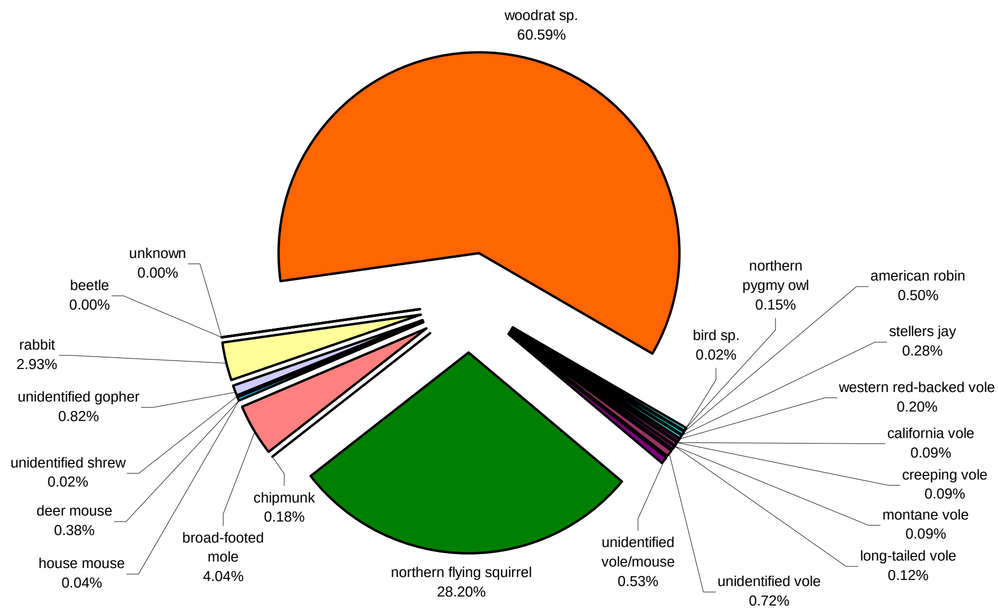
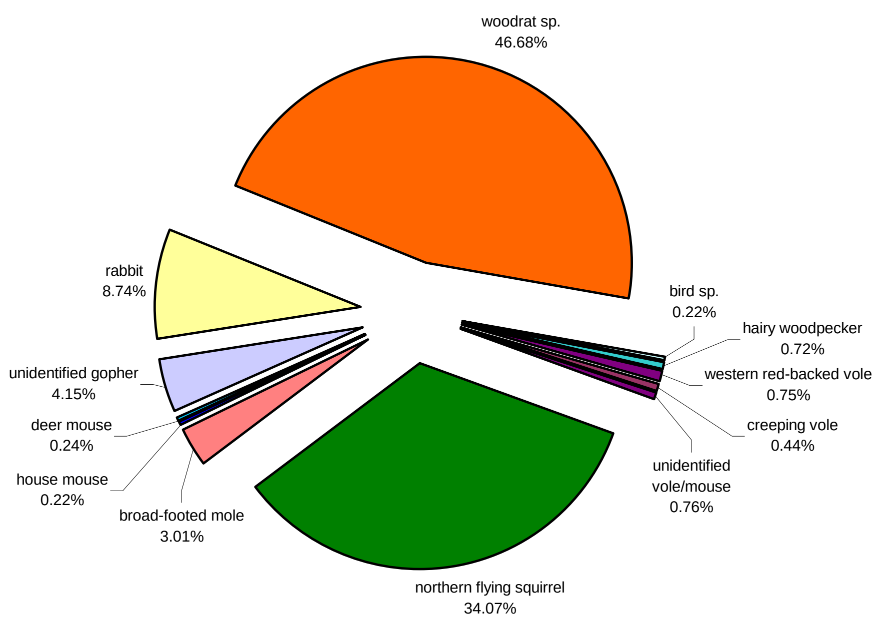


Figure 5 **Percent Biomass by Individual Prey Species for the Cascade Province**
n = 60



Both provinces were dominated by woodrats and Northern flying squirrels. In the Klamath mountains, woodrats comprised 61% of the total biomass and Northern flying squirrels were 28% (Table 3). The Southern Cascades had percentages of biomass for woodrats (47%) and Northern flying squirrels (34%) that were more evenly split. The difference in percentage of woodrats and Northern flying squirrels between provinces could be due to differences in vegetation, climate, sample size or that 42% of the prey items identified in the Southern Cascades came from one site (SK302, Ikes Creek).

Secondary prey items differed slightly between the Klamath mountains and Southern Cascades. In the Klamath mountains, secondary prey biomass included broad-footed moles (4%), rabbits (3%), voles (1%), gophers (1%), birds (1%), and mice (1%) (Table 4). In the Southern Cascades rabbits (9%), gophers (4%), moles (3%), voles (1%), birds (1%) and mice (1%) made up the secondary prey biomass for the province (Table 4). Secondary prey species seem to have slightly more significance in the overall diet composition of the owls in the Southern Cascades as secondary prey species make up 35% of the biomass (Table 4) (Figure 5). As opposed to the Klamath mountains where 11% of the total biomass are taken up by secondary species (Table 4) (Figure 4).

TABLE 4. Differences in Percent Individual Prey Count and Biomass between the Klamath mountains and Southern Cascade Provinces

Common Name	Klamath mountains Province		Southern Cascade Province	
	Percent of individual species (n = 279)	Percent Biomass (n = 46094g)	Percent of individual species (n = 60)	Percent Biomass (n = 9158g)
American robin	1.08	0.05		
Beetle sp	0.36	0.00		
Bird sp	0.36	0.02		
Bird sp			1.67	0.22
Broad-footed mole	9.68	4.04	6.67	3.01
California vole	0.36	0.09		
Chipmunk	0.36	0.18		
Creeping vole	0.27	0.09	3.33	0.44
Deer mouse	2.87	0.38	1.67	0.24
Hairy woodpecker			1.67	0.72
House mouse	0.36	0.04	1.67	0.22
Long-tailed vole	0.36	0.36		
Montane vole	0.36	0.09		
Northern flying squirrel	35.84	28.20	40.00	34.07
Northern pygmy owl	0.36	0.15		
Rabbit	0.36	0.63		
Rabbit	0.72	1.81		
Rabbit			1.67	8.74
Stellers jay	0.36	0.28		
Unidentified gopher	1.43	0.82	6.67	4.15
Unidentified shrew	0.36	0.02		
Unidentified vole	1.08	0.20		
Unidentified vole	2.15	0.55		
Unidentified vole/mouse	0.36	0.04	1.67	0.22
Unidentified vole/mouse	3.23	0.49	3.33	0.55
Western red-backed vole	1.43	0.20	5.00	0.75
Woodrat sp	35.13	60.59	25.00	46.68
Unknown mammal	0.36	0		
Total	**100**	**100**	**100**	**100**

*Individual prey items in which mean weights were estimated are separated by weights in the table.

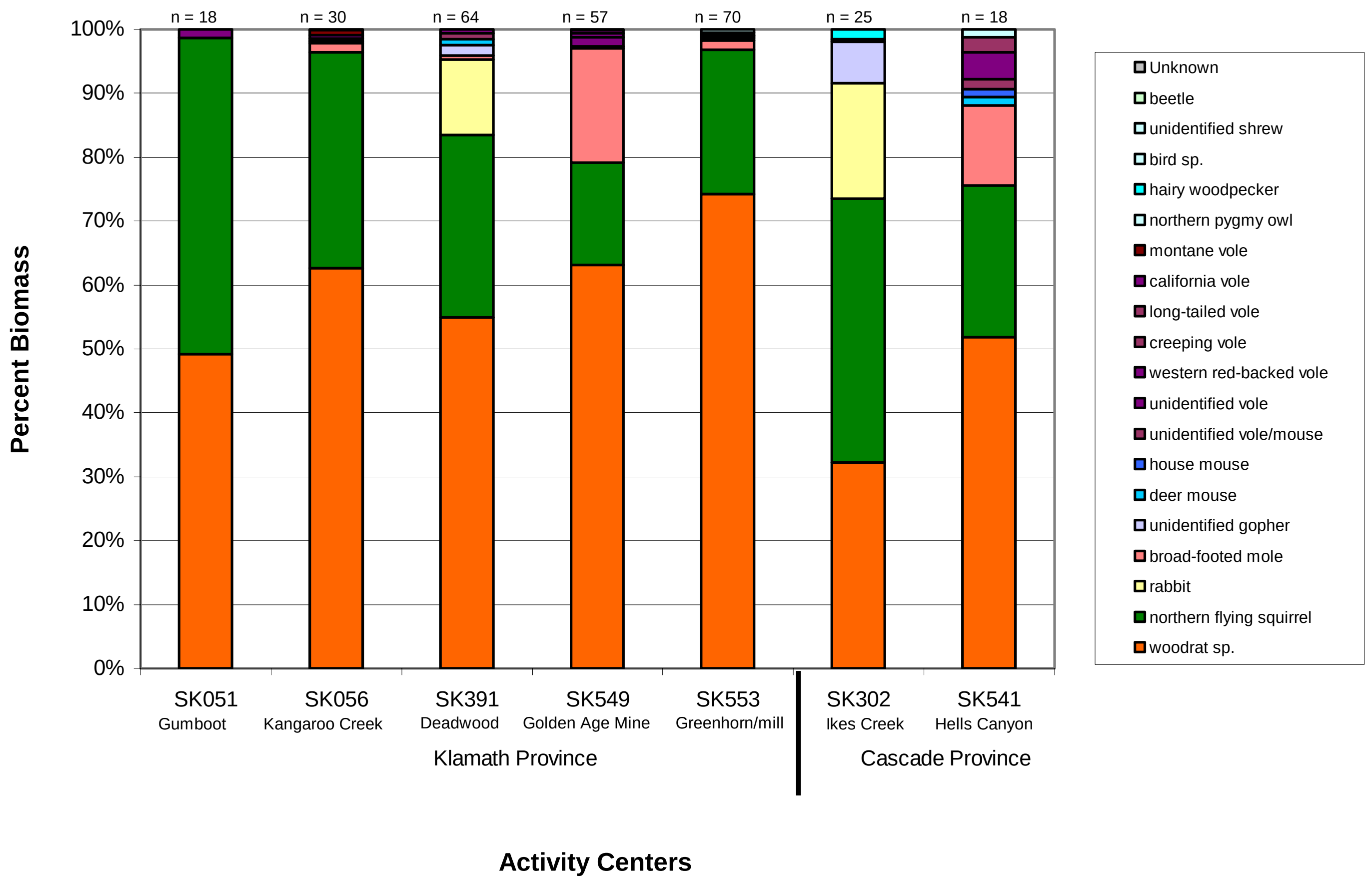
4.2 Variations by Habitat

To better understand relationships between prey items and habitats, the percent biomass by prey species within owl sites was compared to habitats found within the same owl sites. Since pellets were collected opportunistically there is a non-normal distribution of pellets within this study (Figure 2). To determine which owl sites had an adequate sample size for further habitat analysis our samples were compared with similar studies which have used ≥ 20 prey items per site (Forsman *et al*., 2004, Smith et. al, 1999) or ≥ 10 prey items per site (Forsman et. al., 2004) on estimates of means and overall diet composition. Based on our distribution of prey items by owl site and results from other similar studies it was determined that owl sites with 18 or more prey items would be used for this habitat analysis.

A total of 7 owl sites had 18 or more prey items. Of the total 339 prey items identified in the 20 sites, 282 prey items or 83% came from these 7 owl sites (five in the Klamath mountains and two in the Southern Cascades). The 282 prey items represent 85% or 47,315 grams of the total biomass. We examined this subset of the total sample to see if it was representative of the total sample. In the total sample woodrats accounted for 58% and Northern flying squirrels 28% of the biomass (Figure 3). In the subset sample, woodrats accounted for 60% and Northern flying squirrels 27% of the biomass. This subset appears to be representative of the total sample.

We found relatively minor differences in the distribution of individual prey items between owl sites. We compared the percent biomass between woodrats and Northern flying squirrels between owl sites. In the Klamath mountains woodrats percent biomass ranged from 49% (SK051) to 74% (SK553) and Northern flying squirrels percent biomass ranged from 16% (SK051) to 49% (SK549) (Figure 6). In the Southern Cascades woodrats were 32% (SK302) and 52% (SK541) of the biomass and Northern Flying Squirrels were 41% (SK302) and 24% (SK541) of the total biomass by owl site (Figure 6). Although the biomass percentages varied by site, both woodrats and Northern flying squirrels were important components in the diet at every owl site. There was no divergence between sites, meaning no one owl site contained the entire total biomass for either Northern flying squirrels or for woodrats.

Figure 6 Percent Biomass by Sites with ≥ 18 Individual Prey Items (n = total individual prey items)



Further analysis was completed to determine if any habitat associations occur between the seven owl sites. A regression analysis was completed to determine which species were normally distributed and could be used for further analysis. Through this analysis the woodrats sp. and Northern flying squirrels had adequate sampling to complete further analysis. To simulate owl foraging area the amount of each habitat type was calculated within a 0.7 mile circle (980 acres) around each of the seven owl sites. Based on radio telemetry results from owls located in both the Klamath and Southern Cascades provinces 75% of night time foraging locations are within 591 acre core use areas (Irwin *et al*, 2004). The habitats within the 0.7 mile circle came from a Geographic Information System (GIS) coverage that has been verified through a combination of aerial photographs, field verifications and forest inventory plot data.

A series of *a priori* hypothesis were made based on our current scientific understanding of woodrat and flying squirrel biology and life requisites. These questions intentionally limited the number of independent variables that were examined. We made these *a priori* hypothesis due to our limited sample size (n=7). It was our intention to verify other published results and not necessarily make any new associations with our limited sample size. The complete list of *a priori* hypothesis which may influence these species are listed in Table 5. In general, for Northern flying squirrels we examined the amount of large, dense conifer stands in relation to the percent prey biomass. We also examined the amount of Douglas-fir stands which support mistletoe and fungi which are reported to provide food for the species. We also examined the potential influence of elevation in determining the percent prey biomass. For woodrats we examined the amount of Ponderosa pine stands and sparse and open stands known to support woodrat den sites. Based on published studies we also examined the potential influence of elevation in determining the percent prey species biomass.

4.2.1 Flying Squirrels

A total of 14 *priori hypotheses* were examined (Table 6). To test these *a priori* hypothesis a step-wise logistical regression of 14 independent variables was calculated using PC Minitab (Minitab Inc.). None of the 14 independent variables were significant ($p<0.05$) at predicting percent flying squirrel biomass (dependent variable). Due to our relatively small sample size several independent variables demonstrated positive correlations (i.e. positive coefficients) with the percent flying squirrel biomass but were not significant. The amount of WHR size class 6 (i.e. old growth) ($R2 = 0.45$, $p<0.1$), amount of WHR size class 4, 5 and 6 ($R2 = 0.28$, $p>0.1$), percent of white fir habitat ($R2 = 0.20$, $p>0.1$) and elevation ($R2 = 0.13$, $p>0.1$) for the 0.7 mile circle. Also several independent variables demonstrated negative correlations (i.e. negative coefficients) with the percent flying squirrel biomass but were not significant. The amount of WHR size class 0 through 3 ($R2 = 0.27$, $p>0.1$) and the amount of non-conifer (R2 0.18, $p>0.1$) within the 0.7 mile circle.

4.2.2 Woodrats

A total of 14 *a priori* hypotheses were also examined for woodrats (Table 5). To test these *a priori* hypothesis a step-wise logistical regression of 14 independent variables was also calculated using PC Minitab (Minitab Inc.). Only one of the 14 independent variables was significant ($p<0.05$) at predicting percent woodrat biomass. The percent of Ponderosa pine habitat within a 0.7 mile circle was significant ($p<0.05$) at predicting the percent of woodrat biomass for the owl site (Figure 7). Due to our relatively small sample size one additional independent variable demonstrated positive correlations (i.e. positive coefficient) with the percent woodrat biomass but was not significant. The percent of Douglas-fir habitat ($R2 = 0.13$, $p>0.1$) within the 0.7 mile circle. Also several independent variables demonstrated negative correlations (i.e. negative coefficients) with the percent woodrat biomass but were not significant. The amount of white fir habitat ($R2 = .18$, $p>0.1$) within the 0.7 mile circle. Also, elevation of the owl site was negatively correlated with the percent of woodrat biomass for the site ($R2 = 0.23$, $p>0.1$) but was not significant (Figure 8).

Due to statistical results from the step-wise logistical regressions one model was constructed to predict the percent of woodrat biomass for the site. The percent of Ponderosa pine habitat was added to the percent of Douglas-fir habitat within a 0.7 mile circle which was significant ($R2 = 0.85$, $p<0.05$) at predicting the percent of woodrat biomass for the site (Table 5).

Table 5 Regression of 14 Independent variables

Dependent Variable	Independent Variable	n	R^2	Coefficient (+ or -)	Significance
% F. Squirrel Biomass	% KMC	7	0.052	+	p > 0.1
	% PPN	7	0.078	-	p > 0.1
	% DFR	7	0.130	-	p > 0.1
	% WFR	7	0.203	+	p > 0.1
	% Non-Conifer	7	0.178	-	p > 0.1
	WHR Size 0 to 3	7	0.274	-	p > 0.1
	4 to 6	7	0.277	+	p > 0.1
	6	**7**	**0.451**	**+**	**p < 0.1**
	WHR Density 0,S,P	7	0.113	+	p > 0.1
	M & D	7	0.075	+	p > 0.1
	NSO NR & NRD	7	0.090	+	p > 0.1
	FOR & FORD	7	0.080	-	p > 0.1
	NON	7	0.072	-	p > 0.1
	Elevation	7	0.129	+	p > 0.1
% Woodrat Biomass	% KMC	7	0.146	-	p > 0.1
	% PPN	**7**	**0.531**	**+**	**p < 0.05**
	% DFR	7	0.131	+	p > 0.1
	% WFR	7	0.179	-	p > 0.1
	% Non-Conifer	7	0.001	+	p > 0.1
	WHR Size 0 to 3	7	0.029	+	p > 0.1
	4 to 6	7	0.036	-	p > 0.1
	6	7	0.001	-	p > 0.1
	WHR Density 0 & S & P	7	0.127	-	p > 0.1
	M & D	7	0.091	+	p > 0.1
	NSO NR & NRD	7	0.013	+	p > 0.1
	FOR & FORD	7	0.011	-	p > 0.1
	NON	7	0.010	-	p > 0.1
	Elevation	7	0.230	-	p > 0.1
	%PPN + % DFR	**7**	**0.847**	**+**	**p < 0.05**

Figure 7 Predicted Woodrat biomass from Percent Ponderosa Pine Type

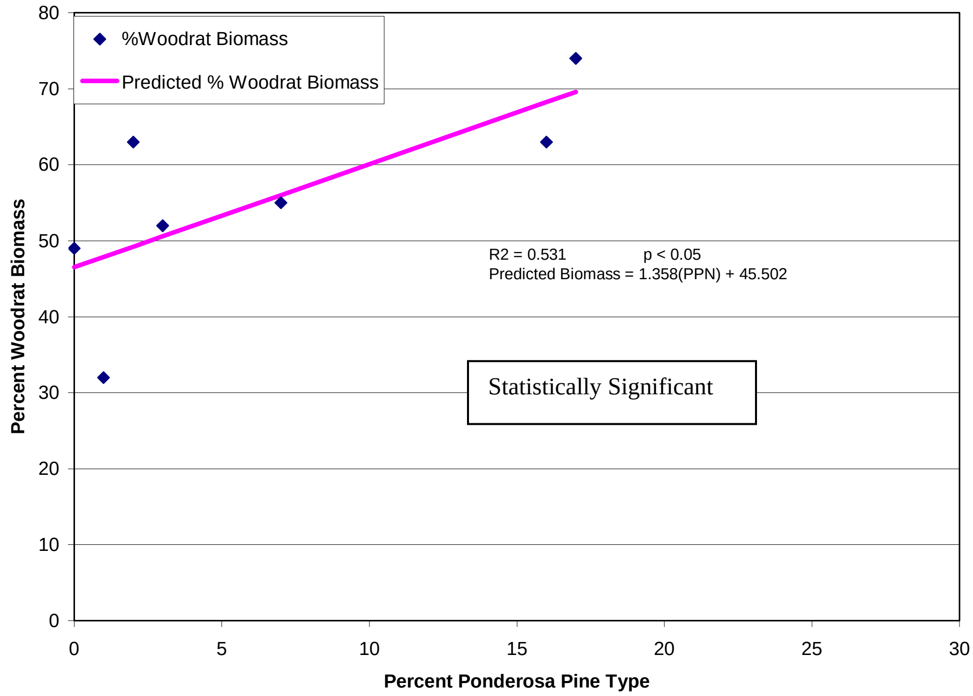
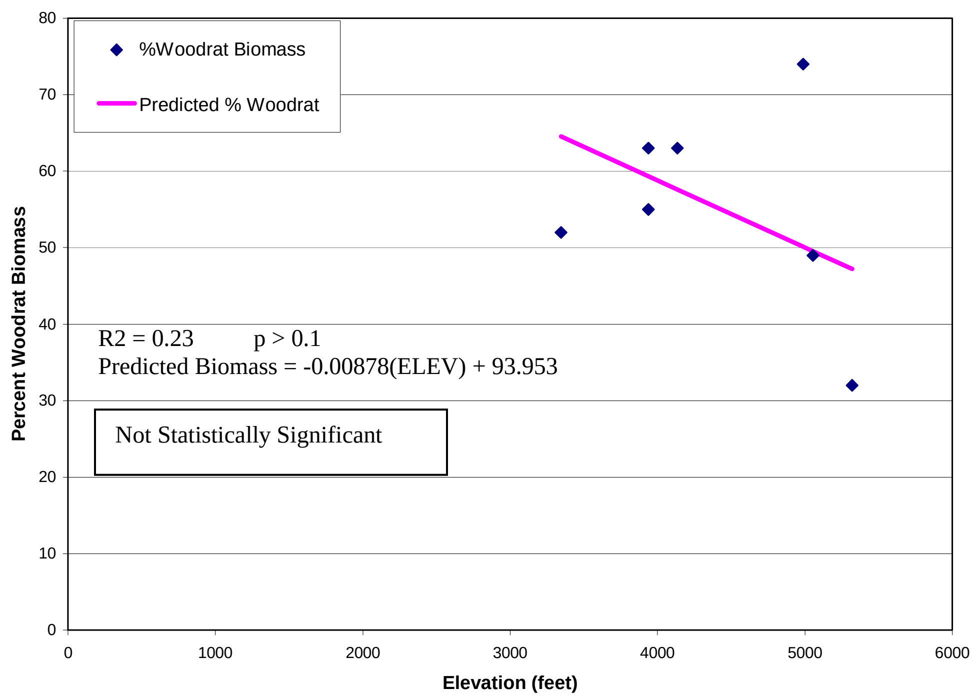


Figure 8 Predicted Woodrat biomass from Elevation (feet)



5.0 Discussion

Geographic Range of the Owl

Our results found that the primary prey species in the eastern Klamath Mountains and Southern Cascades are woodrat sp. and Northern flying squirrel. These two species account for 70% of the individual prey items and 88% of the total biomass in our study. These results are similar to the results of other studies in the Klamath mountains and Southern Cascades provinces of the owl (Forsman *et al*. 2004, Ward *et al*., 1998, Zabel *et al*., 1995, Munton *et al*., 2002). From north to south throughout the range of the spotted owl, Northern flying squirrels decrease while woodrats increase in importance in the diet of the owl (Thomas *et. al*. 1990). To the north in the Klamath Mountains of Oregon (interior southwest) Forsman *et al*., (2004) found that woodrats were the main prey item (49% of the total biomass) although Northern flying squirrels were also important in terms of biomass (30% of the total biomass). To the south in the Sierra National Forest, Munton *et al*., (2002) had similar results, in that Northern flying squirrels were dominant in coniferous forests (45% of the total biomass) while woodrats were the main prey species (74% of the total biomass) in low-elevation oak savannas, oak/foothill pine forests, and riparian-deciduous forests. Our results confirmed that Timber Products Company forestlands lie in the portion of the range where both prey species are important to the survival and reproduction of the owl (Forsman *et al*. 2004).

Our mean biomass of 163.0 grams (SE +/- 5.8 grams) also appears to be similar to results of other studies in the Klamath mountains and Southern Cascades provinces of the owl. Forsman *et al.*, (2004), found in Oregon that more northern or coastal provinces mean biomass was lower ranging from 90.7 grams to 123.6 grams. While, mean biomass was higher in Oregon's southern coastal region (131.4 grams) and in the interior southwest province (142.1 grams) that is adjacent to our study area. Also, studies of radio telemetry owls in the Klamath mountains province found significantly smaller owl home ranges for sites with higher mean prey biomass (Zabel *et al*., 1995). Based on our results it appears that in the Klamath mountains and Southern Cascades owls benefit from availability of larger prey items which may explain relatively smaller home range sizes found in local owl telemetry studies (Irwin *et al*., 2004).

Southern Cascades versus Klamath Province

There appears to be a small difference between the Klamath mountains and Southern Cascades provinces in our study. The amount of woodrat biomass appears to be higher in the Klamath mountains as compared to the Southern Cascades. However, a potential sampling bias in our field data collection (i.e. n=279 Klamath Mountains vs. n=60 Southern Cascades) could be influencing this potential relationship. Examination of percent of woodrat and Northern flying squirrel biomass by each owl site indicates that the Klamath mountains and Southern Cascades owl sites cannot be separated within the total sample.

The influence of generally more open and drier habitats in the Southern Cascades than in the Klamath Mountains may be influencing a difference in secondary prey species. In the Southern Cascades rabbits and gopher comprise 12.8% of the biomass while only 3.7% in the Klamath mountains. These open habitat species may play an important role in the Southern Cascades in "replacing" or "substituting" for woodrat biomass.

Habitat Type and Elevation

Other studies have found that typically Northern flying squirrels are the predominate prey in higher elevation coniferous forests while woodrats make up the majority of prey in lower elevation oak woodlands (Munton *et al*., 2002). Our results appear to confirm this observation as our Ponderosa pine habitats were significant ($p<0.05$) at predicting woodrat biomass. While not significant, other results indicate that Northern flying squirrels are correlated with higher elevation habitats like white fir and negatively correlated with lower elevation non-conifer habitats like open oak woodland and grasses.

Munton *et al*., (2002) also found that the primary prey species at higher elevations (>4000 feet) was flying squirrels while woodrats were at lower elevations (<4000 feet). While not significant our results examining elevation also found that woodrat biomass was greater at lower elevations than at higher elevations. Our results suggest that flying squirrels may be the primary prey species at owl sites above 5,000 feet that are dominated white fir habitats. Our results also suggest that woodrats may be the primary prey species at owl sites below 5,000 feet that are dominated by Ponderosa pine and Douglas-fir habitats. The difference in elevation (5,000 feet vs. 4,000 feet) may be explained by the relatively high elevations of our conifer forests and owl sites which are some the highest recorded owl nest sites in the range of the species (Farber and Crans, 2000).

Habitat Tree Size and Density

Similar to other studies we did not find significant differences in the size or amount of large trees or density of stands (canopy closure) between sites to predict percent biomass of woodrats or flying squirrels (Zabel et al., 1995). Our results also indicate that owl diets consist of a variety of prey items with woodrat sp. and Northern flying squirrel being the dominant prey item. However, due to our relative small sample size (n=7) we had several tree size independent variables that were modestly correlated with flying squirrels but were not significant. We also had several tree density independent variables that were modestly correlated (negative coefficient) with flying squirrels but were not significant. Our results indicate that maintaining a variety of habitats for both woodrat sp. and Northern flying squirrel within owl sites maybe beneficial for foraging Northern spotted owls.

6.0 Conclusions

1) Northern spotted owls consume a wide variety of prey including 16 individual species of mammals, 5 species of birds, and 1 species of insect.

2) Based on 339 individual prey items, woodrat sp. and Northern flying squirrel represented 70% of the individual prey items and 88% of the biomass in our study.

3) Mean biomass of 163.0 grams (SE+/- 5.8 grams) appears to be similar to results of another study in the interior southwest province of Oregon (142.1, SE +/- 5.0 grams).

4) Woodrat sp.(60.6%) followed by Northern flying squirrel (28.2%) biomass were the primary prey species for Northern spotted owls in the Klamath mountains.

5) Woodrat sp. (46.6%) followed by Northern flying squirrel (34.1%) biomass were the primary prey species of Northern spotted owls in the Southern Cascades.

6) No independent variables including tree species, size or density were significant at predicting the percent of Flying squirrel biomass for an owl site.

7) The percent of Ponderosa pine habitat within a 0.7 mile circle was significant ($R2=0.53$, $p<0.05$) at predicting the percent of woodrat biomass for an owl site.

8) Results of a step-wise logistical regression constructed a model where the percent of Ponderosa pine and Douglas-fir habitat within a 0.7 mile circle was significant ($R2=0.85$, $p<0.05$) at predicting the percent of woodrat biomass for an owl site.

9) While not statistically significant, elevation may be negatively associated with the percent of woodrat biomass and positively associated the percent Northern flying squirrel biomass for an owl site.

10) Our results indicate that owl diets consist of a variety of prey items. Habitat associations with each prey species indicate that maintaining a variety of habitats within owl sites maybe be beneficial for foraging Northern spotted owls.

7.0 Acknowledgements

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Habitat Relations

Habitat Selection by Northern Spotted Owls in Mixed-Coniferous Forests

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ABSTRACT Conservation planning for the federally threatened northern spotted owl (*Strix occidentalis caurina*) requires an ability to predict their responses to existing and future habitat conditions. To inform such planning we modeled habitat selection by northern spotted owls based upon fine-scale (approx. 1.0 ha) characteristics within stands comprised primarily of mixed-aged, mixed coniferous forests of southwestern Oregon and north-central California. We sampled nocturnal (i.e., primarily foraging) habitat use by 71 radio-tagged spotted owls over 5 yr in 3 study areas and sampled vegetative and physical environmental conditions at inventory plots within 95% utilization distributions of each bird. We compared conditions at available forest patches, represented by the inventory plots, with those at patches used by owls using discrete-choice regressions, the coefficients from which were used to construct exponential resource selection functions (RSFs) for each study area and for all 3 areas combined. Cross-validation testing indicated that the combined RSF was reasonably robust to local variation in habitat availability. The relative probability that a fine-scale patch was selected decreased nonlinearly with distances from nests and streams; varied unimodally with increasing average diameter of coniferous trees and also with increasing basal area of Douglas-fir (*Pseudotsuga menziesii*) trees; increased linearly with increasing basal areas of sugar pine (*Pinus lambertiana*) and hardwood trees and with increasing density of understory shrubs. Large-diameter trees (>66 cm) appeared important <400 m from nest sites. The RSF can support comparative risk assessments of the short- versus long-term effects of silvicultural alternatives designed to integrate forest ecosystem restoration and habitat improvement for northern spotted owls. Results suggest fine-scale factors may influence population fitness among spotted owls.

KEY WORDS discrete choice, habitat selection, mixed-coniferous forests, northern spotted owl, resource selection function, risk assessment, RSF, *Strix occidentalis caurina*.

Public forest and resource managers in the western United States are seriously challenged to recover wildlife listed under the United States' Endangered Species Act of 1973 while concomitantly addressing economic interests, climate-change concerns, and forest-health problems. Private timberland managers are equally challenged with producing wood products and fiber sustainably while meeting environmental goals such as avoiding incidental take, a legal term for harming, harassing, or killing listed species incidental to otherwise legal activities. No other federally listed wildlife species exemplifies such dilemmas more than the threatened northern spotted owl because it is closely associated with economically- and ecologically valuable late-successional and old-growth forests, many of which are considered at risk to devastating wildfires and epidemics of insects and forest diseases (United States Fish and Wildlife Service 2008).

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An early conservation strategy for the northern spotted owl (Thomas et al. 1990) recommended development and testing of silvicultural prescriptions that might enhance existing habitats in the short term (<5 yr) or produce new habitats over the long run (>50 yr). The latest recovery plan for the northern spotted owl (United States Fish and Wildlife Service 2008) proposed a strategy for dry forest landscapes of the eastern and southern Cascades Mountains that would employ silvicultural prescriptions to reduce fuel loads and restore more-natural ecosystem patterns and processes over the long term. Before potential silvicultural prescriptions are widely applied for such purposes, there is first a need to understand how spotted owls are likely to respond. This is particularly true for treatments that might target specific tree size-classes for removal or retention, reduce forest density, or modify tree species composition, such as to favor fire-adapted or shade-intolerant species.

Unfortunately, scant information exists to support comparative risk- versus benefit assessments of the short- and long-term consequences to northern spotted owls from implementing, or not implementing, ecologically motivated silvicultural treatments. This is especially true for relatively dry mixed-age, mixed-coniferous forests that occur in the eastern Cascades Mountains of Washington and Oregon and the southern Cascades of northern California, where spotted owl–habitat relationships remain poorly documented. Irwin et al. (2007) developed a resource selection function (RSF) that could be linked with forest vegetation simulators or wildfire-risk models within a risk-assessment framework for mixed-coniferous forests occupied by the California spotted owl (*S. o. occidentalis*), and Roloff et al. (2005) used extant literature and an unpublished model to compare short- and long-term risks to spotted owl habitat from large, intensive wildfires in the southern Oregon Cascades. However, owl–habitat relationships may differ between the 2 subspecies and robust models are needed that incorporate silviculturally induced changes in tree species composition and density, as well as associated changes in understory vegetation. Predictive modeling of spotted owl responses to vegetative conditions at scales ranging from individual home ranges to the population level will assist in conservation and recovery planning.

Scale of an investigation plays a critical role in determining patterns of habitat selection (Johnson 1980, Karl et al. 2000). Previous investigations of habitat selection by northern spotted owls compared amounts of used versus available seral stages, age classes, or cover types at the scale of forest stands within annual home ranges (e.g., Forsman et al. 1984, Lehmkuhl and Raphael 1993, Glenn et al. 2004) or across landscapes (Meyer et al. 1998). Such categorical analyses included implicit assumptions that forest stands were relatively homogeneous in structure and tree- and understory-species composition, and that space use by owls was evenly distributed within stands and across home ranges.

However, structure and composition often vary widely within seral stages (Spies and Franklin 1991), and classification of forest stands according to successional stages can be ambiguous by collapsing such variation. Moreover, as central-place foragers (Carey and Peeler 1995, Rosenberg and McKelvey 1999), spotted owls do not use their home ranges evenly (Bingham and Noon 1997). Further, vegetation classifications based upon even-aged concepts may not apply in mixed coniferous forests where frequent disturbances and previous timber harvesting created multi-aged cohorts within stands (Camp 1999, Taylor and Skinner 1998). Also, selective silviculture and forest-fuel reduction programs do not change seral stages; instead they modify heterogeneity by altering tree density and composition, tree size-class distribution, and understory vegetation, complicating seral-stage mapping. Lacking such details, seral-stage or cover-type classifications could mislead relative risk analyses that compare initial spotted owl responses to habitat modification with potential long-term responses to future forest conditions.

Zabel et al. (1992) recommended that researchers measure continuous fine-scale details such as basal area and tree density for evaluating responses by spotted owls to modifications of forest habitats. Indeed, northern spotted owls are capable of identifying and intensively using small patches within what otherwise would be classified and mapped as homogeneous stands or seral stages based on characteristics of predominant overstory trees (Buchanan et al. 1995; Carey and Peeler 1995; Irwin et al. 2000, 2007). Wildlife habitat selection and home range characteristics emerge from successive behavioral choices made at such small scales (Moorcroft and Lewis 2006). These choices may affect the balance of costs and benefits, such as tradeoffs between foraging and risk of being killed by a predator (Partridge 1978, Rosenzweig 1985). Foraging habitat selection and other nocturnal behaviors such as territory maintenance are assumed to influence lifetime reproductive performance and survival (Newton 1979). Fluctuations in reproduction and fledgling survival, in turn, are believed to drive annual variability and short-term population trends in spotted owl populations (Franklin et al. 2000, Seamans et al. 2001).

We investigated patch-scale habitat selection by northern spotted owls in dry, mixed-conifer forests to inform forest and wildlife resource managers and thereby contribute to integrated owl recovery and forest restoration. We quantified nocturnal habitat choices by individual northern spotted owls in relation to physical (i.e., abiotic) environmental factors and spatial variation in vegetation structure, density and composition resulting from natural disturbances and previous forestry practices (largely partial harvesting). Our goal was to construct and test RSFs linking data from forest-inventory plots with nocturnal locations of radio-tagged northern spotted owls occupying landscapes that represented a gradient from relatively less-intensively managed federal forests to more-intensively managed private industrial timberlands. Resource selection function (RSF) models have applications in cumulative effects analyses or risk assessments, forest landscape management planning, and population viability analyses (Boyce et al. 1994, Boyce and McDonald 1999, Aldridge and Boyce 2007). We wanted to use the RSFs to suggest silvicultural prescriptions for testing within an adaptive management framework and to inform relative risk assessments for larger scales. Thus, our objectives were: 1) identify factors associated with habitat selection by northern spotted owls in dry, mixed coniferous forests; 2) quantify vegetative and abiotic factors into a reliable RSF model that can predict selected patches within spotted owl home ranges; and 3) inform large-scale conservation and management strategies that account for owl habitat selection in mixed-conifer forests.

STUDY AREA

We identified 3 dry-forest study areas near Klamath Falls (KLAM) and Medford (MED), Oregon, and Yreka (YREK), California, USA (Fig. 1) at the interface of the Southern Cascades and Klamath Mountains Provinces of southwestern Oregon and north-central California. We chose these areas because land management agencies or private landowners had scheduled silvicultural activities in areas occupied by northern spotted owls and because they exhibited effects of a broad range of previous forest management activities. Elevations ranged from 600 m to 2,200 m above mean sea level. Forests primarily included those within the Mixed-Conifer, *Abies concolor* and *Abies magnifica shastensis* Zones (Franklin and Dyrness 1981, Sawyer 2007).

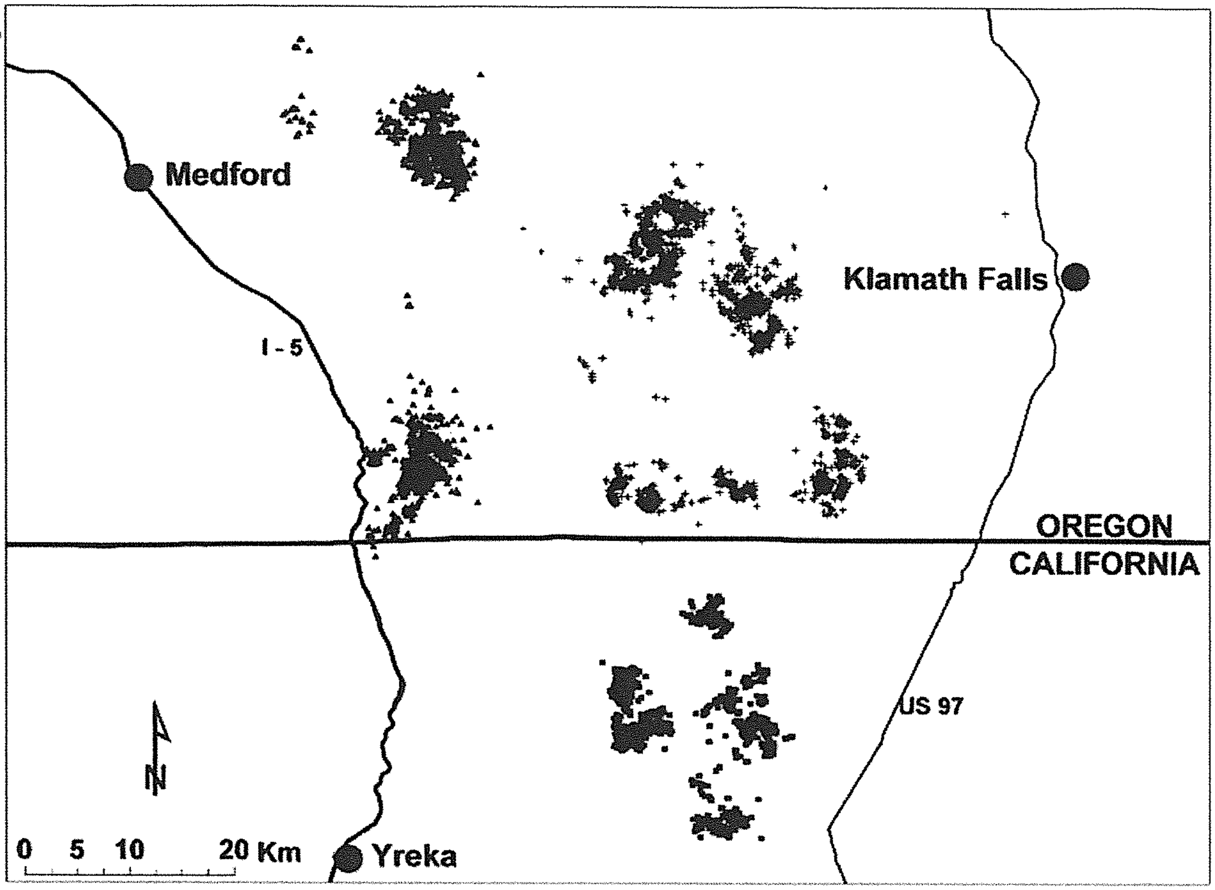

Figure 1. Study-area locations for evaluating foraging (nocturnal) habitat selection by radio-tagged northern spotted owls, including telemetry locations from 1998 to 2003 at Medford, Oregon (solid triangles), 2002–2006 at Klamath Falls, Oregon (pluses), and 1998–2003 at Yreka, California (solid squares), USA.

Mixed conifer forests, which predominated at mid- and lower elevations in our study areas, were shaped by long dry periods annually and by frequent wildfire disturbances that created multiple cohorts within stands (Taylor and Skinner 1998). Over the past century, many of these forests were also modified via selective harvesting, clearcutting and shelterwood harvesting, as well as fire suppression activities. Combined, these multiple factors and disturbances promoted highly variable forest landscapes comprised of heterogeneous mixtures that ranged from shrubfields, recent clearcuts and partially harvested stands, dense patches of mixed-age shade-tolerant trees such as white fir (*A. concolor*) and large remnant, shade-intolerant trees such as Ponderosa pine (*Pinus ponderosa*) and Douglas-fir (Skinner 1995) to multi-layered patches dominated by large, presumably old trees. Many forest stands were considered at-risk to extensive stand-replacing wildfires, particularly in conjunction with outbreaks of insects and forest diseases.

Major tree species included California red fir (*Abies magnifica)* or Shasta red fir (*A.m.* var *shastensis*) at the highest elevations, whereas mid- and lower elevations were comprised of Douglas-fir, sugar pine, ponderosa pine, incense cedar (*Libocedrus decurrens*), and white fir, with occasional California black oak (*Quercus kelloggii*), Oregon white oak (*Q. garryana*), and locally abundant bigleaf maple (*Acer macrophyllum*) and Pacific madrone (*Arbutus menziesii*). Important shrubs included golden chinquapin (*Castanopsis chrysophylla*), Pacific dogwood (*Cornus nuttallii*), canyon live oak (*Quercus chrysolepis*), creeping snowberry (*Symphoricarpos mollis*), various *Ceanothus* spp., and green manzanita (*Arctostaphylos patula*). The forests also were occupied by potential predators of spotted owls including northern goshawks (*Accipiter gentilis*) and great-horned owls (*Bubo virginianus*). During our study barred owls (*Strix varia*), a major competitor (Gutiérrez et al. 2007), were scarce compared to other regions in the range of northern spotted owls.

METHODS

Field Methods

Telemetry.—We collected data from 1998 to 2003 at MED and YREK, and from 2002 to 2006 at KLAM. Within these areas, we chose locations that had been occupied for ≥5 yr by spotted owl pairs that had exhibited successful reproduction prior to our study. Adult spotted owls were located and captured using accepted procedures and animal-welfare protocol (Forsman 1983). All captured birds were fitted with 7.5–8.0 g backpack harness transmitters (<1.5% adult owl body mass) and monitored for nesting attempts and reproductive success. Radio-tagged owls were recaptured and fitted with new transmitters biannually, or sooner if transmitters failed prematurely. Loehle et al. (2005) reported comparatively high survival rates (>0.90) for a widespread sample of radio-tagged owls that included those in this study. Foster et al. (1992) found that backpack-harness transmitters >19 g reduced reproductive success among spotted owls, consistent with effects of transmitters on birds in general (Barron et al. 2010). During our study, annual fecundity rates of owl pairs ranged from 0.0 to 0.35, but we had no unbiased means of determining whether the comparatively small transmitter-backpack units significantly influenced reproductive rates.

We recorded habitat use via standard radio-tracking methods described by Carey et al. (1989) and Millspaugh and Marzluff (2001). We sought to map the locations of each owl 2–3 nights per week each year to provide a reasonably large, temporally independent sample (Guetterman et al. 1991). We rotated the order of tracking weekly to create a range in nocturnal (i.e., 1 hr after sunset to 1 hr before sunrise) sampling times for each bird. We obtained transmitter signals using hand-held 3-element Yagi directional antennae (Wildlife Materials, Inc., Carbondale, IL or Telonics, Mesa, AZ). We triangulated positions of owls, which often remained motionless as sit-and-wait predators, from 3 azimuths recorded within 10–15 min from geo-referenced receiving stations along access roads, using methods similar to Glenn et al. (2004). Coordinates of receiving stations and telemetry locations were stored in a database using LOAS software (Ecological Software Solutions, LLC, Tallahassee, FL, USA). Extensive road systems helped mitigate many of the well-known radio-tracking problems by allowing field personnel to acquire most signals <400 m from owls. We mapped azimuths of signals in the field on 1:24,000 topographic maps. If a mapped triangulation polygon was >3 ha, we discarded the location and recorded another sample. We assessed the accuracy of our telemetry system by placing transmitters at locations <600 m from and unknown to radio-tracking crews. Average distance of 159 estimated locations to the true geo-referenced transmitter locations was 84 m (SE = 12 m), with a median value of 56 m, and 94% of the triangulations resulted in error polygons <1.0 ha.

Sampling available habitat conditions.—We defined a patch as a 1-ha unit that was more homogeneous with regard to tree- and understory-species composition and density, structures, and tree size than the stand within which it was embedded. To characterize such patches, we obtained forest inventory data from collaborating private landowners who inventoried their forests during the study period. Our field crews also inventoried associated federal timberlands shortly after we completed radio-tracking, using random-start assignment and the same methods as applied to private timberlands, which included an approximate density of 1 inventory plot/1.6 ha. Thus, the distribution of inventory plots was within the resolution of the telemetry system. Cooperators provided additional inventory information to update habitat conditions for areas where timber harvesting occurred during the study. We estimated available habitat conditions within cumulative individual 95% utilization distributions (1–1.5 yr), using program BIOTAS (Ecological Software Solutions, LLC). Following Irwin et al. (2007) we assigned habitat data to telemetry locations based upon the inventory plots, except that we discarded telemetry points ≥100 m from inventory plots (i.e., approx. mean telemetry error + 1 SE).

We identified variables to measure based on previous research involving factors influencing prey species (e.g., Carey 1991, 1995; Carey et al. 1992, Zabel et al. 1995, Carey and Harrington 2001, Anthony et al. 2003), habitat selection by spotted owls (e.g., Haufler and Irwin 1994, Glenn et al. 2004, Irwin et al. 2004, McDonald et al. 2006), or potential utility for silvicultural options (e.g., Irwin et al. 2007). These variables included vegetation characteristics, physical environmental factors, and map-based features. We used variable-radius plots (Bell and Dilworth 1990) to estimate several metrics of forest density: basal area, quadratic mean diameter (QMD; diam of a tree of average basal area), trees per hectare (TPH), tree density-by-diameter class, and stand-density index (SDI) by diameter class (Long 1985, Lilieholm et al. 1993). We counted shrub clumps, downed trees, and snags (>50 cm dbh) in 0.2-ha circular plots. We derived map-based features from a digital elevation model in a geographic information system (GIS).

Statistical Analyses

We employed a statistical method that permitted an examination of factors that could be scaled-up from patches used by a collection of individuals to predict how a spotted owl population might respond to variation in topography and vegetation conditions across a landscape. We chose the discrete-choice RSF (Manly et al. 2002, McDonald et al. 2006) as an estimating function and for its predictive value, not for statistical inference because statistical inference is not a particularly useful concept in habitat modeling (Boyce et al. 2002). Discrete-choice models can account for habitat changes that occur during a study (e.g., logging or wildfires), and allow comparisons among used resource units, or covariates of the resource units, with those available (described as choice sets) within individual home ranges.

Classic discrete-choice models assume that when a choice is made from each of several sets of units, a new random sample of available units is taken (Manly et al. 2002: 162), but McDonald et al. (2006) showed that a simplified discrete-choice model based upon a single random sample of available units yields valid results. If the choices are independent and data are available for all units that may be selected, then the classic discrete-choice model can be applied because it is not necessary that the choice set change for each selection (McDonald et al. 2006). Therefore, we acquired a single random-start sample of available habitat choices (i.e., choice sets) within home-range sized units. We developed new choice sets after timber harvesting (usually thinning from below) changed habitat conditions within home ranges.

The methods of analyses and model construction that we adopted have been applied in previous spotted owl studies (McDonald et al. 2006, Irwin et al. 2007). Briefly, we accounted for variation in habitat availability within home ranges and during the study period by developing choice sets

Table 1. Abbreviations and descriptions of variables used in candidate models to characterize habitat selection by northern spotted owls in southwestern Oregon and northern California, USA, 1998–2006.

Variable	Definition and unit	Abbreviation
Basal area	**Cross-sectional area of all stems in a stand measured at breast height (m^2/ha)**	**BA**
Douglas-fir BA	Basal area occupied by Douglas-fir trees >12.7 cm dbh	BADFIR
Ponderosa pine BA	Basal area occupied by ponderosa pine trees >12.7 cm dbh	BAPPIN
Sugar pine BA	Basal area occupied by sugar pine trees >12.7 cm dbh	BASUG
White fir BA	Basal area occupied by white fir trees >12.7 cm dbh	BAWFIR
Incense cedar BA	Basal area occupied by incense cedar >12.7 cm dbh	BAINCED
Red fir BA	Basal area occupied by red fir >12.7 cm dbh	BARFIR
Hardwood BA	Basal area occupied by hardwood species >12.7 cm dbh	BAHDW
Quadratic mean diam	Diam of tree corresponding to average basal area of a stand of trees (cm)	QMD
Stand density index	**Combination of density and size [TPH(dbh/10)$^{1.77}$]**	**SDI**
Trees/hectare	Total number of trees/ha >12.7 cm dbh in a stand	TPH
Size class	**Density or basal area of live trees of specified size groups (e.g., $TPH_{\geq 13}$ is density of trees ≥13 cm dbh; $BA_{\geq 66}$ is basal area of trees ≥66 cm dbh**	**$BASAL_{xx}$ or TPH_{xx}**
Large snags	**No. of snags ≥66 cm dbh and >1.8 m tall**	**SNAG**
Shrub count	Number of shrubs counted in a 0.2-ha plot	SHRUB
Downed woody debris	**Number of large downed logs (≥66 cm) per 0.2-ha plot**	**DWD**
Distance to streams	Distance (m) from telemetry or random point to nearest permanent stream	STREAM
Elevation	Elevation of point (m) above mean sea level	ELEV
Roads	Distance (m) to nearest traveled road	ROAD
Nest	Distance (m) to nesting site or center of activity	NEST
Slope	Angle of slope, in degrees	SLOPE
Heatload	**Expression of slope and aspect effects, calculated as tan(SLOPE) × sin(ASPECT) + tan(SLOPE) × cos(ASPECT), following Stage (1976)**	**HEATLOAD**

circumscribed by 95% contours of the utilization distributions of individual radio-tagged spotted owls. Use of a 95% contour to define the template of availability is objective, repeatable, and consistent with home range studies for many species (White and Garrott 1990, Bingham and Noon 1997). Although home ranges of mated pairs have a high degree of overlap (Forsman et al. 1984), males and females hunt independently for prey. We did not assume uniform distribution within the zone of availability. In fact, by including map-based covariates (e.g., distance from nest sites), we explicitly accounted for non-uniform spatial patterns of distribution of use within home ranges. Utilization sets encompassed habitat choices made during 1- to 1.5-yr periods of telemetry-point acquisition for individual owls. This was done to ensure that the owls used a small proportion of the available units (Manly et al. 2002), thereby minimizing statistical contamination of the available units (Johnson et al. 2006). We compared vegetative habitat and physical **environmental covariates (Table 1) for used locations** (i.e., utilization sets) with samples of conditions at available forest inventory points within home ranges (i.e., choice sets).

We used a stratified Cox proportional hazards model in S-PLUS 8.1 (Tibco Software, Inc., Palo Alto, CA) as an approximating function to obtain estimates of coefficients for variables to include in exponential RSF models for each study area and for all study areas combined following McDonald et al. (2006),

$$w(x_i) = \exp(\beta_1 x_1 + \ldots + \beta_i x_i) \qquad (1)$$

where $w(x_i)$ **is the relative probability of selection given the set of independent variables,** $x_1 - x_i$.

We assigned used locations (telemetry points) a value of 1 and available locations (inventory plots) a value of 2 (Manly et al. 2002:208, McDonald et al. 2006). Each 1.0- to 1.5-year sample of used locations and corresponding sample of inventory plots (or choice set) comprised a stratum in the model. Strata are similar to the way that blocking factors control nuisance variation in analysis of variance (ANOVA). The stratified Cox proportional hazards model thereby accounts for potential variation among individuals and years, although it does not provide coefficients for strata.

Adhering to the principle of parsimony, we limited the number of models considered by proceeding in stages and by depending upon existing knowledge to identify covariates for plausible a priori models as hypotheses to account for variation in habitat selection patterns (Franklin et al. 2000, Burnham and Anderson 2002, Glenn et al. 2004). Although Wiens et al. (2008) suggest that information-theoretic methods are not strictly necessary because a primary purpose of RSF modeling is prediction, we used Akaike's Information Criterion (AIC) for selecting the most parsimonious models (Burnham and Anderson 2002), while ensuring that 95% confidence intervals of parameter coefficients did not overlap **0.00. Differences in AIC (or Δ_i) values >2 were considered** to indicate that models were statistically distinguishable. We used the likelihood-ratio test ($P = 0.05$) to identify models that merited further consideration.

RSF Model Development

We initiated the modeling process by comparing a small number of models (5–6) for each study area that included map-based (or planimetric) and physical environmental covariates (slope, aspect, elevation, and distances to roads, streams, and nests), including their quadratic and pseudo-**threshold (i.e., $\log_e$) transforms. We modeled aspect using trigonometric functions that included an interaction with the** tangent of slope (Stage 1976). Then, after finding no strong correlations (>0.4) among independent vegetation variables except basal area of trees >66 cm in diameter, which was correlated with QMD at KLAM ($r = 0.71$), we developed separate models that included important map-based variables plus either basal area, total tree density, or QMD and SDI (including linear and quadratic terms). We then evaluated map-based factors + patch-condition variables in models that contained the density of trees and basal area, each by size class. We included an interaction term that included distance to nests and basal area of large trees (and also QMD) because the apparent influence of large trees decreases with increased distance from nest sites (Ripple et al. 1997, Meyer et al. 1998). We selected 5–7 top models among those combinations (approx. 25 models) for further development. To these models, we added covariates representing basal areas of specific conifer species and all hardwoods, as well as counts of shrubs, snags and coarse woody debris, resulting in an additional 30 models. Finally, we compared the top 5–8 models among the 60–61 total models from individual study areas by combining data across all 3 study areas. We used selection ratios (Manly et al. 2002:141, McDonald et al. 2006) to evaluate the change in level of selection from unit changes in individual covariates, and used marginal plots to illustrate the influences of important variables that had quadratic or interaction effects by holding other variables constant at their mean values. We reported the top 5 models combined across the 3 study areas; we did not employ model-averaging because the highest-ranking models contained different forms of the same covariates and all other models had very little support, based on Δ_i.

Model testing.—Mindful that, "essentially all models are wrong, but some are useful" (Box and Draper 1987:424), we considered a useful model should be reasonably robust to variation in habitat and environmental conditions resulting from disturbances, mountainous terrain, differences among years, and differences among individual animals (Wiens et al. 2008). Given that maximum likelihood estimators assigned to exponential RSFs are approximate (Manly et al. 2002) and that there is a lack of statistical tests for model fit and accuracy (Boyce et al. 2002, Boyce 2010), the utility of RSF models depends on their ability to predict. We tested the predictive capabilities of the overall RSF by assessing the assumption that the overall model was approximately proportional to probability of use and that it could accurately order owl home ranges according to average relative probability.

We applied k-fold cross validation methods described by Howlin et al. (2004), Johnson et al. (2006), and Wiens et al. (2008), except that we compared expected to observed numbers of observations using linear regression and chi-square tests for RSFs from 3 independent study areas. We excluded data from each study area and iteratively re-estimated RSF coefficients of the best overall model for each excluded study area and for the remaining 2 study areas. We regressed estimated RSF relative probabilities of habitat-inventory plots from excluded study areas (observed) against those predicted (i.e., expected) based upon 2-study area RSFs. Following Howlin et al. (2004) and Johnson et al. (2006), we concluded the combined model was different from a random or neutral model if the slope of each regression line was different from zero. Models that are proportional to probability of use should have regression slopes not different from 1.0, an intercept of zero, and high R^2 values (Howlin et al. 2004, Johnson et al. 2006).

In addition, having independent study-area specific RSFs allowed us to determine the consistency and relative strengths of coefficients of individual model covariates among the 3 study areas. Coefficients of an overall RSF that is useful over wide geographies should not differ substantially and standard errors should not overlap zero when RSFs are estimated separately for independent study areas. We used paired t-tests to compare RSF model coefficients to assess whether changes in availability by iteratively removing each study area's data influenced the relative probability of selection. Finally, we believe that a useful model should have the capability to identify low, moderate, and high quality home ranges, so we followed the recommendations of Johnson et al. (2006) of applying chi-square tests for each observed and expected proportion to determine in which RSF probability-bins the observed frequency might differ from expected. A non-significant chi-square value indicates a model that is approximately proportional to use. Howlin et al. (2004) and Johnson et al. (2006) advocated the use of GIS to provide equal-area binning of the relative probabilities of pixels for testing purposes, but because our data were sample based, we used equal-probability bins. As an additional qualitative test and for purposes of illustration, we plotted telemetry points on relative probability maps produced from applying the combined RSF to habitat-inventory plots, smoothed into low to very high relative probabilities of selection.

RESULTS

Database

We sampled habitat selection by 71 radio-tagged spotted owls in the 3 study areas (Table 2). We delineated 133 12- to 18-month sets of telemetry points, and recorded 10,242

Table 2. Summary of database of northern spotted owls in 3 study areas in southwestern Oregon (OR) and northern California (CA), USA, 1998–2006.

Parameter	Klamath Falls, OR	Medford, OR	Yreka, CA
Years of study	2002–2006	1998–2003	1998–2003
Spotted owls radio-tracked	24	26	21
Strata[a]	45	51	37
Telemetry points	2,834	4,390	3,018
Inventory plots[b]	4,029	2,469	1,807

[a] Sample of telemetry locations acquired during 12- to 18-month period and associated habitat-inventory plots within a spotted owl home range.
[b] Variable-radius inventory plots.

telemetry locations and 8,305 inventory plots within cumulative 95% utilization distributions. We combined the 133 utilization sets with corresponding inventory plots within home ranges into 133 strata for estimating RSFs. We acquired slightly more telemetry data during the March–September nesting season than the non-nesting season (54% vs. 46%).

Based upon data from inventory plots, we found wide variation in habitat conditions within owl home ranges among the 3 study areas. Inventory plots sampled at MED contained >300 small-diameter (<25 cm dbh) trees/ha versus <201/ha at the other 2 areas, and had no appreciable red fir or sugar pine. Instead, the MED plots contained about twice as much basal area of Douglas-fir and white fir trees, more hardwood basal area, and greater densities of shrubs than plots at the other 2 study areas. We found the largest amounts of ponderosa pine at inventory plots within owl home ranges at YREK. In some cases, a single large tree provided the majority of basal area, although in many parts of our study areas basal area was the sum of numerous small trees, similar to Camp (1999).

We observed several differences among univariate comparisons (t-test, $\alpha = 0.05$) between all inventory plots and those assigned to nearest telemetry points. Compared to overall inventory plots, plots associated with telemetry points were closer to nest sites and streams, contained trees with larger QMD, greater densities and basal area of trees >66 cm diameter at breast height (dbh), greater basal area of Douglas-fir (except at KLAM), and more incense cedar (except at YREK). Plots associated with locations used by radio-tagged northern spotted owls at KLAM contained greater basal area in hardwoods, and telemetry locations contained more shrubs, except at KLAM.

We observed that 4–6 spotted owls at KLAM and MED moved to lower elevations for 6–8 weeks each winter, roosted in north-slope timber stands, and hunted within adjacent oak savannahs or manzanita shrubfields. Walk-in observations at night revealed that these owls hunted from scattered trees or snags ≤600 m from the nearest conifer forests. Approximately 8% of all telemetry locations occurred in patches with low tree basal area (<14 m^2/ha) during those periods.

Resource Selection Modeling

Top models for all 3 study areas combined included 3 abiotic or map-based variables: distance to nests (NEST), distance to streams (STREAM), and SLOPE (Table 3). Relative probabilities of habitat-inventory plots being selected at night declined rapidly with distance from nests and streams and increased with increasing slope. Aspect, slope-aspect interaction (HEATLOAD), elevation, and distance to nearest roads were not important.

The strongest support for vegetative variables in top overall models for the 3 study areas combined included QMD, basal areas of Douglas-fir, sugar pine and hardwoods, shrub counts, and interactions between basal area of trees ≥66 cm dbh (i.e., $BA_{>66}$) and distance to nests (Table 3). The final RSF then, was estimated as:

$$\begin{aligned} w(x) = \exp(&-0.207 \log_e(\text{NEST}+1) \\ &-0.0403 \log_e(\text{STREAM}+1) \\ &+0.00163(\text{SLOPE}) + 0.236(\text{QMD}) \\ &-0.223(\text{QMD}^2) + 0.0023(\text{BAHDW}) \\ &+0.00374(\text{SHRUB}) + 0.00184(\text{BADFIR}) \\ &-0.0000212(\text{BADFIR}^2) + 0.00556(\text{BASUG}) \\ &+0.00181(\text{BA}_{\geq 66}) + 0.0000518(\text{NEST}) \\ &-0.000000423(\text{BA}_{\geq 66} \times \text{NEST}) \end{aligned} \qquad (2)$$

Table 3. Coefficients and standard errors for habitat and environmental covariates in top discrete-choice resource selection functions for northern spotted owls in 3 mixed conifer study areas in southwestern Oregon and northern California, 1998–2006.

	Model A		Model B		Model C		Model D		Model E	
Covariate	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Log(NEST + 1)	−2.07e−1	8.57e−3	−2.08e−1	8.61e−3	−2.07e−1	8.57e−3	−2.07e−1	8.54e−3	−2.07	8.51e−3
Log(STREAM + 1)	−4.03e−2	3.78e−3	−3.96e−2	3.79e−5	−3.95e−2	3.78e−3	−3.97e−2	3.79e−3	−4.00e−2	3.78e−3
SLOPE	1.63e−3	6.70e−3			1.63e−3	6.70e−3				
SDI_{25-56}							**1.43e−3**	**9.75e−4**	**2.02e−3**	**1.21e−3**
QMD	2.36e−1	6.26e−2	2.35e−1	6.24e−2	2.14e−1	6.02e−2	2.18e−1	6.13e−2		
QMD^2	**−2.23e−1**	**5.39e−2**	**−2.01e−1**	**5.52e−2**	**−1.58e−1**	**5.24e−2**	**−1.56e−1**	**5.27e−2**		
$BA_{\geq 66}$	**1.81e−3**	**5.39e−4**	**1.82e−3**	**5.41e−4**			**1.84e−3**	**5.44e−4**	**3.27e−3**	**3.44e−3**
${BA_{\geq 66}}^2$									**−2.16e−5**	**1.42e−5**
BAHDW	2.30e−3	5.52e−4	2.28e−3	5.56e−4	2.52e−3	5.63e−4	2.13e−3	5.43e−4	1.88e−3	5.65e−4
SHRUB	3.74e−3	8.13e−4	3.68e−3	8.14e−4	3.81e−3	8.19e−4	3.61e−3	8.12e−4	3.63e−3	8.15e−4
BADFIR	1.84e−3	6.21e−4	1.85e−3	6.21e−4	2.12e−3	6.26e−4	1.78e−3	6.19e−4	1.84e−3	6.25e−4
$BADFIR^2$	**−2.12e−5**	**8.85e−6**	**−2.14e−5**	**8.88e−6**	**−2.31e−5**	**8.91e−6**	**−2.31e−5**	**8.91e−6**	**−2.34e−5**	**8.92e−6**
BASUG	5.56e−3	9.74e−5	5.61e−3	1.49e−3	5.36e−3	1.46e−3	5.48e−3	1.49e−3	5.48e−3	1.49e−3
QMD*NEST					**−1.98e−5**	**8.38e−6**				
$BA_{\geq 66}$*NEST	**−4.23e−7**	**1.71e−7**					**−4.10e−7**	**1.68e−7**	**−3.72e−7**	**1.71e−7**
NEST	5.18e−5	4.59e−6			5.71e−5	4.56e−6	5.15e−5	4.59e−6	5.10e−5	4.58e−6
Δ_i[a]	**0.00**		**2.8**		**9.2**		**14.4**		**24.6**	
Model rank	1		2		3		4		5	

[a] Differences in Akaike's Information Criterion (AIC) relative to the smallest AIC value (Burnham and Anderson 2002); models with values >2 are considered distinguishable.

Table 4. Selection ratios [exp(coefficient)] for variables in the top resource selection function for radio-tagged northern spotted owls in 3 mixed conifer study areas in southwestern Oregon and northern California, 1998–2006. Selection ratios measure the multiplicative change in relative probability of selection when a variable changes by 1 unit, assuming all other variables remain constant. Selection ratios were not estimated for variables involved in quadratic effects of interactions because those ratios vary with values of other variables.

Variable	Acronym	Selection ratio	Approx. 95% CI
Distance to nest (m)	NEST	0.813	0.806–0.820
Distance to stream (m)	STREAM	0.961	0.956–0.965
Slope (°)	SLOPE	1.002	1.001–1.003
Quadratic mean diam (cm)	QMD	NA	NA
Basal area of Douglas-fir (m^2/ha)	BADFIR	NA	NA
Basal area of trees ≥66 cm diam	$BA_{\geq 66}$	NA	NA
Nest distance and $BA_{\geq 66}$ interaction	NEST × $BA_{\geq 66}$	NA	NA
Basal area of hardwoods (m^2/ha)	BAHDW	1.002	1.001–1.003
Shrub density (no./0.2 ha)	SHRUB	1.004	1.003–1.005
Basal area of sugar pine (m^2/ha)	BASUG	1.006	1.004–1.006

The top model indicated that relative probabilities of selecting patches at night were associated with quadratic, or unimodal distributions of both QMD and basal area of Douglas-fir trees. Relative probabilities of habitat-inventory plots with high basal area of large trees being selected decreased with distance to nests. Relative probabilities that patches were selected at night increased linearly with increasing basal area of sugar pine and hardwoods and with increasing shrub counts. Although some models suggested a positive linear effect for SDI of intermediate-sized trees (25–56 cm dbh), the 95% confidence intervals overlapped 0.0 for that covariate, so we did not retain it in the final model. No models indicated support for pseudo-threshold relationships for vegetation covariates. We found no strong support among top models for tree density-by-size classes, basal area of ponderosa pine, white fir or red fir, or for density estimates of snags and coarse woody debris. However, some support was evident for a positive linear effect of basal area of trees of 25–66 cm dbh at KLAM, for a positive linear effect of basal area of incense cedar at MED, and for a negative influence of increasing basal area of ponderosa pine at MED.

Selection ratios (Table 4) indicated strong negative effects on relative probability of selection as distance to nest sites and to streams increased. Among other effects, the selection ratio for basal area of hardwoods suggested that the estimated relative probability of an owl selecting a patch at night increased by approximately 2% for each additional 10% increase in basal area of hardwoods, approximately 4% for each 10% additional increase in the number of shrub clumps/0.2 ha, and 6% for each 10% additional increase in basal area of sugar pine trees. Marginal plots for important model variables involved in quadratic or interaction effects (Fig. 2) indicated that the relative probability of a location within an owl's home range being a selected point for foraging declined rapidly for the first 200–300 m from nest sites (Fig. 2A). Also, relative probability appears maximized in patches with approximately 25–35 m^2/ha basal area of Douglas-fir trees (Fig. 2B). The relative probabilities of selected patches having high basal area of trees >66 cm dbh declined to low values beyond 400 m from nests (Fig. 2C). Finally, relative probability of selection appeared maximized in patches of trees with average QMD of 40–55 cm (Fig. 2D).

Model validation.—Model performance evaluations involving independent study-area RSFs indicated that nearly all coefficients for individual variables in the top model did not differ among the 3 paired study-area RSFs (Table 5), with the exception of basal area of hardwoods when MED data were excluded. Yet, variation in availability among study areas (and probably smaller sample sizes) had a detectable

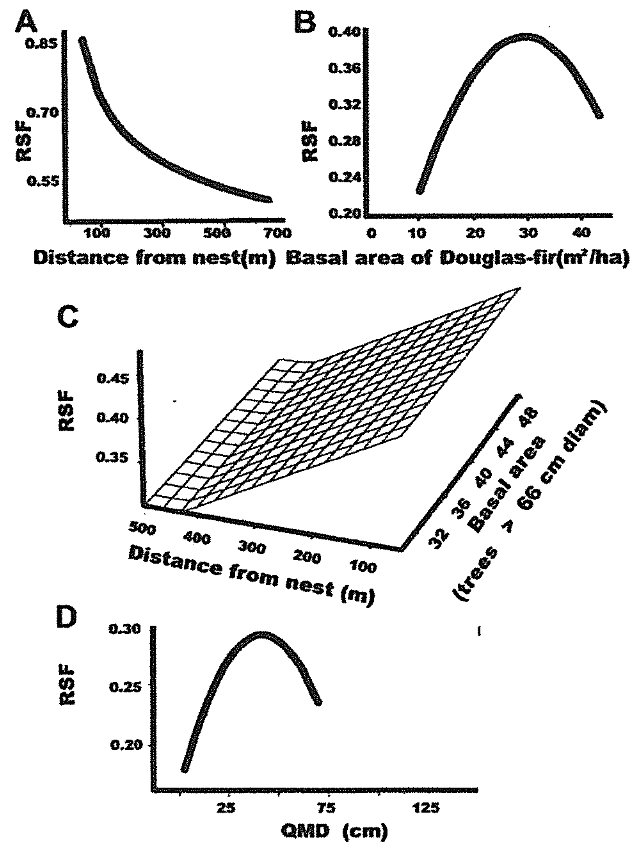

Figure 2. Marginal plots for relative probability values based on applying the top-ranked resource selection function (RSF) for northern spotted owls monitored from 1998 to 2003 at Medford, Oregon and Yreka, California, and from 2002 to 2006 at Klamath Falls, Oregon, in which all other independent variables are held constant at their means. Variables in the top-ranked model include: (A) distance from nest sites; (B) basal area of Douglas-fir trees; (C) basal area of large trees (>66 cm dbh) with increasing distance from owl nest sites; and (D) quadratic mean diameter (QMD; diam of a tree of average basal area in a patch).

Table 5. Cross-validation comparison of coefficients and standard errors (SE) of resource selection functions (RSF) for radio-tagged northern spotted owls monitored from 1998 to 2003 at Medford, Oregon and Yreka, California, and from 2002 to 2006 at Klamath Falls, Oregon. Models were constructed from covariates of overall top-ranking model in Table 3 with data from single-study areas removed and excluding the interaction between basal area of trees ≥66 cm and distance to nest sites.

	MEDFORD + YREKA		MEDFORD + KLAMATH		KLAMATH + YREKA	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Log(NEST + 1)	−2.26e−1	1.24e−2	−2.34e−1	0.99e−2	−1.80e−1	1.07e−2
Log(STREAM + 1)	−4.60e−2	4.69e−3	−4.22e−2	4.90e−3	−3.26e−2	4.37e−3
SLOPE	1.95e−3	7.06e−4	1.35e−3	8.69e−4	1.88e−3	8.49e−4
QMD	1.77e−1[a]	1.12e−1	2.85e−1	7.17e−2	3.93e−3	6.77e−2
QMD^2	−9.30e−1	9.62e−2	−1.86e−1	5.87e−2	−1.64e−1	5.98e−2
BADFIR	2.60e−3	6.67e−4	1.15e−3[a]	7.88e−4	2.66e−3	8.86e−4
BADFIR^2	−2.60e−5	9.52e−6	−1.25e−5	1.04e−5	−3.22e−5	1.65e−5
BASUG	1.46e−3[a]	2.68e−3	7.21e−3	1.78e−4	6.212e−3	1.51e−3
BAHDW	1.92e−3	5.95e−4	2.29e−3	5.78e−4	4.58e−3[b]	1.19e−3
SHRUB	4.89e−3	9.15e−4	1.89e−3	1.06e−4	3.95e−3	1.04e−3

[a] 95% Confidence interval overlapped 0.0.
[b] Coefficient differed from others in same row.

influence on RSF models, because confidence intervals for coefficients for a few covariates overlapped 0.0. These included QMD and sugar pine for MED + YREK (i.e., KLAM excluded) and basal area of Douglas-fir and shrub counts for the RSF for MED + KLAM (i.e., YREK excluded).

Regressions between observed and predicted RSF values of excluded independent study-area datasets indicated that the overall RSF was approximately proportional to use, because intercepts were zero (except at YREK), slopes were greater than zero, overlapped 1.0, and R^2 values were high. Regressing the independently estimated KLAM RSF values against those produced by re-estimating the top RSF by combining MED and YREK data returned an intercept of 0.0028 (SE = 0.0014), a slope of 0.918 (SE = 0.046), and $R^2 = 0.879$. When the independently estimated MED RSF relative probability values were regressed against those produced by re-estimating the top RSF by retaining data from KLAM and YREK, the intercept was −0.027 (SE = 0.015), the slope was 1.046 (SE = 0.045), and the $R^2 = 0.880$. When we regressed the YREK RSF values against those produced by an RSF constructed by combining MED and KLAM data, the intercept was 0.098 (SE = 0.003), slope was 0.963 (SE = 0.021), and R^2 was 0.890. Inspection of the data for individual owl home ranges for that regression indicated that the inconsistent intercept YREK was related to 6 owls at KLAM and MED that made winter movements to lower elevations and used habitats that did not occur frequently in home ranges at YREK. In cross-validation comparisons that involved 10-fold binning the relative probability values and re-estimating the top model at each study area, each chi-square test was non-significant ($P = 0.994$ at KLAM; $P = 0.787$ at MED; $P = 0.787$ at YREK), indicating the model had acceptable predictions and could correctly assign relative probability values to each owl home range. An ANOVA comparing RSF values among the 3 study areas indicated that average values of spotted owl home ranges at MED were greater than those at KLAM and YREK ($P = 0.043$). The top overall model was capable of predicting telemetry-point distributions at each of the 3 study areas (e.g., KLAM; Fig. 3).

DISCUSSION

We used a repeated-study approach to estimate a discrete-choice RSF that appears capable of accurately predicting foraging locations and is reasonably robust to variation in habitat availability across our study region. Covariates in the RSF model are generally consistent with expectations from previous research on spotted owls and their prey base, and with predictions from foraging theory. Such theory suggests that interactions among vegetation structures and abiotic factors should influence the balance between costs (e.g., energy expenditure, risk to being killed by a predator while foraging) and gains (e.g., energy or nutritional benefits) of alternate patch choices (Partridge 1978, Rosenzweig 1985, Stephens and Krebs 1986). Our analyses also identified spatial interactions between physical environmental factors and fine-scale vegetation details that are associated with foraging habitat selection. For example, northern spotted owls spent disproportionate amounts of time searching for prey in forest patches near or in riparian zones of small, low-order streams. Solis and Gutiérrez (1990), Carey (1995), and Carey and Peeler (1995) made similar observations for northern spotted owls, as did Irwin et al. (2007) for California spotted owls. Our results are also consistent with previous research that found that habitat choice by spotted owls is influenced by hardwood trees (Glenn et al. 2004, Irwin et al. 2007) and understory shrubs (Carey 1995) that produce fruit and mast supplies for the owls' small mammal prey.

Also similar to previous investigators (Hunter et al. 1995, Ripple et al. 1997, Meyer et al. 1998, Thome et al. 1999), we found strong empirical support for selection of patches with large (>66 cm dbh), presumably older trees when such trees were near nest sites. The statistical interaction between basal area of large trees with distance from nest sites in our RSF probably reflects selection of such large trees for nests (Buchanan et al. 1993, Hershey et al. 1998, LaHaye and

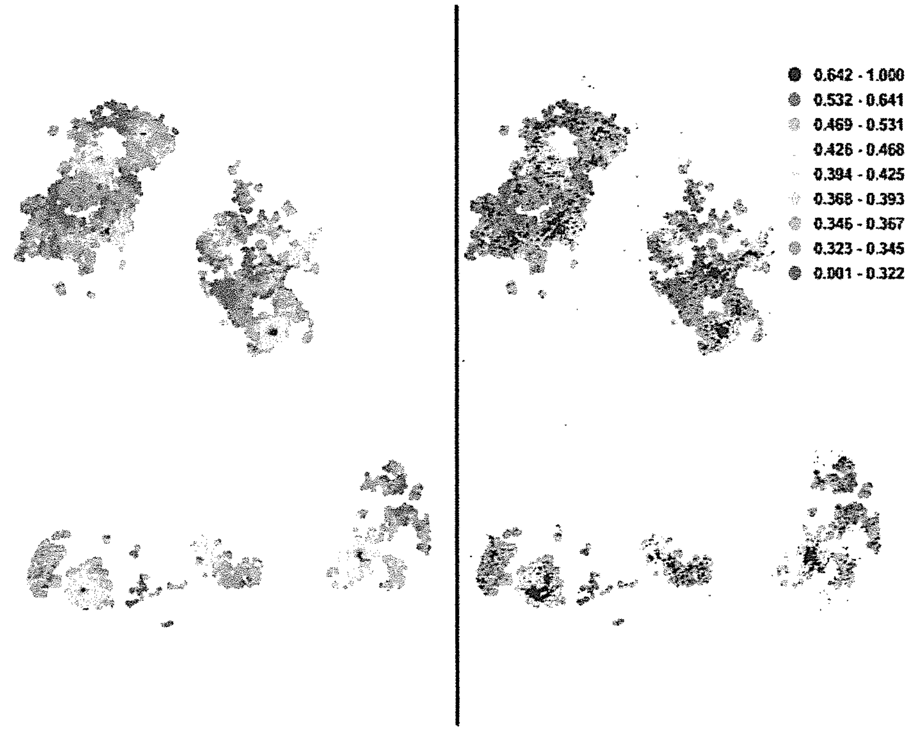

Figure 3. Illustration of the application of our regional resource selection function (RSF) to habitat-inventory plots in the Klamath Falls study area (KLAM) of southwestern Oregon, USA. Colored circles represent increasing relative probabilities of use by northern spotted owls from low (blue) to high (red). We overlaid the relative probability maps on the right half on triangulated locations of radio-tagged northern spotted owls (black dots), demonstrating a close association between predicted and actual nocturnal use by 26 radio-tagged spotted owls monitored from 2002 to 2006. Telemetry points (dots) beyond the colored areas were outside the 95% contour of the utilization distributions and therefore had no associated habitat-inventory plots.

Gutiérrez 1999), as well as concentrated use near nests, intuitive for central-place foragers (Carey and Peeler 1995). We considered this effect an interaction, rather than a confounding effect, because it was biologically plausible and was statistically significant (Hosmer and Lemeshow 1989:67). This was further supported by correlation analysis indicating that basal area of trees >66 cm dbh did not vary with distance from nests ($r < 0.2$, $P = 0.29$). If selection for such large trees occurred equally at all locations within home ranges, the interaction term in our model would not have been statistically significant. Selection of large trees for nests and choice of nest-site location may afford greater protection against predators and/or inclement weather (Newton 1979, Buchanan et al. 1995), but the need to care for nestlings may restrict travel. If that hypothesis holds, then tradeoffs probably occur between conditions that promote nestling survival and other conditions that promote access to abundant sources of prey (Franklin et al. 2000). For example, Carey et al. (1992) found that spotted owls are capable of depleting populations of prey in intensively hunted sites, which would include areas near nest sites. Therefore, it seems plausible that an optimal landscape for spotted owls in this region might include a grove or stand of large-diameter trees that **promotes security while raising young that is embedded** within a heterogeneous forest landscape that provides high-quality foraging habitat (Franklin et al. 2000). In our study areas, selection of patches with such large trees apparently extended to about 400 m from nest sites (Fig. 2C), which would encompass an area of 50 ha.

We also identified several influences on spotted owl habitat selection that have not been included in previous studies of northern spotted owls. For example, we found that the relative probability of a patch being selected at night increased in unimodal (convex) relationships with increasing QMD and with basal area of Douglas-fir trees, suggesting that an optimal forest overstory condition may exist that promotes successful acquisition of prey. Densities of important prey such as northern flying squirrels (*Glaucomys sabrinus*) are anticipated to be low in open forest patches with low basal area (Waters and Zabel 1995). Alternative prey that occur in open areas, such as woodrats (*Neotoma* spp.), might be less readily captured if the areas contain extremely dense understory shrubs (Solis and Gutiérrez 1990) or hardwoods. Such very dense protective cover for prey could explain why hardwoods were not selected by spotted owls at MED, where hardwoods were highly abundant, whereas owls may acquire prey as the prey seek mast on the surface of dense manzanita shrub mats. Similarly, northern flying squirrels may be relatively abundant but less readily captured in very dense conifer patches with high basal area. Douglas-fir trees may be a favored tree species for foraging because red tree voles are associated with intermediate basal areas **(approx. 20 m^2/ha)** of trees 45–90 cm dbh (Dunk and Hawley 2009), and because of associations between Douglas-fir and the hypogeous ectomycorrhizal fungi that support northern flying squirrels (Carey and Peeler 1995, Lehmkuhl et al. 2006). Also, we found that basal area of sugar pine, which was not abundant, exerted strong effects in

RSF models. Sugar pine may be important for spotted owl prey because sugar pine cones are large (up to 56 cm in length) and produce large amounts of large seeds (>150 seeds/cone at 0.23 g/seed, Kinloch and Scheuner 1990). Finally, we observed that some 25% of spotted owls often foraged within oak savannahs in winter at lower elevations or within manzanita shrubfields (in all seasons) that contain low basal areas of conifer trees. The presence of a few scattered trees or snags probably facilitated hunting for prey, which we presume included dusky-footed woodrats (*Neotoma fuscipes*). For example, a pair of spotted owls at YREK made extensive use of an 8- to 10-yr-old 120-ha burn at high elevation that contained extensive manzanita patches and scattered live trees.

Contrary to anticipated negative influences, our top-ranking RSF did not include SDI, density of small-diameter trees, or overall tree densities, although coefficients were often in the expected direction in some models we tested. Also, we were unable to confirm that downed woody debris or large snags influenced foraging habitat selection in this landscape. However, densities of such structures were low and highly spatially variable.

Stand-level categories of seral-stages or age classes representing late-successional and old-growth forests have heretofore provided the basis for habitat mapping, predictive modeling, and conservation planning (e.g., Thomas et al. 1990, United States Fish and Wildlife Service 2008) because of consistent results of chi-square analyses that demonstrated disproportionately greater use by northern spotted owls. Indeed, old-forest seral stage and local ad hoc definitions of foraging habitat can accurately predict nesting locations of northern spotted owls (e.g., Zabel et al. 2003). However, spatial interactions and abiotic factors such as proximity to productive riparian zones have not previously been included in conservation planning. Further, such habitat-type categories correlate relatively weakly or in contradictory patterns with population performance measures among northern spotted owls (e.g., Raphael et al. 1996, Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005). Such variation led Boyce et al. (2005) and Gosselin (2009) to suggest that the habitat issue for northern spotted owls remains unclear. We suggest that the confusion resulted because vegetation cover-types inadequately capture fine-scale, complex interactions and features that influence population performance among spotted owls, as has been observed for other bird species (Cushman et al. 2007).

Waring and Running (2007) stated that scientists can safely progress from patch, to site or individual organism scales to eco-regional simulations only after attaining reasonably good understanding of factors and principles underlying ecological processes operating at fine scales and after those features have been synthesized into some type of demonstrably reliable model framework. This study, Irwin et al. (2007), and Lehmkuhl et al. (2006) suggest that fine-scale details matter greatly to spotted owls and their prey, thereby calling into question the dependency on coarse stand-level characteristics such as vegetation-type or seral stage. Habitat-type categories at the scale of forest stands may be too coarse to serve as a reliable surrogate for complex interactions among overstory and understory vegetation structure, tree species composition, and the physical environment. Future researchers may want to incorporate basal area by tree species for use in scaling up to larger areas, because of its link with leaf-area index (Oren et al. 1987). Leaf-area index can be measured remotely and has been used in ecosystem models. Doing so might promote development of ecosystem function models that link RSFs for spotted owls with mechanistic models of space use (Moorcroft and Barnett 2008).

Our datasets undoubtedly contain errors commonly associated with telemetry triangulation in mountainous environments and with assignment of vegetation data that may vary across scales finer than the resolution of our telemetry system (approx. 1 ha). Equally important, use-availability studies such as ours do not necessarily provide information on habitat quality or evidence that the preferred conditions are necessary for spotted owl survival and reproduction. Inferences from RSFs are associative, not causative. Primary factors of interest, or environmental exposures, are themselves involved in complex interactions with each other and with other factors that, in turn, may be confounded with still other factors (Riggs et al. 2008).

Despite those caveats, RSFs that are constructed from fine-scale vegetation details and physical environmental influences, and incorporate features of foraging habitat believed to influence owl population fitness may illuminate basic determinants of habitat selection, that is, those factors to which animals are adapted (Manly et al. 2002). For example, we observed winter foraging in relatively open oak stands at lower elevations and in manzanita shrub-fields at all elevations. Such patch conditions might influence survival or reproductive success by promoting high nutritional condition of females prior to egg-laying and incubation, as Meijer et al. (1988) demonstrated for Eurasian kestrels (*Falco tinnunculus*). However, patches of non-coniferous vegetation, often at ecotonal situations at lower elevations, or small burned areas at higher elevations, traditionally have been assumed to be non-habitat for northern spotted owls. We recommend further research on the potential importance of such foraging habitats. Moreover, new research is needed to link RSF models such as ours to indicators of fitness, such as correlating the RSF values at habitat-inventory plots within a core area (approx. 200 ha) with estimates of reproductive success and survival.

MANAGEMENT IMPLICATIONS

The U.S. Fish and Wildlife Service (2010) recommended development of relative risk assessment tools and province-specific definitions of foraging habitat. Our RSF supports both objectives. We believe our analyses also support habitat improvement as integral to conservation and recovery for northern spotted owls in fire-prone, mixed coniferous forests, with caveats that our RSF model should not be applied beyond the ranges of conditions in our study areas and that nest sites require special protection (e.g., Hershey et al. 1998), including retention of greater basal area and large trees.

Silvicultural activities that retain mature sugar pines and create intermediate basal areas (25–55 m^2/ha) dominated by 30–60 cm dbh Douglas-fir trees are likely to improve foraging habitats for northern spotted owls by supporting hardwoods and shrubs important to dusky-footed woodrats (Atsatt and Ingram 1983). Residual basal area appears most important, and probably can be achieved in the 1st entry of a silvicultural prescription that emphasizes retention and growth of shade-intolerant trees such as Douglas-fir and sugar pine, which are well adapted to growing in canopy gaps. Gaps between 0.07–0.13 ha provide sufficient light for regeneration of shade-intolerant tree species such as ponderosa pine (Gersonde et al. 2004). Silvicultural prescriptions derived from our study would require testing in an active adaptive management framework.

Discrete-choice RSFs allow conclusions to be made at the population level (Cooper and Millspaugh 1999, Manly et al. 2002), thereby facilitating landscape assessment. Thus, our RSF could assist landscape scale conservation planning by forecasting short-term consequences of alternative silvicultural treatments at scales of a home range or territory-sized unit ($\leq$400 ha), following McDonald and McDonald (2002) and scaling up to assess alternative conservation strategies across landscapes, similar to Boyce et al. (1994). Because numerous locations of northern spotted owls have been obtained via surveys or can be identified via modeling (e.g., Zabel et al. 2003, U.S. Fish and Wildlife Service 2010), the RSF can also apply large-scale vegetation data (e.g., Ohmann and Gregory 2002) to assist with forecasting long-term consequences of forest management alternatives at landscape scales when linked with forest-growth simulators and fire-risk models (e.g., Ager et al. 2007). Associated probabilistic maps also could be correlated with demographic performance (Aldridge and Boyce 2007).

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NORTHERN SPOTTED OWL RESOURCE PLAN

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Amended March 7, 2014

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1.0 INTRODUCTION

Within the range of the Northern spotted owl (*Strix occidentalis caurina*) W.M. Beaty & Associates, Inc. (WBA) manages private forestland owned by four separate private owners. These private owners include Red River Forests, LLC, Shasta Forests Timberlands, LLC, Lassen Forest I Pondosa, LLC and Area H, LLC, hereinafter referred to as "WBA managed lands". The general philosophy of these land owners is to maintain and enhance the value of the land and resource base to pass on their legacy to their heirs. Aside from the economic incentives for maintaining the productivity of their forests, the landowners have strong conservation ethics and a willingness to manage their properties as healthy natural areas that provide aesthetic, recreational, wildlife, community, and other values.

The WBA managed lands are located near the eastern edge of the geographic range of Northern spotted owl (NSO). As expected for the peripheral margins of a species geographic range, NSO density is low in this region irrespective of land ownership and management history. Surveys for NSOs have been conducted on WBA managed lands since 1992. Over 1,000 calling stations have been surveyed and in no case has a NSO pair or nest site ever been detected on these lands. However, individual NSOs have been detected on rare occasions during surveys. Follow-up surveys conducted in the vicinity of these sporadic detections have rarely relocated NSOs that had responded at night. A nest, NSO pair, or an area that showed any signs of consistent use by NSOs (accumulations of whitewash, prey remains, regurgitated pellets, molted feathers, etc.) have never been located.

Only a portion of the WBA managed lands lie within the NSO evaluation area (Appendix A). California Forest Practice Rules (CFPRs) specifically define the NSO Evaluation Area (14 CCR § 895.1) which includes portions of Shasta and Siskiyou Counties. Additionally, the U.S. Fish and Wildlife Service (USFWS) recommend several other areas be considered when planning timber operations (USFWS 2008[a]). The Technical Assistance document states that these areas should be evaluated to determine if suitable NSO habitat exists and could be impacted by timber operations, and if so, then surveys or seasonal operating restrictions should be considered to avoid take of a NSO (USFWS 2008[a]). Specifically, this Northern Spotted Owl Resource Plan (NSORP)(14 CCR § 939.9(f)) applies to approximately 91,286 acres of WBA managed lands that lie within the NSO Evaluation Areas and within or adjacent to the those areas specified in the 2008 USFWS guidance document (Appendix A).

2.0 PURPOSE AND NEED

State and federal requirements for the protection of NSOs are continuing to evolve. The understanding of what constitutes suitable habitat for NSOs has increased over time, thus enabling better predictions of NSO occurrence and likelihood of impacts to NSOs associated with timber operations in specific sites. By applying the best available scientific information regarding NSO habitat combined with a long history of NSO survey information, this NSORP (14 CCR § 939.9(f)) establishes a programmatic approach that can be used by WBA and the California Department of Forestry and Fire Protection (Cal Fire) to ensure that take of NSOs (14 CCR § 939.10) will not occur on WBA managed lands.

Surveys for NSOs are typically conducted using a two year protocol prior to harvest activities that might affect NSO habitat or could potentially result in take of NSOs. Usually the first year of surveys is conducted the year prior to scheduled operations and the second year of surveys is conducted immediately prior to the onset of operations for that year. This timing ensures that the most currently available information is used to ensure take of NSOs will not occur. Most timber operations on WBA managed lands are low intensity, single tree selection harvests that may improve habitat, not alter habitat, or remove a small proportion of the habitat. Given the low intensity silvicultural practices on the property that maintain mature forest cover, large trees, and other habitat elements important to NSOs (large snags, cull trees, hardwood, densely forested areas with multiple canopy layers), it is not likely that NSOs or NSO habitats will be adversely impacted by timber operations. Likewise, timber operations are not usually significantly constrained by regulatory requirements to maintain occupied habitat since no nest sites or areas of concentrated use by NSOs are currently known to be present on WBA managed lands.

Developing a programmatic approach to ensure take of NSOs will not occur has proven benefits for WBA managed lands, Cal Fire and USFWS. Such an approach identifies specific information that will be provided in THPs, clearly identifies how habitat suitability is determined, and specifically describes how and when NSO surveys will be conducted, and establishes a procedure that will be applied in the event that a NSO is detected within an area that may be subject to timber harvesting. A feedback mechanism also ensures that as time passes and knowledge of where and how NSOs may be using habitat within the area covered by this NSORP increases, all parties share a common understanding as to how to ensure take of NSO does not occur. By establishing programmatic procedures, WBA and Cal Fire can avoid duplicating efforts and analyses necessary to ensure take of NSOs will not occur.

WBA prepared the original NSORP in cooperation VESTRA Resources, Inc, under the direction of Robert L. Carey a Certified Wildlife Biologist, Private Consulting Biologist No. 0029, and Spotted Owl Expert designated by Cal Fire to fulfill the requirements of 14 CCR § 939.9(a). Also, this NSORP has been edited and amended by Stuart L. Farber, WBA Wildlife Biologist, a Spotted Owl Expert designated by Cal Fire. This NSORP meets the definition of a Spotted Owl Resource Plan (14 CCR § 939.9(f)) which is "a plan that demonstrates an approach to preventing a taking of the northern spotted owl while conducting timber harvest operations. A Spotted Owl Resource Plan necessarily involves more than one timber harvest plan area (14 CCR § 895.1). WBA has previously used programmatic methods to address concerns for NSOs with both the California Department of Fish and Wildlife (DFW) (NSORP 1997) and the USFWS (Northern Spotted Owl Management Plan 1999). While both of these prior agreements were effective, they became obsolete because of changes in how NSO regulations under the CFPRs were being implemented. Based on past experience, there are proven benefits to be derived from this type of programmatic approach.

3.0 OBJECTIVES

A primary goal of this NSORP is to ensure take (14 CCR § 939.10) of NSOs will not occur during timber harvest operations conducted on WBA managed lands. An additional goal is to establish a programmatic approach to addressing NSOs in THPs prepared by WBA such that review of individual THPs as related to NSOs can be streamlined. To achieve these goals the objectives of this NSORP are to:

(1) Describe a method to determine when NSO surveys are appropriate.

(2) Establish a method that can be used to determine what areas of habitat will be surveyed when preparing THPs on WBA managed lands.

(3) Describe the protection measures that will be used in THPs implemented on lands managed by WBA to prevent take of NSOs.

(4) Provide baseline information to Cal Fire as a prerequisite of this NSORP.

(5) Describe a method of information exchange to assure Cal Fire that WBA's operations are in compliance with the NSORP.

Approval of this NSORP by Cal Fire will fulfill the requirements of 14 CCR § 939.9(f) with respect to NSOs for individual THPs filed under this NSORP. The criteria of 14 CCR § 939.10 has been used and it has been determined that when the terms and conditions detailed in this NSORP are fulfilled, that take of NSO will not occur.

4.0 SUITABLE HABITAT

The following methods will be used to determine when NSO surveys are appropriate and what areas of habitat will be surveyed. The CFPRs describe forest stand conditions that are "functional" NSO nesting, roosting, and foraging habitat (14 CCR § 895.1). Additionally, Cal Fire in cooperation with the USFWS has provided guidance to THP submitters on criteria that should be used to determine habitat suitability for NSOs in portions of interior northern California (USFWS[b]). Both the CFPRs and the USFWS use forest conditions to define NSO habitat. The USFWS adds other physiographic features and spatial elements that influence the likelihood that a particular area will support NSOs, however several of these parameters are not stated in quantitative terms. Both of these definitions include parameters such as tree diameter, basal area, density of trees of certain sizes, and canopy closure and include structural elements such as multi-storied canopies, large snags and trees with deformities, large woody debris, and decadence within the stand. Topographic relief and microclimate may also influence suitability of habitat. This NSORP uses the USFWS guidance (USFWS 2008[b]) document to categorize NSO habitat on WBA managed lands.

A critical component of the USFWS guidance (USFWS 2008[b]) is proximity of one habitat type (nesting and roosting) to another (foraging). Recent scientific research efforts to predict the likelihood of a NSO inhabiting specific forest stands in northern California have used a model selection methodology (Zabel et al. 2003). This method uses statistical analytical procedures to identify precisely which forest attributes, in what types of spatial arrangement are common among many sites known to be used by NSOs. Based on radio telemetry data from several study sites in northern California that are similar to areas covered under this NSORP, the investigators developed individual regression models that evaluated the importance of an array of variables with respect to NSO habitat suitability. The individual models were then combined to include the variables that contributed the most to predicting habitat suitability. These variables were then ranked for importance and combined into a single regression equation. The combination of parameters that best explain the differences between sites that support NSOs, and sites that do not support NSOs are expressed in a model that best predicts NSO occupancy. The final model indicated that a combination of foraging and nesting and roosting habitat was a key predictor of occupancy by NSOs (Zabel et al. 2003).

It has also been shown in other studies that NSO habitat is a combination of nesting and roosting areas interspersed and juxtaposed with foraging areas (Farber and Crans 2000, Franklin et al. 2000, Hunter et al. 1995, Irwin et al. 2004, Zabel et al. 2003). In northern California, Zabel et al. (2003) used a model selection approach and found the availability of different types of habitat, specifically nesting, roosting, and foraging habitats within a NSO core use area, could predict the likelihood that a NSO would occur in a specific area. Zabel et al (2003) concluded that their results are a good predictor of NSO occupancy within a given 200 ha (500 acre) core area and that at the 0.20 to 0.50 probability level, these results may be useful in predicting absence of NSOs within their study area. As noted above, the area of inference from Zabel et al. (2003) is similar to the lands covered under this NSORP in terms of forest type, Klamath and Sierra Mixed Conifer types, with moderate topography and Mediterranean climate.

In conclusion, based on this best available scientific information, WBA has developed a method for determining where NSOs are likely to be detected during surveys (USFWS 2011). Thus in general, areas where a NSO is likely to be detected will be surveyed; areas where NSOs are not likely to be detected will be excluded from surveys. Where NSOs are more likely to be detected, all surveys shall follow the most current USFWS protocol (USFWS 2011), except for the deviations stated in the NSORP, and future changes to the USFWS protocol. The survey stations shown on the THP maps shall be used for all survey visits. Survey stations will be marked on the ground with paint or flagging if necessary to facilitate consistent station relocation or located at clearly identifiable locations (road intersections, marked Section lines, etc.).

4.1 Habitat Assessment Procedure

All WBA managed lands that will be subject to timber harvesting and are within the NSO Evaluation Area (14 CCR § 895.1) or within or adjacent to townships identified in the USFWS Guidance document (Appendix A), will be evaluated for the potential to provide habitat for NSOs. Habitat function will be determined based on the WBA timber inventory that identifies areas that meet the criteria of High Quality Nesting and Roosting Habitat, Nesting and Roosting Habitat, Foraging Habitat, and Low Quality Foraging Habitat as described in USFWS guidance (USFWS 2008[b]). However, because stands that meet the criteria for Foraging or Low Quality Foraging Habitat are very unlikely to support NSOs if there is not at least some Nesting and Roosting habitat nearby, several conditions are included in determining which stands will be surveyed for NSOs. A combination of forest inventory data, aerial photograph interpretation, and field reconnaissance will be used to validate survey area delineation. The WBA inventory design and specifications are very robust in terms of collecting information regarding wildlife habitat. The forest inventory data concerning the habitat parameters of tree diameter, basal area, density of trees of certain sizes, and canopy closure used in the NSO habitat definitions produce results that have a low variance and a high degree of statistical certainty. The forest inventory data combined with the WBA geographic information system (GIS) allows for a robust spatial analysis that depicts proximity to other stands (habitat polygons) that are used in determining where surveys for NSOs will be conducted. The results of habitat assessments for NSOs are validated during field reconnaissance and through the use of aerial imagery. Annual updates to the WBA forest inventory are conducted and will be used to determine areas of NSO habitat on an annual basis. As recommended by Zabel et al. (2003), WBA uses a conservative interpretation of the available science and accepts a probability of use as low as 0.20 when classifying NSO habitat. For the purposes of this NSORP, NSO habitat is defined as:

4.2 Foraging Habitat

(1) Foraging habitats are areas where forest stands meet the structural criteria for Foraging habitat or Low Quality Foraging habitat and are within 0.5 miles of areas that at least meet the criteria for Nesting and Roosting habitat (USFWS 2008[b]).

(2) Foraging habitats are also areas where stands meet the structural criteria for Foraging habitat or Low Quality Foraging habitat (USFWS 2008[b]) and it is unknown whether any areas of at least Nesting and Roosting habitat exist within 0.5 miles (i.e. this assumes Nesting and Roosting habitat maybe present in areas where WBA does not have timber inventory data and remotely sensed data are unavailable or inconclusive).

4.3 Nesting and Roosting Habitat

(1) Nesting and Roosting habitats are areas that meet the criteria for High Quality Nesting and Roosting Habitat or Nesting and Roosting Habitat (USFWS 2008[b]).

4.4 THP Measures and Site-Specific Suitable Habitat Assessment

To ensure take of Northern spotted owls will not occur from any current and future WBA forest management activities a site-specific suitable habitat assessment shall be completed as part of all proposed THPs. USFWS (2008[b]) guidance states the use of "thresholds" to guide habitat assessment often simplifies more complex habitat conditions. The USFWS also acknowledges that suitable habitat retention guidelines are based on means for the entire Northern Interior Region (USFWS 2008[b]), and retention of suitable habitat should also be guided, when possible, by site specific abiotic considerations including: (1) Distance to nest, (2) Contiguity, (3) Slope position, (4) Aspect, (5) Elevation and (6) Tree species composition. THPs shall follow these guidelines as suggested by the USFWS, to complete a site-specific habitat assessment for all occupied NSO activity centers on or within 1.3 miles of WBA managed lands. Each assessment shall include review of:

(1) Suitable habitat type maps based on USFWS 2008[b].

(2) Forest inventory information including suitable habitat species composition, QMD, basal area, canopy closure and presence of larger trees and forest structures.

(3) Digital ortho photography

(4) Location of all previously known nest, roost and detection locations.

(5) Abiotic factors include the suitable habitat distance to nest, distance to stream, slope and overall topography, elevation, aspect and habitat connectivity.

The intent of the assessments are to use site-specific (ie. activity center specific) information to identify current and future habitats on WBA managed lands that should be retained. The habitat retention is to ensure "take" of Northern spotted owl will not result from any current or future WBA forest management activities. This site-specific approach is completed in lieu of using a one-size-fits-all approach that uses robust habitat retention guidelines to ensure "take" does not occur (USFWS 2008[b]). By using a site-specific assessment, as recommended by the USFWS (2008[b]), specific local conditions and habitat shall be used to identify habitat retention within the 0.5 mile Core Use Area and the 1.3 mile Foraging Area of each activity center. Habitat retention, for the purposes of this NSORP, are those habitat stands designated by the S.O.E. and Cal Fire during the site-specific assessment that are necessary to ensure take will not occur from the proposed NSORP, and subsequent THPs relying on this NSORP.

Also, during the site-specific assessments, specific stands may be identified as having high abiotic conditions, but relatively lower, current suitable habitat conditions. In the future, if these high abiotic condition stands are managed for retention of suitable habitat structures (ie. snags, down logs, dense groups of trees, platforms) and are managed to grow into larger size and higher density suitable habitats, these stands have high value for nesting, roosting and foraging Northern spotted owls. Accordingly, voluntary retention means, for the purposes of this NSORP, are habitat stands designated by the S.O.E. and reviewed by Cal Fire during the site-specific assessment as stands where voluntary retention and management would benefit conservation of NSO sites in the future. In other words, these voluntary retention stands are not necessary to ensure take will not occur from this proposed NSORP, and subsequent THPs relying on this NSORP, rather, these stands would benefit conservation of the species.

4.4.1 0.5 Mile Core Use Area

The concept of “core areas” was first proposed as areas within a home range receiving concentrated use by territorial animals (Samuel *et al*, 1985). Within habitats nearest the nest tree(s), core areas typically include the current nest tree, alternate nest trees, and frequently used roost trees, if known. More recently, numerous scientific studies have been conducted to determine which scales of habitat may be important for NSOs. An observation study in the Klamath province found the mean nearest neighbor distance between owl territories was 389 acres (Hunter et al, 1995). Another observation study found that owl core areas in the Klamath province are found to have significantly different habitats than random sites at the 494 acre scale (Gutierrez et al. 1998). Also, in the southern Cascades the best owl survival model used a 412 acre circle (Anthony et al. 2002). In other words, core use areas for Northern spotted owls are those 0.5 mile areas that are used disproportionately within home ranges (Bingham and Noon 1997; Irwin et al, 2004, Irwin et al. 2010, USFWS 2008[b]). Also, studies have described both the amount and quality of habitat (biotic) and location of the habitat (abiotic) as important factors in retaining Northern spotted owls in forested landscapes (Clark 2002, Irwin et al. 2004, Irwin et al. 2010, USFWS 2008[b]).

Accordingly, suitable habitats within the 0.5 mile Core Use Area shall be assessed to ensure that take will not occur as a result of any WBA forest management activities. The site-specific assessment shall use information described in Section 4.4 of this NSORP, and if necessary, designate habitat retention or identify voluntary habitat measures within the 0.5 mile Core Use Area. Accordingly, if a NSO activity center is located within WBA managed forestland or within 1.3 miles of WBA managed lands the following measures shall be assessed, or when a new activity center is established shall be assessed, and implemented:

THP Measures and Maintenance
Summary of 0.5 Mile Core Use Area

(1) Nesting Core Use Area shall be a 0.5 mile radius circle (502 acre) centered on the Northern spotted owl activity center.

(2) Suitable habitat shall be retained following site-specific review by an S.O.E. and CAL FIRE, using guidance provided by the USFWS (2008[b]),in order of importance: (1) High Quality Nesting and roosting habitat (2) Nesting and roosting habitat (2) Foraging habitat (3) Low Quality Foraging habitat. Foraging and Low Quality Foraging habitat in abiotically favorable locations may be retained instead of nesting and roosting habitats in less favorable locations.

(3) Suitable habitat shall be retained also considering: (1) Current nest trees (2) Alternative and historic nest trees (3) Current and historic detection locations (4) Natural and manmade landscape features such as ridges, streams, meadows, roads and previous harvest boundaries.

(4) Abiotic factors are significant predictors of owl use. To meet the habitat standards the following abiotic factors (in order of importance) shall be considered when deciding between which habitats to retain: (1) Distance to nest (2) Distance to stream (3) Slope (4) Elevation (5) Aspect

(5) Timber harvesting within habitats specifically retained on WBA managed lands within the Core Use Area are limited to silviculture which would reduce potential threats from wind throw, wildfire, forest pests, tree disease or overstocking, maintains the existing suitable habitat type and structures described in Item 2 and 3 above, and only following a field based assessment by a S.O.E. with concurrence from CAL FIRE.

4.4.2 1.3 Mile Foraging Outer Ring Area

Results of several studies have also indicated that roosting and foraging areas, represented by both daytime and nighttime telemetry locations, are best predicted by abiotic conditions (Clark 2002, Irwin et al. 2010). Suitable habitats within the 1.3 mile Foraging Outer Ring Area shall be assessed to ensure that take will not occur as a result of any WBA forest management activities. The site-specific assessment uses information described in Section 4.4 of this NSORP, and if necessary, designate habitat retention or identify voluntary habitat measures within the 1.3 mile Foraging Outer Ring Area. Accordingly, if a NSO activity center is located within WBA managed lands or within 1.3 miles of WBA managed lands the following measures shall be assessed, or when a new activity center is established shall be assessed, and implemented:

THP Measures and Maintenance
Summary of 1.3 Mile Foraging Outer Ring Area

(1) Foraging Ring Area includes habitats within a 1.3 mile radius circle (3,380 acre) ring area centered on the Northern spotted owl activity center.

(2) Suitable habitat shall be retained following site-specific review by an S.O.E. and CAL FIRE, using guidance provided by the USFWS (2008[b]),in order of importance: (1) Foraging habitat, (2) Low Quality Foraging habitat. Foraging and Low Quality Foraging habitat in abiotically favorable locations may be retained instead of nesting and roosting habitats in less favorable locations.

(3) Abiotic factors are significant predictors of owl use. To meet the habitat standards the following abiotic factors (in order of importance) should be considered when deciding between which habitats to retain: (1) Distance to nest (2) Distance to stream (3) Slope (4) Elevation (5) Aspect (6) Connectivity.

(4) Timber harvesting within habitats specifically retained by WBA managed lands within the Foraging Use Area are limited to silviculture which would reduce potential threats from wind throw, wildfire, forest pests, tree disease or overstocking, and maintains the existing suitable habitat type and structures described in Item 2 above.

4.4.3 Abiotic Factors

As previously described, abiotic factors are an important predictor of owl use (Clark 2002, Irwin et al. 2004, Irwin et al. 2010). Other studies in the Klamath province have also found that abiotic factors like elevation and slope position help discriminate between owl use areas and random sites (Blakesley et al. 1992). As recommended by the USFWS (2008[b]), when reviewing habitats within 1.3 mile of a known NSO activity center the following descriptions of abiotic factors are used to evaluate habitat quality and potential use:

(1)	Distance to Nest	Distance from the habitat to the active nest site (ie. smaller distance means more use)
(2)	Distance to Stream	Distance from the habitat to either an annual or intermittent stream (ie. smaller distance means more use)
(3)	Slope	Slope position of the habitat (ie. lower third of slope)
(4)	Elevation	Habitat and use is generally a non-linear relationship with a negative coefficient (ie. lower is generally means more use).
(5)	Aspect	Aspect of the habitat (ie. North and East favored).
(6)	Connectivity	Degree of connectivity to other abiotically favorable habitats.

4.5 Suitable Habitat Assessment for New Activity Centers

In the event a NSO is detected in a location not previously occupied, and the detection(s) meet USFWS (2011) standards for an activity center, a site-specific suitable habitat assessment shall be completed. The assessment shall be completed by a S.O.E., designated by Cal Fire to fulfill the requirements of 14 CCR § 939.9(a). The assessment shall follow the procedures described in Section 4.4.1 and 4.4.2, suitable habitat descriptions in Section 4.4, and submitted to CAL FIRE as described in Section 6.0 of this NSORP.

5.0 SURVEYS

A key component of the USFWS guidance (USFWS 2008[b]) is the proximity and arrangement of one suitable habitat type to another. In other words, the spatial relationship between nesting and roosting habitat where owls reproduce and high quality foraging and low quality foraging habitats where owls can roost and forage. Recent research in northern California predicts the probability of Northern spotted owls using specific suitable habitats (Zabel et al. 2003). This study used statistical modeling to identify the location and spatial arrangement of suitable habitat used by Northern spotted owls. Based on radio telemetry data from several study sites in northern California, that are similar to areas covered under this NSORP, the research identified a combination of variables that best explain habitat differences between sites that do or do not support Northern spotted owls. The final model indicated that a combination of nesting and roosting habitat and foraging habitat was a key predictor of occupancy.

Results of other Northern spotted owl habitat studies also indicate a combination of nesting and roosting areas interspersed with foraging areas are beneficial for owls (Farber and Crans 2000, Franklin et al. 2000, Hunter et al. 1995, Irwin et al. 2004, USFWS 2008[b], Zabel et al. 2003). Franklin et al. 2000, found that territory specific owl survival was associated with the amounts of older nesting and roosting habitats and edge foraging habitats within a core use area of 390 acres (0.4 mile circle). Irwin et al. 2010, telemetered owls and found that abiotic conditions and habitat conditions within 400 meters (0.25 mile circle) of nest sites best predicted habitat use.

Based on the results of these studies, WBA has developed a local site-specific method for determining where Northern spotted owls are likely to be detected (USFWS 2011). The local site-specific method concludes that Northern spotted owls are only likely to occur and occupy sites in a landscape when High Quality Nesting and Roosting habitat or Nest and Roosting habitat exists within 0.5 mile of existing Foraging habitat. Accordingly, for operations within 1.3 miles of a known occupied Northern spotted owl activity center or within the Northern spotted owl evaluation area (14 CCR 895.1) or within the USFWS recommend areas to be considered when planning forest management operations (USFWS 2008[a]), a survey will be conducted prior to commencement of forest management activities considering the following:

5.1 Surveys: Silviculture prescriptions that maintain suitable habitat

As previously stated, uneven-aged silvicultural prescriptions such as low intensity individual tree selection and group selection are widely used within WBA managed lands. These low intensity silvicultural practices typically retain mature forest cover, large trees, and other habitat elements important to Northern spotted owls such as large snags, cull trees, hardwoods, and densely forested areas with multiple canopy layers. When suitable habitat exists prior to harvest, and uneven-aged silvicultural prescriptions will retain pre-habitat types (ex. foraging as foraging), survey of suitable habitat will be conducted when the following criteria are met:

(1) If no suitable habitat exists within the THP boundary or within 0.5 miles of the THP boundary, then NSO surveys will not be necessary.

(2) If no suitable habitat exists within the THP boundary, but suitable High Quality Nesting and Roosting or Nesting and Roosting habitat exists within 0.5 miles of the THP boundary, surveys shall be conducted in all suitable High Quality Nesting and Roosting, Nesting and Roosting and Foraging habitat that lies within 0.5 miles from the THP area, that is legally accessible to WBA. If timber harvesting is to occur outside the breeding season of February 1st to August 31st, no surveys shall be necessary or conducted.

(3) If suitable habitat exists within the THP and suitable High Quality Nesting and Roosting or Nesting and Roosting habitat exists within 0.5 miles of the THP boundary, surveys shall be conducted in High Quality Nesting and Roosting, Nesting and Roosting, and Foraging habitat that lies within the THP and within 0.5 miles from the THP area, that is legally accessible to WBA.

5.2 Surveys: Silviculture prescriptions that do not maintain suitable habitat

When suitable habitat exists prior to harvest, and uneven-aged silvicultural prescriptions will not retain suitable habitat or will be degraded (ie. nesting reduced to foraging) immediately following operations, survey of suitable habitat will be conducted when the following criteria are met:

(1) If no suitable habitat exists within the THP boundary or within 1.3 miles of the THP boundary, then NSO surveys will not be necessary.

(2) If no suitable habitat exists within the THP boundary, but suitable High Quality Nesting and Roosting or Nesting and Roosting exists within 1.3 miles of the THP boundary, surveys shall be conducted in the suitable High Quality Nesting and Roosting and Nesting and Roosting, and Foraging habitat that lies within 1.3 miles from the THP boundary, that is legally accessible to WBA. If timber harvesting is to occur outside the breeding season of February 1st to August 31st, no surveys shall be necessary or conducted.

(3) If suitable habitat exists within the THP and suitable High Quality Nesting and Roosting, Nesting and Roosting habitat exists within 1.3 miles of the THP boundary, surveys shall be conducted in High Quality Nesting and Roosting, Nesting and Roosting, and Foraging habitat that lies within the THP boundary and within 1.3 miles from the THP area, that is legally accessible to WBA.

5.3 Modification of USFWS 2011 Protocol: 3-visit surveys

Since listing of NSOs under the federal ESA, protocol surveys have been conducted following guidance provided by the USFWS 1992 protocol (Forsman 1983, USFWS 1992). Based on almost 20 years of surveys and new scientific information regarding detectability of Northern spotted owls (Dugger et al. 2011, Kroll et al. 2010, Olson et al. 2005), the USFWS proposed new guidance in the USFWS 2010 protocol. Subsequently, based on additional new information and public comments the USFWS recommended the USFWS 2011 protocol, an errata and revisions in 2012.

The USFWS 2011 protocols were developed for NSOs over the entire range of the species from California to Washington. Recent research has indicated that the effectiveness of surveys conducted to detect NSOs has been reduced across a wide portion of the species distribution by the occurrence of barred owls (*Strix varia*) which is reflected in the current USFWS 2011 protocol. Based on this research, surveys conducted where barred owls occur more frequently the USFWS has recommended a two-year 6-visit survey.

Recent research in landscapes where barred owls occur in lower densities, in portions of the Southern Cascades and Klamath provinces of California, detection probability of Northern spotted owls using operational surveys can support presence and site status determination at USFWS desired levels of confidence (Farber and Kroll 2012)(Figure1)(Appendix C). In addition, the USFWS Technical Assistance 81333-2011-TA-0027 (USFWS 2011[d]) concurred that a 3-visit survey effort was appropriate for this landscape. The research included both stand-based searches and nighttime station-based surveys. The stand-based searches are informed daytime searches conducted within Northern spotted owl core use areas (Bingham and Noon 1998, Zabel et al. 2003) centered on activity centers. Informed daytime searches are routes developed by biologists using current and historical biological information important in finding owls, which includes: (1) Historic or current location of spotted owl nest and roost sites, (2) Suitable habitat with core areas, (3) Location of previous night and daytime spotted owl detections and, (4) Location of abiotically favored suitable habitats. This information is readily available in WBA managed lands GIS database and is used to develop the informed daytime stand search routes. Recently, the USFWS has recommended informed daytime searches as part of the most current survey protocol (USFWS 2011).

Figure 1

Northern Spotted Owl Detection Probability

Detection probability is the 1-visit probability (p_{ij})(probability matrix below) that a Northern spotted owl is detected when an owl is actually present. The original USFWS (1992) survey protocol assumed a one-visit detection probability of Northern spotted owls was 0.65. Using the probability matrix below, the original USFWS (1992) protocol then recommended a 3-visit survey that would produce a 3-visit confidence interval of 0.97, or in other words, during a 3-visit survey 97 out of 100 times a Northern spotted owl would be detected, if in fact, the owl was present.

Several studies conducted in landscapes with high densities of barred owls, have indicated that detection probability of Northern spotted owls has been reduced by the presence of barred owls (Dugger et al. 2005, Olson et al. 2005, Kroll et al. 2010). In 2010, the USFWS reviewed the results of these studies and proposed that the average 1-visit detection probability, across the entire range of the species, was currently 0.40. Based on this 1-visit detection probability and the probability matrix below, the USFWS (2011) recommended a 6-visit survey that would produce a 6-visit confidence interval of 0.95.

Recently, in the Southern Cascades and Klamath provinces of California, in landscapes where barred owls occur in lower densities, Farber and Kroll (2012) found a current average 1-visit detection probability of 0.67. Based on this 1-visit detection probability and the probability matrix below, Farber and Kroll (2012) recommended a 2-visit night survey in combination with one informed day search that would produce a confidence interval greater than 0.95, the USFWS standard for confidence in determining Northern spotted owl site status.

	p_{ij}								
	0.30	0.35	0.40	0.45	0.50	0.60	0.70	0.80	0.90
No. visits	p_i^*	p_i^*	p_i^*	p_i^*	p_i^*	p_i^*	p_i^*	p_i^*	p_i^*
1	0.30	0.35	0.40	0.45	0.50	0.60	0.70	0.80	0.90
2	0.51	0.58	0.64	0.70	0.75	0.84	0.91	0.96	0.99
3	0.66	0.73	0.78	0.83	0.88	0.94	0.97	0.99	1.00
4	0.76	0.82	0.87	0.91	0.94	0.97	0.99	1.00	1.00
5	0.83	0.88	0.92	0.95	0.97	0.99	1.00	1.00	1.00
6	0.88	0.92	0.95	0.97	0.98	1.00	1.00	1.00	1.00
7	0.92	0.95	0.97	0.98	0.99	1.00	1.00	1.00	1.00
8	0.94	0.97	0.98	0.99	1.00	1.00	1.00	1.00	1.00
9	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
10	0.97	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00

Accordingly, conducting one informed daytime stand-based search and two nighttime station-based surveys each year for two years will meet the USFWS standard for confidence (>0.95) in site status (Farber and Kroll 2012). Also, based on this level of detection probability, conducting two informed daytime stand-based searches and three nighttime station-based surveys for one year will meet the USFWS standard for confidence (> 0.95) in site status. The stand-based searches should be focused earlier in the nesting season, either March, April, May or June, although, the month (ie. Julian date) during the nesting season was not a significant variable in improving detection probability (Farber and Kroll 2012).

However, Farber and Kroll (2012) infrequently found 13 barred owls during 1,282 surveys which detected 480 spotted owls. In addition, barred owls were never detected more than once within 0.5 miles of a known spotted owl activity centers. Accordingly, based on the scientific scope of inference for this study, where barred owls are repeatedly detected (more than once) within Northern spotted owl 0.5 mile core use areas, the recommended survey procedures may be less effective in determining presence or absence of NSOs.

In summary, based on the results and recommendations of research conducted within portions of the Southern Cascades and Klamath provinces of California, surveys shall be conducted following the USFWS (2011) protocol with the following modification.

5.4 Modification of USFWS 2011 Protocol: Multiple Season and Single Surveys

For all forest management activities where surveys are required, the following modifications shall be followed for all surveys:

(1) Prior to conducting surveys, all available historic and current Northern spotted owl information shall be reviewed. Information shall include; historic or current location and status of activity centers, suitable habitat maps for activity centers, location of previous detection locations, previous nest and roost locations and location of abiotically favored suitable habitat.

(2) Where a barred owl <u>has</u> been previously detected more than once within an existing occupied Northern spotted owl 0.5 mile core use area the survey shall be conducted following the USFWS (2011) protocol guidance and USFWS Technical Assistance.

(3) Where a barred owl <u>has not</u> been previously detected more than once within an existing occupied Northern spotted owl 0.5 mile core use area the following survey shall be conducted:

- (a) Where a 2-year survey is conducted, each survey year shall include:
  - (i) One informed daytime stand-based search of the best abiotic locations of suitable habitat with 0.5 miles of a known occupied activity center. The

stand-based search shall be conducted as early in the nesting season, as feasible, in either March, April, May, or June.

(ii) Two nighttime station-based surveys following USFWS (2011) guidance regarding survey station placement and procedures.

(iii) Survey results for a 2-year survey are valid until the beginning of the following breeding season Feb 1st. Years following 2-year survey shall follow USFWS (2011) guidance regarding spot-check surveys.

(b) Where a 1-year survey is conducted, the each survey shall include:

(i) Two informed daytime stand-based search of the best abiotic locations of suitable habitat with 0.5 miles of a known occupied activity center. The stand-based search shall be conducted as early in the nesting season, as feasible, in either March, April, May, or June.

(ii) Three nighttime station-based surveys following USFWS (2011) guidance regarding survey station placement and procedures.

(iii) Survey results for a 1-year survey are valid until the beginning of the following breeding season Feb 1st.

5.5 Modification of USFWS 2011 Protocol: Early Season Determination of Nesting

The USFWS 2011 protocols were developed for NSOs over the entire range of the species from California to Washington. As stated in the USFWS 2011 protocol if surveys commence during the early period of the nesting season (March and April), the protocol requires that 2 visits of a 6-visit survey be conducted during the month of June. Due to interior Northern California's more southern latitude, relative to the entire NSO range (Timber Products Company 2005) and nesting season chronology (Irwin et al. 2004), an additional modification to the USFWS 2011 protocol applies to all surveys conducted under this NSORP.

(1) If barred owls <u>are present</u> as described in Section 5.4 (2) of this NSORP, a 2-year, 6-visit USFWS protocol is required and 2 visits of the 6 visit survey survey shall be conducted after May 15th of the nesting season.

(2) If barred owls <u>are not present</u> as described in Section 5.4 (3a) of this NSORP, and a 2-year survey is conducted, 1 of the 2 nighttime station-based surveys shall be conducted after May 15th of the nesting season.

(3) If barred owls <u>are not present</u> as described in Section 5.4 (3b) of this NSORP, and a 1-year survey is conducted, 1 of the 2 informed daytime stand-based searches and 1 of the 3 nighttime station-based surveys shall be conducted after May 15th of the nesting season.

6.0 TIMBER HARVEST PLAN PREPARATION PROCEDURES

The following reporting procedure for THPs in the NSO evaluation area shall demonstrate that take of NSOs will not occur and has been avoided as per 14 CCR § 939.10. The following information shall be submitted to Cal Fire with the THP or amendment(s) that may impact NSOs to demonstrate that the terms, conditions, and procedures in the NSORP have been followed.

<u>Surveys: If Surveys are Necessary</u>

A survey summary shall be provided with each THP and NSO related amendment, including a map showing all calling stations, the location of all active and historic NSO nests and activity centers within 1.3 miles, the THP boundary, roads (appurtenant, seasonal private, permanent private, seasonal public, permanent public, and temporary), landings, helicopter landings and flight corridors, and the NSO habitat types shall be provided at the time of filing. The highest known status (resident single, pair, nesting,) shall be used to determine if an historical activity center is located within this area. Locations recorded within the database that do not adequately establish a valid activity center will be considered but will not require buffer zones or habitat protection.

The following information shall be provided to Cal Fire at the time of THP submittal in Section III of the THP and in NSO related amendments:

- Map of call stations and current year survey results
- Habitat analysis around all activity centers within 1.3 miles and THP boundary
- Estimates of pre harvest and post-harvest habitat acres within the THP area

<u>Surveys: If Surveys are Not Necessary</u>

For THPs within the NSO Evaluation Area or those areas referenced in the USFWS guidance (Appendix A) a map showing the lack of NSO habitat shall be provided. This map shall show the boundaries of all timber stands that meet the criteria within 0.5 miles of the THP boundary.

<u>THP Measures</u>

When the location of a NSO or activity center dictate the need, the following information shall be provided to Cal Fire at the time of THP filing and also be included in Section II, Item 32 of the THP and in NSO related amendments:

- A list of all applicable THP Measures
- A map showing the THP boundary, nest and roost buffer zones, and any seasonal restrictions

If THP Measures will be applied during any stage of THP implementation, information shall be provided with the THP which demonstrates that the habitat requirements around areas where THP Measures are applied have been or will be met immediately following harvesting. A copy of the Cal Fire NSORP approval letter shall accompany each THP and shall fulfill the requirements of 14 CCR § 939.9(f) and § 939.10.

<u>Amendments</u>

Amendments that if applied could potentially result in an impact to NSOs or NSO habitat but are lacking current NSO information shall be considered not in compliance with the NSORP. Amendments that if applied could potentially result in an impact to NSOs or NSO habitat must include a statement describing any changes to the NSO protection measures included in the original THP. Amendments that if applied could potentially result in an impact to NSOs or NSO habitat and involve changes in yarding, silviculture, acreage, road placement or use, shall be reassessed to ensure that proper buffer zones and restriction areas are identified.

7.0 OTHER CONDITIONS

In each THP conducted pursuant to this NSORP, the California Registered Professional Forester (RPF) must certify that he possesses sufficient knowledge and experience to properly interpret NSO survey results or has consulted with a S.O.E. Conditions which preclude adoption of the THP Measures (Section 4.4) will require USFWS technical assistance and Cal Fire shall be notified at least 30 days prior to operations that could result in take of a NSO. The following baseline information is a prerequisite of this NSORP:

1. Map(s) of WBA managed lands within the NSO Evaluation Area as defined by 14 CCR § 895.1 and those within 0.5 miles of the townships identified by the USFWS Guidance (Technical Assistance 81333-2008-TA-0058 USFWS[a]) including all known NSO activity centers on or within 1.3 miles of those areas (Appendix A)
2. A list of all NSO activity centers on or within 1.3 miles of WBA managed lands that are in the NSO Evaluation Area as defined by 14 CCR § 895.1 or within 1.3 miles of the townships identified by the USFWS Guidance (Technical Assistance 81333-2008-TA-0058 USFWS[a]). This list shall contain a legal description of each activity center and any pertinent information regarding annual status or productivity (Appendix B).

When preparing for timber harvesting operations (THPs, exemptions, emergencies), all appropriate information sources shall be checked to determine whether any NSOs are known to be present in the general vicinity. Appropriate information sources may include: adjacent land managers/owners, the NSO database maintained by DFW, the WBA database, and/or the California Natural Diversity Data Base (CNDDB) maintained by DFW. The THP Measures (Section 4.4) shall be applied around any known activity centers when conducting timber harvesting operations when NSOs are present during the current year as verified by surveys. Currently unoccupied activity centers, as verified by surveys, shall be protected by applying the THP Measures with regard to habitat modification but not auditory disturbance. If the THP Measures will not be applied or will be modified around currently unoccupied activity centers, a USFWS technical assistance shall be required and Cal Fire shall be notified at least 30 days prior to operations.

This NSORP eliminates the need for further consultation with Cal Fire with respect to NSOs provided that all aspects of the NSORP are adhered to as agreed and described above, the THP Measures are applied as described above, and the THP Measures are adopted as an enforceable condition of any THP relying on this NSORP.

Upon request, WBA will provide an opportunity for a Cal Fire and/or USFWS representatives to periodically inspect NSO habitat within project areas. The purpose of these inspections is to coordinate with WBA personnel with respect to the designation of NSO habitat and to evaluate the effectiveness and implementation of agreed upon THP Measures.

8.0 INFORMATION EXCHANGE

WBA shall submit an annual report to Cal Fire by February 1 of each year that this NSORP is in effect. This annual report shall contain:

(1) Summary of survey results including the surveyors name(s) and qualifications in that year. Survey results (positive and negative) shall also be submitted to the DFW for inclusion in the NSO database.

(2) The dates and times of surveys and a map of the areas surveyed including NSO habitat types used to determine survey areas in that year.

(3) Information that summarizes potential impacts to NSOs or NSO habitat from the timber operations that have occurred for THPs filed under this NSORP in that year.

(4) THP maps of all THPs operated under the NSORP in that year.

(5) NSO survey stations, survey results, and NSO detections including NSO observation reports and any information on pair status or productivity in that year.

(6) Maps showing how habitat retention measures associated with activity centers have been met in that year.

This NSORP will become effective upon signature of all parties of this NSORP and shall continue in force and effect until terminated upon 30 days notice by either of the parties. The NSORP may be amended only by mutual written consent of the parties. The contact person for this NSORP representing Cal Fire will be the Forest Practice Manager, Northern Region, 6105 Airport Road, Redding, CA 96002, (530) 224-2481. The contact person representing WBA for this NSORP will be the Chief Forester or Wildlife Biologist, WBA, P.O. Box 990898 Redding, CA 96099-0898, (530) 243-2783. Changes in the contact persons noted above shall be considered minor changes to this agreement and not alter the validity or enforceability of this agreement.

9.0 CONCLUSION

By concurring with Cal Fire on the methods and protection measures outlined, WBA can incorporate a more efficient means of conducting timber harvesting operations, allow for increased efficiency of regulatory agencies, and provide better management for NSOs and other wildlife species. For the NSO, management and take avoidance guidelines are in place, as is a program designed to evaluate their effectiveness. Flexibility within this NSORP allows WBA to modify, and refine our current efforts to manage all the resources on WBA managed lands.

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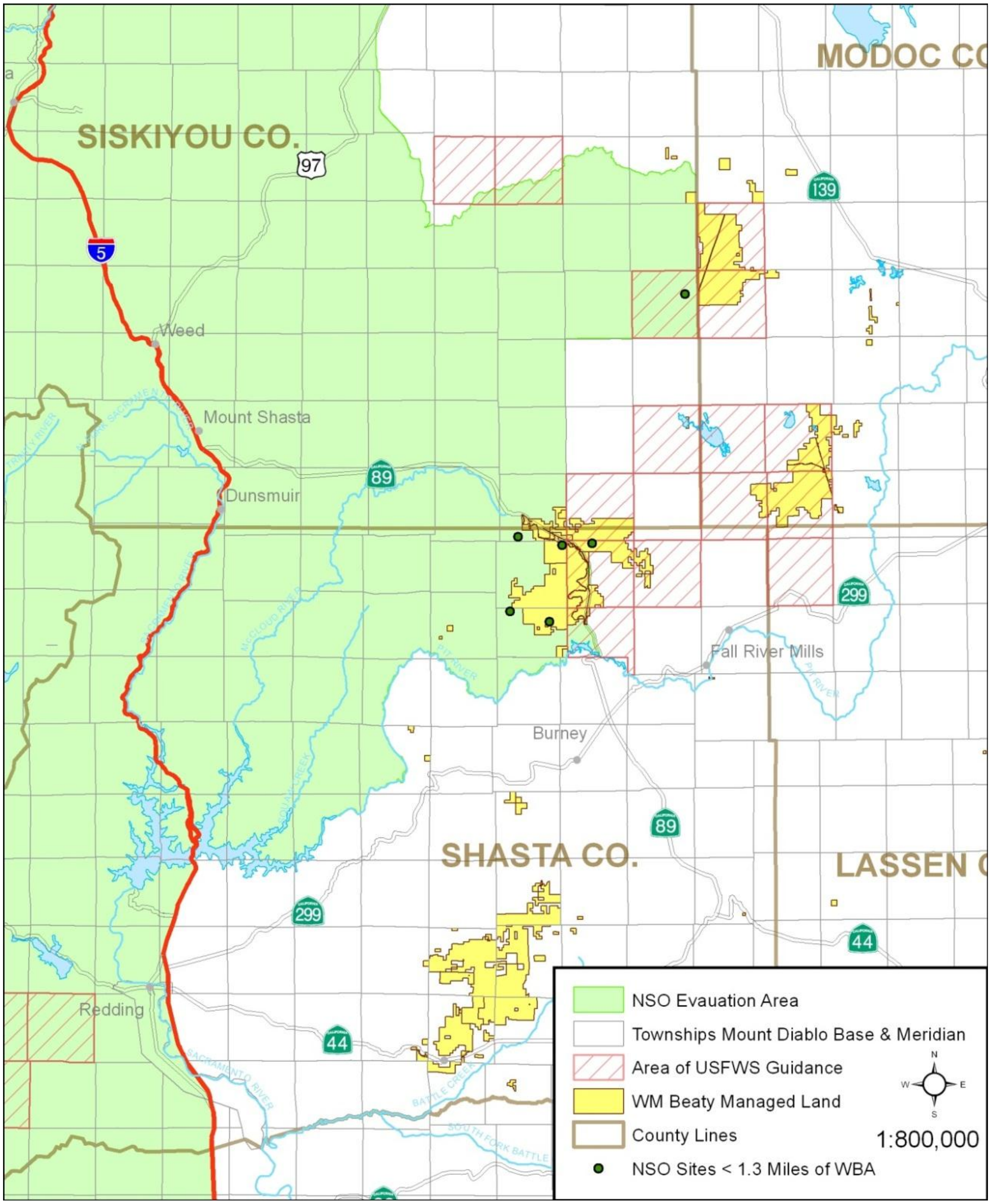
APPENDIX A

Map(s) of WBA managed lands within the NSO Evaluation Area as defined by 14 CCR § 895.1 and those within 0.5 miles of the townships identified by the USFWS Guidance (Technical Assistance Regarding the Southern and Eastern Regulatory Boundaries for the Northern Spotted Owl in California 81333-2008- T A-0058, attached) including all known NSO activity centers on or within 1.3 miles of those areas.



APPENDIX B

A list of all NSO database records depicted areas where detections have occurred on or within 1.3 miles of WBA managed lands that are in the NSO Evaluation Area as defined by 14 CCR § 895.1 or within 1.3 miles of the townships identified by the USFWS Guidance (Technical Assistance Regarding the Southern and Eastern Regulatory Boundaries for the Northern Spotted Owl in California 81333-2008- T A-0058, attached). This list shall contain a legal description of each activity center and any pertinent information regarding annual status or productivity.

Owl Number	Location Name	Owl Number Legal Location (1/64, 1/16, 1/4)	First Year Owl Number Status	Last year NSO Detected at this Location	Survey, Detection, and Activity Center Status
SHA033	Clark Creek	SE, SW, Sec 14, T37N, R2E	Single 1982	Res. Single 1998	5 years of no detection surveys
SHA075	Dickson Flat SW	SW, NE, Sec 1, T38N, R2E	Pair w/ Young 1990	Pair 1991	Declared Unoccupied by CAL FIRE 2013
SHA101	Dickson Flat E	NW, Sec 4, T38N, R3E	Res. Single 1993	Res. Single 1993	Not Valid Activity Center (NVAC) by USFWS and CAL FIRE 2013
SHA113	Rock Creek	SE, SE, Sec 7, T37N, R2E	Single 2001	Single 2008	Not Valid Activity Center (NVAC) by USFWS 11/8/2007
SIS250	Bear Creek W	NW, SE, Sec 32, T39N, R2E	Res. Single 1983	Single 1992	1998 USFWS Consultation NSO#R1308 considers site abandoned.
SIS429	Border Mountain	NW, NE, NE, Sec 14, T42N, R4E	Single 1980	Pair 2013	Nesting pair 2013

APPENDIX C