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Northwest Forest Plan

Status and Trends of Northern Spotted Owl Populations and Habitats From 1994 to 2008

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Abstract

This is the second in a series of periodic monitoring reports on northern spotted owl (*Strix occidentalis caurina*) population and habitat trends on federally administered lands since implementation of the Northwest Forest Plan (the Plan) in 1994.

Here we summarize results from a population analysis that included data from long-term demographic studies from 1985-2008. This data was analyzed separately by study area, and also in a meta-analysis across all study areas to assess temporal and spatial patterns in fecundity, apparent survival, recruitment, and annual rates of population change. Estimated rates of annual population decline ranged from 0.4 to 7.1 percent across federal study areas (weighted average of 2.8 percent) annually. Covariates for barred owls (*Strix varia*), weather, climate, habitat, and reproductive success analyzed and had varying degrees of association with owl demographic parameters. But, we now have more evidence that increasing numbers of barred owls and loss of nesting/roosting habitat contributed to demographic declines in some study areas.

We also summarize results from a habitat analysis that used the above data in conjunction with remote sensed data from 1994 to 2007 to develop "habitat suitability" models and habitat maps. These maps were used to quantify the amount and distribution of owl habitats. We also report on causes of habitat change during this period. On federal lands, nesting/roosting habitat declined by 3.4 percent rangewide, with some physiographic provinces experiencing losses of 10 percent. Dispersal habitat increased by 5.2 percent, but dispersal-capable landscapes declined by 1 percent.

Wildfire remains the leading cause of habitat loss. We developed a rangewide "wildfire suitability" model and map to illuminate the portions of the owl's range where suitable nesting/roosting habitat overlaps with landscapes suitable for the occurrence of large wildfires.

Barred owls and management of owl habitat in fire-prone areas continue to be topics for future monitoring, research, and management consideration.

Keywords: Northwest Forest Plan, effectiveness monitoring, northern spotted owl, geographic information system, owl habitat, habitat suitability, wildfire suitability, demographic study, remote sensing, predictive model, habitat model.

Summary

For the eight federal study areas associated with the effectiveness monitoring program, the average rate of population decline was 2.8 percent per year. Strong evidence of declines in annual rates of population change were reported for five of the eight individual effectiveness monitoring area study sites, but confidence limits on point estimates for three areas in the center of the owl's range (southwest Oregon) overlapped lambda = 1.0, suggesting these three populations may not be declining. Rates of population decline were highest in the northern portions of the owl's range (Washington and northern Oregon) where populations are estimated to have declined 40 to 60 percent since the Plan's implementation.

A variety of covariates including presence of barred owls (*Strix varia*), weather and long-term climate cycles, the amount of suitable nesting/roosting habitat on and adjacent to each study area, and the previous year's reproductive success, were included in the analysis of demographic data to explore associations between them and observed population trends. These covariates had varying degrees of association with owl demographic parameters, but at least one vital rate (i.e., fecundity, apparent survival, or population) was declining on all study areas.

The long-term demographic data we continue to collect is the key to understanding the range of factors that are affecting the recovery of spotted owl populations. At present, the invasion of the competitive barred owl and the amount of suitable nesting/roosting habitat are the factors most associated with spotted owl vital rates. Directly managing barred owl encroachment into spotted owl habitats may be beyond the scope of the Plan, but maintaining large blocks of suitable spotted owl

habitat will likely play a key role in decreasing negative interactions between the two species and increasing the likelihood of the persistence of spotted owl populations.

On federal lands, we estimated nesting/roosting habitat losses for 1994 through 2007 in California, and 1996 through 2006 in Oregon and Washington at 3.4 percent rangewide. Although rangewide losses have not yet exceeded what was anticipated under the Plan, some physiographic provinces have incurred losses up to 10 percent. This and the fact that most of the nesting/roosting habitat loss occurred within reserved land use allocations, and not within the federal matrix outside of these reserves, raises some concern. But in spite of this paradox, the large, repetitive design of reserves appears to still be functioning as intended. Of the 12 million ac of nesting/roosting habitat remaining, 71 percent occurs on federally administered lands, and approximately 70 percent of this is in reserved land use allocations (not including riparian reserves). Over half of the nesting/roosting habitat occurs in the central (core) portions of the owl's range, within the Klamath Mountain provinces of Oregon and California (27 percent) and the western Cascades of Oregon (26 percent). Not enough time has yet elapsed for us to accurately detect or estimate any significant recruitment of nesting/roosting habitat; however, increases were observed in "marginal" (younger) forests indicating that future recruitment of nesting/roosting habitat is on track to occur, as anticipated, within the next few decades.

In addition to providing potential future nesting/roosting habitat, some younger forests function as dispersal habitat. Forest succession accounted for some dispersal habitat recruitment, especially in the more productive tree-growing portions of the range (i.e., Oregon Coast Range). But, partial disturbances of nesting/roosting habitat also accounted for some of this recruitment as well. Loss of dispersal habitat, primarily from wildfires, was observed, but recruitment rates exceeded losses, resulting in a net increase in dispersal habitat of 5.2 percent (rangewide). In spite of this net gain, dispersal-capable landscapes actually decreased by 1 percent within the owl's range because of the spatial distribution this habitat. Even with this small decrease, the network of large reserves remains

fairly well connected, with the exception of the northern portion of the eastern Cascades of Washington and also within the southern tip of the range where some large reserves appear to be isolated (including the Marin County population).

Recent improvements in remotely sensed vegetation and change-detection mapping has resulted in better habitat maps to replace the baseline versions produced for the first monitoring report. Progress in habitat "niche" modeling methods and software has improved our ability to map not only habitat for spotted owls, but also "suitable habitat" for large wildfires. Wildfire remains the leading cause of owl habitat loss. About 3.6 million ac of nesting/roosting habitat remain in landscapes that are naturally prone to large wildfires. Most of this "fire-prone" habitat (85 percent) occurs within the "core" of the owl's range (i.e., the Klamath Mountains and the western Cascades of Oregon). Not all habitat burned is lost to owls, as fire intensity and frequency play a role in the effect of fire on owl habitat use. Our monitoring showed that large wildfires resulted in 30 to 62 percent loss of the nesting/roosting owl habitat within their perimeters.

Wildfire is a natural ecological process under which northern spotted owls have evolved, but the landscapes in which this occurred were heavily altered during the 20th century. Most remaining nesting/roosting habitat is now contained on federal land and its fragmented condition makes it, and the populations that rely on it, more vulnerable to future large wildfires. Conservation management for northern spotted owls in relation to wildfire will involve understanding (1) where suitable owl habitats overlap suitable habitat for large wildfire; (2) the effect of fuel reduction treatments to reduce fire risk on owl habitat use and demographics; and (3) the relationships between fire frequency, severity, and extent on owl habitat use and demographics.

Preface

This report is one of a set of periodic reports produced by the Northwest Forest Plan (the Plan) interagency monitoring program. These reports attempt to answer questions about the effectiveness of the Plan using the latest monitoring methods and research results. The reports focus on establishing baseline information from 1994, when the Plan was approved, and reporting changes that have occurred since then. The series includes late-successional and old-growth forests, northern spotted owl (*Strix occidentalis caurina*) population and habitat, marbled murrelet (*Brachyramphus marmoratus*) population and habitat, watershed condition, government-to-government tribal relationships, socioeconomic conditions, and project implementation. These monitoring reports are also intended to identify potential issues and to recommend solutions for future adaptive management changes and, as noted in the first reporting cycle, to resolve information management issues that inevitably surface during these analyses.

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Chapter 1: Introduction and Background

Raymond J. Davis, Katie M. Dugger, and Shawne Mohoric

In 1994, the Northwest Forest Plan (referred to hereafter as the Plan) amended 19 existing Forest Service and 7 Bureau of Land Management resource management plans within the range of the northern spotted owl (*Strix occidentalis caurina*). An interagency effectiveness monitoring framework was implemented to meet requirements for tracking the status and trends for late-successional and old-growth forests, northern spotted owl populations and habitat, marbled murrelet (*Brachyramphus marmoratus*) populations and habitat, watershed condition, social and economic conditions, and tribal relationships. Monitoring results are reported at 1-year intervals and evaluated at 5-year intervals. The first regional monitoring reports roughly covered the first 10 years of Plan implementation and were documented in a series of General Technical Reports posted at http://www.fs.fed.us/pnw/publications/gtrs.shtml. The first northern spotted owl population and habitat monitoring report was produced in 2005, covering status and trends of populations up to 2003, and habitat up to 2002 (Lint 2005). This report is the second in the series of northern spotted owl effectiveness monitoring reports (Lint et al. 1999) and covers population status and trend up to 2008, and habitat status and trend up to 2007.

The goal of the northern spotted owl monitoring program is to evaluate the success of the Plan in arresting the downward trends in populations and habitats that were largely responsible for the establishment of the Plan. In part, the Plan was designed to maintain and restore habitat conditions necessary to support viable populations of the northern spotted owl on federally administered lands throughout the owl's range (fig. 1-1). The objectives for northern spotted owl effectiveness monitoring are as follows:

1. Assess changes in population trends and demographic rates of spotted owls on federal lands within the owl's range.
2. Assess changes in the amount and distribution of nesting, roosting, foraging (NRF) and dispersal habitat for spotted owls on federal lands.

The first monitoring effort reporting on status and trends of northern spotted owl populations and habitat (Lint 2005) included a summary of the fourth northern spotted owl meta-analysis (Anthony et al. 2006) and produced a habitat baseline map using the latest technology and best available data at the time. This report covers the first 15 years of implementation under the Plan, including a summary of the fifth northern spotted owl population meta-analysis (Forsman et al. 2011) and the development of new habitat maps based on new vegetation data, analytical methods, and habitat modeling technologies.

Lint (2005) realized that as technology advances, there will be a need to refine or adapt old monitoring methods for new analytical approaches. With the help of leaders in the fields of statistics and wildlife demographics, the analytical methods for conducting the population meta-analysis continue to advance. Barred owl (*Strix varia*), climate, and habitat covariates were included in the latest analysis for the first time in 2009 (Forsman et al. 2011). The habitat covariates used were products from the 10-year report (Davis and Lint 2005). The inclusion of these new modeling techniques and covariates allowed us to investigate relationships between them and owl demographics for the very first time.

Likewise, the habitat analysis has evolved to incorporate new habitat modeling and forest pattern analysis software that can be used for identifying habitat conditions, characterization of change to those conditions, and the recruitment of those conditions through forest succession. Improvements were made to the vegetation data used to characterized owl habitat, including the addition of more variables for habitat modeling and analysis. Most notable, a consistent vegetation data set was

produced for the entire range of the northern spotted owl, which has never been available before. This new vegetation data set replaces the two previously used data sets (IVMP and CALVEG) and, along with new modeling software, allowed us to refine the previous baseline habitat map. Therefore the baseline amounts and distribution of owl habitat reported in the 10-year report are replaced by results presented in this report.

Improvements were also made to the remotely sensed data used for estimating habitat changes. These improvements include a finer time sequence of change-detection (annual versus 4 to 5 year intervals) and an improved ability to detect lower intensity disturbances (i.e., thinning, insects, and disease). Another improvement in our ability to detect habitat changes came from the creation of a vegetation data set that contains the same variables as the baseline data set, but for a later period. We called these vegetation data sets "bookends". Our first bookend is from 1994 in California and from 1996 in Oregon and Washington. The other bookend is from 2007 in California and from 2006 in Oregon and Washington. Therefore our habitat maps and our analysis of habitat status and trends cover the period from 1994/96 to 2006/07.

The spotted owl monitoring plan includes two phases of monitoring (Lint et al. 1999). Phase I entails demographic monitoring of individual territorial owls on eight federal study areas to estimate population demographics including survival, fecundity, and rate of population change while also tracking habitat conditions rangewide. The eight federal study areas that are part of phase I occur on federal lands administered by the U.S. Forest Service, Bureau of Land Management, and the National Park Service. They provide population trend data for a representative mix of areas considered key to the success of owl management under the Plan. The scientists who developed the monitoring plan determined that these eight study areas were the minimum number needed to be able to make scientifically credible and defensible inferences of population trends to the broader federal landscape within the owl's range (Lint et al. 1999, Mulder 1997). It is hoped that eventually the demographic

monitoring data can be combined with the habitat monitoring data to develop predictive models of owl occurrence and demographic performance based on observed habitat conditions. This would allow for implementation of phase II, which increases emphasis on habitat monitoring and decreases the population monitoring to a minimum of four study areas, which would provide a means to validate the population predictions of the habitat models. Implementation of phase II depends on our ability to relate owl demography to habitat conditions such that we can relate habitat status and trends directly to population status and trends with acceptable confidence. To date, attempts to develop predictive models have had mixed results (Dugger et al. 2005, Franklin et al. 2000, Olson et al. 2004) and have generally been unsuccessful across the range of the owl; however, some progress has been made as noted above and, as technology continues to advance, this remains our goal.

After 15 years, agency managers continue to be proactive and supportive of the monitoring program. As Lint (2005) stated, this support is, "of utmost importance to the future of the effectiveness monitoring program." The Northwest Forest Plan's effectiveness monitoring program (Mulder et al. 1999) has received national and international attention (Gosselin 2009) and has been noted as the largest and most comprehensive regional forest plan monitoring ever conducted (McAlpine et al. 2007). The monitoring data created and the analysis results presented in the 10-year monitoring report have provided valuable information for managers and policymakers in making informed decisions. Examples include northern spotted owl recovery planning (USDI 2008b) and designation of critical habitat (USDI 2008a) and increased emphasis by regulatory and management agencies to reduce risk of owl habitat and old forests from high-severity fire in dry provinces (Spies et al. 2006).

References

Anthony, R.G.; Forsman, E.D.; Franklin, A.B.; Anderson, D.R.; Burnham, K.P.; White, G.C.; Schwarz, C.J.; Nichols, J.D.; Hines, J.E.; Olson, G.S.; Ackers, S.H.; Andrews, L.W.; Biswell, B.L.; Carlson, P.C.;

Diller, L.V.; Dugger, K.M.; Fehring, K.E.; Fleming, T.L.; Gearhardt, R.P; Gremel, S.A.; Gutiérrez, R.J.; Happe, P.J.; Herter, D.R.; Higley, J.M.; Horn, R.B.; Irwin, L.L.; Loschl, P.J.; Reid, J.A.; Sovern, S.G. 2006. Status and trends in demography of northern spotted owls, 1985–2003. Wildlife Monographs No. 163. 48 p.

Davis, R.; Lint, J. 2005. Habitat status and trend. In: Lint, J., tech. coord. Northwest Forest Plan–the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 21–82.

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

Forsman, E.D.; Anthony, R.G.; Dugger, K.M.; Glenn, E.M.; Franklin, A.B.; White, G.C.; Schwarz, C.J.; Burnham, K.P.; Anderson, D.R.; Nichols, J.D.; Hines, J.E.; Lint, J.B.; Davis, R.J.; Ackers, S.H.; Andrews, L.S.; Biswell, B.L.; Carlson, P.C.; Diller, L.V.; Gremel, S.A.; Herter, D.R.; Higley, J.M.; Horn, R.B.; Reid, J.A.; Rockweit, J.; Schaberl, J.; Snetsinger, T.J.; Sovern, S.G. 2011. Population demography of northern spotted owls. Studies in Avian Biology 40. 106 p.

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

Gosselin, F. 2009. Management on the basis of the best scientific data or integration of ecological research within management? Lessons learned from the northern spotted owl saga on the connection between research and management in conservation biology. Biodiversity and Conservation. 18: 777–793.

Lint, J.; Noon, B.; Anthony, R.; Forsman, E.; Raphael, M.; Collopy, M.; Starkey, E. 1999. Northern spotted owl effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-440. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 43 p.

Lint, J.B., tech. coord. 2005. Northwest Forest Plan–the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 176 p.

McAlpine, C.A.; Spies, T.A.; Norman, P.; Peterson, A. 2007. Conserving forest biodiversity across multiple land ownerships: lessons from the Northwest Forest Plan and the Southeast Queensland regional forests agreement (Australia). Biological Conservation. 134: 580–592.

Mulder, B. 1997. Supplemental information for the policy and management review: general monitoring program, late-succession old-growth, northern spotted owl and marbled murrelet. Report by the Effectiveness Monitoring Team. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, 333 SW 1st Avenue, Portland, OR. 97208-3623.

Mulder, B.S.; Noon, B.R.; Spies, T.A.; Raphael, M.G.; Palmer, C.J.; Olsen, A.R.; Reeves, G.H.; Welsh, H.H., tech. coords. 1999. The strategy and design of the effectiveness monitoring program for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-437. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 138 p.

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

Spies, T.A.; Hemstrom, M.A.; Youngblood, A.; Hummel, S. 2006. Conserving old-growth forest diversity in disturbance-prone landscapes. Conservation Biology. 20: 351–362.

U.S. Department of the Interior [USDI]. 2008a. Endangered and threatened wildlife and plants; revised designation of critical habitat for the northern spotted owl; final rule. Federal Register. 73(157): 47326-47522.

U.S. Department of the Interior [USDI]. 2008b. Final recovery plan for the northern spotted owl (*Strix occidentalis caurina*). 142 p. On file with: U.S. Department of the Interior, Fish and Wildlife Service, 2600 SE 98th Ave., Ste. 100 Portland, OR. 97266.

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Chapter 2: Population Status and Trend

Katie M. Dugger and Raymond J. Davis

Introduction

The collection of demography data is the foundation of the effectiveness monitoring program for northern spotted owls (*Strix occidentalis caurina*) (Lint et al. 1999), designed to monitor the effect of the Northwest Forest Plan (the Plan) on populations. Demographic surveys for spotted owls following standardized data collection protocols began on some study areas as early as 1985 (northwest California: Franklin et al. 1996a, 1996b) even before the monitoring plan was actually finalized. The first rangewide meta-analysis was conducted in 1991 (Anderson and Burnham 1992), then again in 1993 (Burnham et al. 1996) and every 5 years thereafter (1998: Franklin et al. 1999; 2004: Anthony et al. 2006; 2009: Forsman et al. 2011). This long history of owl surveys and demographic data collection represents the single largest, long-term mark-recapture data set in the world for a threatened species (Courtney et al. 2004), and these data are invaluable for monitoring spotted owls under the Plan.

The goal of the population component of the monitoring program is to determine if the Plan is arresting or slowing the declining trend in northern spotted owl populations on federally administered lands throughout the owl's range. This is accomplished with annual data collection on eight federal study areas associated with the effectiveness monitoring plan (Lint et al. 1999). For the 10-year report (Lint 2005), these eight areas and data from three other independent study areas provided relevant data to address this question on federal lands managed under the Plan (Anthony et al. 2006). After 15 years, we report results from the eight federal demographic study areas and one independent study area. These nine areas are spread throughout the owl's range (fig. 2-1) and data on owl occupancy, survival, and productivity were gathered annually from each to estimate apparent adult survival, reproduction, and annual rate of change of owl populations. Detailed results of the analyses of these data and data

from two other, independent study areas within the range of the owl are reported by Forsman et al. (2011). The objectives of the most recent population status and trend meta-analysis were as follows:

- Estimate age-specific survival and fecundity rates and their sampling variances for individual study areas.
- Determine if any trends in adult female survival and fecundity exist across study areas.
- Estimate annual rates of population change (λ) and their sampling variances for individual study areas.
- Determine if the declines in apparent survival and populations, which were documented previously (Anthony et al. 2006), have continued or stabilized.
- Determine whether changes in the amount of suitable habitat, the presence of barred owls (*Strix varia*), or climate explain the observed annual variability in owl vital rates.
- Estimate components of the rate of population change, including apparent survival and recruitment rates that were not done in previous analyses (Anthony et al. 2006, Burnham et al. 1996, Franklin et al. 1999).

Data Sources and Methods

Data from eight demographic study areas in Washington, Oregon, and California were used to estimate status and trends of owl populations on federal lands (fig. 2-1). Although it is not part of the monitoring plan, data from the Rainier study area in Washington were also included because the study area occurs primarily on federal land. The two additional study areas in the latest meta-analysis are the Hoopa on tribal lands and the Green Diamond Resource study area on private timber company lands (Forsman et al. 2011). Because Hoopa and Green Diamond Resources did not include any lands managed under the Plan, they were excluded from this monitoring report, except when meta-analysis results including all 11 study areas are presented.

This monitoring report is based on nine study areas managed under the Plan that include variation in climate, vegetation, and topography and encompass most of the northern spotted owl's geographic distribution. The forests on all study areas are dominated by conifers or mixtures of conifers and hardwoods, although there are regional differences in species composition (for more details, see Forsman et al. 2011). The nine study areas range from 396 to 1,514 mi^2; the median study area size was 691 mi^2 and the mean was 829 mi^2 (table 2-1). These nine study areas encompassed 7,460 mi^2 or approximately 8 percent of the owl's range, and the numbers of years included in these data sets ranged from 17 (Rainier) to 24 (Northwest California). Four of these study areas (Olympic, H.J. Andrews, South Cascades, and Northwest California) primarily comprised federal lands administered by USDA Forest Service (FS), the USDI Bureau of Land Management (BLM), and the USDI National Park Service (NPS) (table 2-1). The other five (Cle Elum, Rainier, Coast Ranges, Tyee, and Klamath) included a mixture of federal, private, and state lands intermixed in a checkerboard pattern of ownership (table 2-1).

Field Data Collection

Data on individually identifiable (i.e., banded) owls were collected from the nine demographic study areas annually. During each breeding season (March through August), multiple visits (usually >3 per season) were made to owl territories to locate banded owls; confirm band numbers, sex, and age; and band any unmarked owls. In addition, the number of young produced was documented for each territorial owl, and fledglings were banded resulting in a known-age population of spotted owls on each study area. For details on the standardized field methods used to capture, mark, age, sex, and estimate productivity see Franklin et al. (1996a). These methods resulted in complete capture histories over time of every owl banded during this study and the number of young fledged per territorial female (NYF) located each year. From these data, annual apparent survival (φ) by sex and age, annual productivity (NYF) by age, and the annual rate of population change (λ) was estimated (Forsman et al. 2011).

Data Analysis

During a 9-day period in January 2009 (9th through 17th), a workshop was held at Oregon State University in Corvallis, Oregon, to analyze the data from 11 study areas. This workshop was led by research scientists with internationally recognized expertise in population dynamics, statistics, and the analysis of capture-recapture data. The analyses were conducted under the direct guidance of these scientists. Consistent with the previous four workshops convened since 1991 to analyze spotted owl demographic data, all participants adopted formal protocols for error-checking data sets and for the development of a priori model sets for each parameter of interest (Anderson et al. 1999). Thus, the data were collected and prepared in a consistent manner among study areas, and there were no analyses of additional models after post hoc examination of initial results (i.e., all data sets were analyzed the same way). Detailed results from this workshop (summary presented here) are reported in Forsman et al. (2011), and these analyses represent a retrospective, observational study, which assesses the strength of association between owl vital rates and a variety of explanatory covariates rather than addressing direct cause-effect relationships.

Error Checking

Crew leaders from each study area compiled survival, fecundity, and rate of population change data sets in a consistent manner, following specific instructions provided by workshop organizers. When digital files were completed, data entry was error checked by independent members of the workshop organizing team. The capture-history files for estimation of survival and annual rate of population change were error checked by randomly drawing 10 capture histories from each study area file and comparing them to paper copies of the field data that supported each of these capture histories. Fecundity data entry was error checked in a similar way, with 10 records of reproductive success for a

specified female in a given year compared to paper copies of the field data forms. If errors were found in the first round of checking the errors were corrected and the process was repeated with another sample of 10 records. If errors were found in the second round of data checking, the entire file was returned to the crew leader and principal investigator for review and correction. This sequence of error checking and correction was continued until no errors were found in 10 randomly drawn records, although it's possible that a low level of data entry error might still persist. Copies of error-checked records and field data forms submitted to confirm these records were archived, and all crew leaders signed statements before submitting data for analyses: certifying the accuracy of their data.

Estimating Survival

Cormack-Jolly-Seber open population models (CJS) (Franklin et al. 1996a, Lebreton et al. 1992) in program MARK (White and Burnham 1999) were used to estimate apparent survival of owls each year. Because survival estimates from CJS models cannot separate losses of individuals who died from losses owing to permanent emigration, these models estimate apparent survival, which incorporates the annual site fidelity of individuals ([true survival] x [site fidelity] = [apparent survival]). Spotted owls show high annual site fidelity (Forsman et al. 2002), so permanent emigration does not seriously bias model estimates, and apparent survival is believed to be very close to true survival (Anthony et al. 2006, Forsman et al. 2011). The general approach used to generate survival estimates from capture-recapture data on individual study areas was as follows:

- Decide on a set of a priori models for analysis and the order in which models will be run.
- Evaluate goodness-of-fit of the data to the general CJS model and estimate an over-dispersion parameter (c-hat = $\hat{c}$) using the median c-hat approach in Program MARK.
- Use the estimated c-hat to adjust covariance matrices for over-dispersion and to obtain quasi-Akaike's information criteria ($QAIC_c$) for model selection.

- Run all models for capture probability and apparent survival developed in the pre-analysis a priori model set.
- Select appropriate models for inference based on $QAIC_c$ model selection results (Burnham and Anderson 2002).

Several covariates expected to affect survival, including age, sex, the cost of reproduction, the proportion of territories where barred owls were detected each year, and climate covariates, were also included in the analysis. The nature (positive or negative) of these effects was hypothesized a priori, and the appropriate models reflecting these effects were included in the initial model sets prior to analysis.

The meta-analysis of all 11 study areas combined was conducted in a similar fashion, but in addition to study area, time trends, the cost of reproduction, and the barred owl covariate, models also included land ownership, ecological region, latitude, climate, and habitat change.

Estimating Fecundity

All analyses of reproductive rate were based on the annual number of young produced per territorial female (NYF), but to be consistent with previous reports (Anthony et al. 2006, Forsman et al. 1996, Franklin et al. 1999) estimates from these models were presented as "fecundity", where fecundity is the average annual number of female young produced per female owl (NYF/2). This adjustment assumes a 1:1 sex ratio at birth, which has been supported by previous genetic analyses of blood collected from juveniles (Fleming et al. 1996). Models were developed a priori to investigate the effects of age, general time variation, a variety of time trends, the proportion of owl territories where barred owls were detected each year, and an even-odd year effect, which has previously been shown to reflect a temporal cycle in spotted owl reproduction (i.e., Anthony et al. 2006). In addition, climate and habitat

covariates were included in the analysis. The general approach used to generate fecundity estimates was as follows:

- Decide on a set of a priori models for analysis and the order in which models will be run.
- Determine whether spatial variance (the random effect of territory) should be included in the modeling process.
- Use Proc Mixed in SAS (SAS Institute Inc. 2008) to fit all a priori models to the annual averages of NYF using a regression model based on a normal distribution.
- Select appropriate models for inference based on $QAIC_c$ model selection results (Burnham and Anderson 2002).

There was no consistent pattern regarding the best model for fecundity among study areas, so a nonparametric approach was used to estimate mean NYF by age class. The mean NYF was computed for each year and age class. Then these means were averaged across years within each age class. The estimated standard error was computed as the standard error of the average of the averages among years. This method gave equal weight to all years, regardless of the number of birds actually observed, and it did not force a model for changes over time.

As was done for survival, a meta-analysis of fecundity with all 11 study areas combined was conducted, and in addition to the covariates included in the individual study area analysis, landownership, latitude, climate, and ecological region were also included. Analysis details and meta-analysis results are reported in Forsman et al. (2011).

Estimating Annual Rate of Population Change and Realized Population Change

The reparameterized Jolly-Seber method (Pradel 1996) was used to estimate annual rates of population change (λ_{RJS}) in Program MARK using capture-recapture data. A parameterization was used

to generate annual estimates of λ (λ_t) for each study area, which allowed for decomposition of λ into two components, apparent survival (φ) and recruitment (f), where:

$$\lambda_t = \varphi_t + f_t$$

Apparent survival (φ_t) reflects both survival of territory holders within study areas and site fidelity, so both death and permanent emigration are included in this parameter. Recruitment (f_t) is the number of new owls in the population at time t+1 per animal in the population at time t and reflects both individuals born on the study area that become established territory holders, and immigration of recruits from outside the study area. Thus, the estimate of λ_t accounts for all of the losses and gains in the study area populations during each year and results in minimum bias in estimation of the annual rate of population change (Anthony et al. 2006).

In addition to an analysis of annual population change for each individual study area, a meta-analysis was conducted with all 11 study areas combined, where landownership, latitude, climate and weather, and ecological region were also included. Analysis details and meta-analysis results are reported in Forsman et al. (2011).

Estimates of realized population change (Δ_t) were also computed and reflect the proportional change in estimated population size relative to population size in the initial year of analysis, and were computed following the methods of Franklin et al. (2004). On each study area, annual estimate of realized population change was calculated as:

$$\widehat{\Delta}_t = \prod_{i=x}^{t-1} \hat{\lambda}_i$$

where x was the year of the first estimated λ_t. For example, given three, year-specific lambdas of say 0.9 in 1993, 1.2 in 1994, and 0.7 in 1995, the realized population change would be 0.9 x 1.2 x 0.7 = 0.756. This value means that at the end of 1995, the population was 75.6 percent of the starting

population in 1993. Thus, estimates of realized population change clearly illustrate the long-term, cumulative trends in annual population changes.

Results

The following is a summary of the demographic analysis of apparent survival, fecundity, annual rate of population change, and realized population change for the northern spotted owl reported by Forsman et al. (2011). These analyses are the most long-term and comprehensive to date across the range of the owl; however, although the 11 study areas included in this analysis covered a large portion of the owl's geographic range, they were not randomly selected. Thus, results cannot be considered representative of owl populations throughout its entire range and cannot be used to assess demographic trends on nonfederal lands because only two study areas on nonfederal lands were included in the analysis. However, Forsman et al. (2011) believed their results to be representative of most owl populations on federal lands as they include nine large study areas, with comprehensive geographic coverage and a variety of landownership and management strategies. Thus, the results from the nine study areas associated with federal land managed under the Plan can be used to make inferences to populations on those lands.

Survival

For the nine individual study areas, the number of banded owls included in the survival analysis were 615 1-year-olds, 668 2-year-olds, and 2,910 adults (>3 years old) with 19,680 total encounters across all individuals and age classes (table 2-1). The number of recaptures in this data set was 4.5 times the number of initial captures.

In general, survival was similar between sexes (except for Olympic where survival was higher for males) and higher for adults compared to subadults (table 2-2). Factors including time and time trends,

the proportion of territories where barred owls were detected each year, reproductive rate (fledglings per pair) in the previous year, and weather had varying effects on survival depending on the study area. Mean annual estimates of model-averaged apparent survival of female owls ranged from 0.529 to 0.794 for 1-year-olds, 0.674 to 0.864 for 2-year-olds, and 0.819 to 0.865 for adults (≥3 years old) (table 2-2). Most notably, survival was declining on all but the Klamath study area and in some cases the declines occurred primarily in the last 10 years or so (Coast Ranges, H.J. Andrews, Tyee, South Cascades). Declines were most evident in Washington and strongest in the last 5 years for the Cle Elum and Rainier study areas. The Klamath study area was the only one for which no trend in survival was observed, although large amounts of annual variation in adult survival were observed (see fig. 5b in Forsman et al. 2011).

For the Rainier and Olympic study areas in Washington, survival was negatively associated with high rates of reproduction in the previous year, but this effect was not evident on any of the other study areas. In the meta-analysis of all 11 study areas, the negative cost of reproduction on survival was an important covariate and a consistent effect across all study areas. The analyses of individual study areas supported the negative effect of barred owls on survival, but the effect was variable among study areas: decreased survival was associated with higher proportions of territories where barred owls were detected for Rainier, Coast Ranges, and H.J. Andrews, with weaker evidence found for the Olympic and Northwest California, and negligible evidence of a barred owl effect for Cle Elum, Tyee, and Klamath study areas. The results of the meta-analysis support much stronger negative effects of barred owl presence on spotted owl survival. The model with an additive barred owl effect ranked higher compared to the model with an interaction between barred owl presence and study area, supporting the importance of a consistent barred owl effect across all study areas, rather than an effect that varies in magnitude among areas.

The effects of climate, weather, and the amount of suitable owl habitat on survival were only investigated during the meta-analysis. There was some support for decreasing time trends in survival and a negative relationship between early nesting season precipitation and survival, but the amount of suitable habitat had no effect (Forsman et al. 2011). In addition, there was also some support for differences in survival among ecological regions, with the lowest survival rates reported for study areas in Washington mixed-conifer regions and highest survival for the Coast Ranges. The meta-analysis suggested several factors affected survival, but none of the covariates explored in this analysis explained a substantial portion of the variation among years and study areas (between 0.0 and 5.7 percent only).

Fecundity

The analysis across all 11 study areas by Forsman et al. (2011) included 11,450 observations of the number of young produced by territorial females, and 90 percent of those observations were from adult females (>3 years old). The younger age classes were observed breeding much less frequently (3.8 percent for 1-yr-olds, 6.1 percent for 2-yr-olds) and age had a strong effect on productivity (Forsman et al. 2011). Mean fecundity was highest for adults (0.330, SE = 0.025), lower for 2-year-olds (0.202, SE = 0.042) and nearly negligible (0.07, SE = 0.015) for 1-year olds (Forsman et al. 2011).

Fecundity differed greatly by study area, and adult fecundity was highest on Cle Elum (0.553, SE = 0.052) and lowest in the Coast Ranges (0.263, SE = 0.04) (table 2-3). There was considerable annual variation in fecundity, but the patterns in variation were not consistent among study areas. A cyclic, even-odd-year effect where fecundity was high in even years and low in odd years was still important for some study areas (Forsman et al. 2011), but has generally become less evident since the last analysis (Anthony et al. 2006). Overall, fecundity was declining in four areas (Cle Elum, Klamath, South Cascades, Northwest California), stable in two areas (Olympic, Tyee), and increasing in three areas (Rainier, Coast Ranges, H.J. Andrews) (table 2-4).

The effects of several covariates on owl fecundity were also reported by Forsman et al. (2011). The proportion of owl territories on each study area where barred owls were detected at least once during a breeding season had a negative effect on fecundity for three study areas (Coast Ranges, Klamath, South Cascades), a positive effect on fecundity in one study area (H.J. Andrews), and no effect on the other five areas. There was also evidence that low temperatures during the early nesting season had negative effects on fecundity in three study areas (Rainier, Coast Ranges, South Cascades); late nesting season temperatures had negative effect on fecundity on one study area (Tyee); and high precipitation during the early nesting season had negative effects on fecundity in three study areas (Cle Elum, Coast Ranges, Northwest California). Support for a negative effect of barred owls and effects of climate and weather on fecundity was generally weak. In Oregon, increased fecundity on 4 of 5 study areas (Coast Ranges, H.J. Andrews, Tyee, South Cascades) were associated with higher annual estimates of the amount of suitable habitat associated with each study area; however, more suitable habitat resulted in decreased productivity on the Klamath study area (Forsman et al. 2011). There was little indication of any association between the amount of suitable habitat and fecundity on the Washington study areas, and this association was not investigated for California study areas because comparable maps to develop the covariate were not available (Forsman et al. 2011).

Annual Rate of Population Change

Estimates of the annual rate of population change (λ) on the nine study areas ranged from 0.929 to 0.996 (table 2-4). There was strong evidence that populations on the Cle Elum, Rainier, Olympic, Coast Ranges, H.J. Andrews, and Northwest California study areas declined during the study (table 2-4, fig. 2-2), with particularly low estimates of λ for Cle Elum and Rainier, which suggested population declines of 6.3 and 7.1 percent per year, respectively (table 2-4). Point estimates of λ for the Tyee, Klamath, and South Cascades study areas were all <1.0, but 95-percent confidence intervals (CIs)

included 1.0 (table 2-4), suggesting populations may be stationary. The weighted mean estimate of λ for all the study areas included in the analysis by Forsman et al. (2011) was 0.971 (SE = 0.007, 95-percent CI = 0.960 to 0.983), which indicated that the average rate of population decline was 2.9 percent per year during the study. The weighted mean estimate of λ for the eight federal effectiveness monitoring areas (excluding Rainier) was 0.972 (SE = 0.006, 95-percent CI = 0.958 to 0.985), which indicated an estimated decline of 2.8 percent per year.

Results from the meta-analysis on the annual rate of population change indicated that both survival and recruitment differed by ecological region, with the highest survival in the Oregon Coast Douglas-fir region and lowest survival in Washington mixed-conifer region (Forsman et al. 2011). Recruitment was highest in the Oregon/California mixed-conifer region and lower elsewhere (Forsman et al. 2011). A negative association between barred owl detections and survival in the rate of population change analysis was also evident and consistent with results from the meta-analysis of survival (see above). A weak association between survival and the Pacific Decadal Oscillation was also evident, with higher survival observed during warmer phases of this regional climate cycle. No other climate or weather covariates were important. Estimates of recruitment were higher on study areas comprising primarily federal lands (Olympic, H.J. Andrews, South Cascades, Northwest California) compared to mixed or private ownerships. Recruitment was also higher when the proportion of suitable owl habitat was higher within study areas, but was lower in association with higher proportions of suitable habitat outside study area boundaries.

Realized Population Change

Estimates of realized population change reflected the trend in the proportion of the population remaining each year, based on annual changes in λ in relation to the population at the beginning of the study (Forsman et al. 2011). Populations in Washington and northern Oregon (Olympic, Rainier, Cle

Elum, Coast Ranges) declined by 40 to 60 percent during this study (fig. 2-3), and there is some evidence that populations on the H.J. Andrews and Northwest California study areas were also declining (20 to 30 percent) although 95-percent CIs around estimates of realized population change overlapped 1.0 slightly (fig. 2-3). There was less evidence that populations on South Cascades, Tyee, and Klamath areas were in decline (5 to 15 percent), but many point estimates of realized population change for these areas were less than 1.0 even though 95-percent CIs broadly overlapped 1.0 (fig. 2-3).

Discussion

These demographic results are a summary of Forsman et al. (2011) and they represent the fifth meta-analysis of demographic data from northern spotted owls (Anderson and Burnham 1992, Anthony et al. 2006, Burnham et al. 1996, Franklin et al. 1999). The second meta-analysis of demographic rates of northern spotted owls was conducted in 1993 and included 11 study areas (Burnham et al. 1996, Forsman et al. 1996). At that time, owl fecundity rates varied among years and with owl age, and exhibited no increasing or decreasing trend over time (Burnham et al. 1996). Survival rates were dependent on age, and there was a decreasing trend in adult female survival. The annual rate of population change was <1.0 for 10 of 11 areas examined, with an estimated average rate of population decline of 4.5 percent per year (Burnham et al. 1996). By 2004, owl fecundity was relatively stable among the 14 study areas examined, survival rates were declining on 5 of the 14 areas, and populations were declining on 9 of 13 study areas for which there were adequate data to estimate λ (Anthony et al. 2006). However, the annual rate of decline was less, as mean λ for the 13 areas was 0.963, indicating populations were declining 3.7 percent annually during the study (Anthony et al. 2006).

Declines in fecundity, survival, and rate of population change were observed across most study areas in this most recent analysis by Forsman et al. (2011). Over the last 15 years, populations on all 11 areas included in the recent meta-analysis declined on average 2.9 percent per year (Forsman et al.

2011). This is a lower rate of decline than the 3.7 percent reported in the last meta-analysis (Anthony et al. 2006), but the rates of decline are not directly comparable between analyses. The current analysis represents a different time series than past efforts, and data collection on two of the study areas included in past analyses was discontinued (Wenatchee, Warm Springs Reservoir), so these areas could not be included in the most recent analysis (Forsman et al. 2011). In addition to the Rainier study area, apparent survival rates of owls were declining on seven (Cle Elum, Olympic, Coast Ranges, H.J. Andrews, Tyee, South Cascades, Northwest California) of the eight study areas associated with the Plan (table 2-4) and fecundity was also declining in four of these populations (table 2-4; Forsman et al. 2011). In Washington and northern Oregon, the number of declining populations and the rate of decline raises concern about the long-term sustainability of the owl throughout its range (Forsman et al. 2011).

The reasons for declines in spotted owl populations were not readily apparent in any of the previous meta-analyses (Anthony et al. 2006, Burnham et al. 1996, Franklin et al. 1999). The analysis done by Forsman et al. (2011) incorporated covariates to investigate the influence of barred owls, weather and climate, and habitat on fecundity, survival, and rate of population change. As a result, we now have some evidence that increasing numbers of barred owls and loss of habitat contributed to demographic declines reported in some study areas (Forsman et al. 2011). The presence of barred owls appeared to be the strongest and most consistent negative factor relating to spotted owl survival, but the strength of the response was variable among study areas. Forsman et al. (2011) concluded that although their results do not represent cause-effect relationships, they certainly suggest that barred owl invasion into the range of the spotted owl is at least partly to blame for the continued decline of the owl on federal lands. However, recovery of habitat lost over the last century is a slow process and likely continues to negatively impact owl populations.

From the perspective of evaluating the effectiveness of the Plan on the conservation and recovery of the owl, the relationship between demographic rates and habitat are of particular

importance. Because of the differences in the vegetation data used to develop habitat models for the 10-year report, as discussed in chapter 3 of this report, the development of the habitat covariate in California was not possible, and its effect on demographic rates could only be investigated for Washington and Oregon (see Forsman et al. 2011 for details). From this analysis, there was evidence that the percentage cover of suitable owl habitat had a positive influence on recruitment of owls in the meta-analysis of λ (Forsman et al. 2011); however, this relationship was not strong or prevalent for all demographic parameters or among all study areas.

Based on the meta-analysis of λ, there was some evidence that apparent survival was related positively to the percentage cover of suitable habitat in the Cle Elum, Coast Ranges, H.J. Andrews, and Tyee study areas in Washington and Oregon (Forsman et al. 2011). Also, a positive relationship between recruitment and the percentage cover of suitable owl habitat within the study area in the meta-analysis of λ was also found (Forsman et al. 2011). Recruitment was also highest on federally owned lands where the amount of suitable habitat was highest compared to private lands (Davis and Lint 2005). One possible explanation for this result is that more suitable habitat within the study areas provided areas where nonterritorial owls could survive until they were able to recruit into the territorial population.

Summary

After 15 years of population monitoring, we continue to observe significant annual declines in spotted owl populations (2.9 percent all ownerships, 2.8 percent federal ownership; Forsman et al. 2011). Our ability to monitor the trend in owl populations is improving with newer technologies, the inclusion of explanatory covariates, and more years of data. We now have some evidence to support the suggestions of Anthony et al. (2006) that possible causes for declines in owl survival and populations may include high densities of barred owls and loss of habitat. However, a lot of uncertainty remains, and we are just beginning to understand the effects of these two factors on owl demography. We also

must continue to stress the caution put forth in the Plan for projecting current estimates of population decline into the future.

At its implementation, the Plan's assumption was that owl populations across the range would continue to decline for the first 3 to 5 decades, eventually stabilizing at lower levels as losses of habitat lessen and habitat is restored in the network of large reserves scattered throughout its range. Since the Plan's inception, the rate of habitat loss has certainly lessened, here we report an overall habitat decline of 3.4 percent on federal lands in the last 15 years (see chapter 3 in this report), which is less than the anticipated rate of habitat loss of 5 percent per decade. We also report an overall 2.8 percent annual population decline on federal lands, with higher declines in the northern portions of the range and stationary populations in the central portion of the range as first noted by Anthony et al. (2006). These stationary populations were also not expected at the Plan's implementation (Lint 2005). Although habitat is being maintained, the restoration of habitat under the Plan is still a few decades away. Forest succession is a slow process, but there are suggestions that it can be accelerated through well-designed silviculture (Garman et al. 2003, Muir et al. 2002). We were not yet able to accurately measure recruitment of nesting/roosting habitat with current technologies; however, we were able to detect recruitment of the younger forests that serve as dispersal habitat (see chapter 3 in this report). We speculate that declining spotted owl populations will not begin to stabilize across the range at least until nesting/roosting habitat begins to increase significantly. And although habitat is a key element in the conservation of spotted owls (Lint 2005), it may no longer be the primary factor affecting population stability in either the short or long term. The rapidly increasing trend in barred owl populations has produced an unanticipated and confounding influence, as these species may compete for resources.

The answer to the question, "Will the Plan reverse the declining population trend and maintain the historical geographic range of the northern spotted owl?" still eludes us. Five more years of monitoring has shed more light on the subject, but a definitive answer will require more long-term

monitoring to better understand the temporal and spatial variability in owl demographics and the factors that affect owl vital rates. Until then, we believe that habitat maintenance and restoration, as currently envisioned under the Plan, remains essential to the owl's recovery. However, additional conservation measures (i.e., barred owl control) that were not envisioned under the Plan may ultimately be needed to recover the species in the face of the barred owl expansion into the Pacific Northwest.

References

Anderson, D.R.; Burnham, K.P. 1992. Demographic analysis of northern spotted owl populations. In: Final draft recovery plan for the northern spotted owl. Volume 2: 66–75. Unpublished report. On file with: U.S. Fish and Wildlife Service, 2600 SE 98th Ave., Ste. 100 Portland, OR. 97266. Portland, Oregon, USA.

Anderson, D.R.; Burnham, K.P.; Franklin, A.B.; Gutiérrez, R.J.; Forsman, E.D.; Anthony, R.G.; White, G.C.; Shenk, T.M. 1999. A protocol for conflict resolution in analyzing empirical data related to natural resource controversies. Wildlife Society Bulletin 27: 1050–1058.

Anthony, R.G.; Forsman, E.D.; Franklin, A.B.; Anderson, D.R.; Burnham, K.P.; White, G.C.; Schwarz, C.J.; Nichols, J.D.; Hines, J.E.; Olson, G.S.; Ackers, S.H.; Andrews, L.W.; Biswell, B.L.; Carlson, P.C.; Diller, L.V.; Dugger, K.M.; Fehring, K.E.; Fleming, T.L.; Gearhardt, R.P; Gremel, S.A.; Gutiérrez, R.J.; Happe, P.J.; Herter, D.R.; Higley, J.M.; Horn, R.B.; Irwin, L.L.; Loschl, P.J.; Reid, J.A.; Sovern, S.G. 2006. Status and trends in demography of Northern Spotted Owls, 1985–2003. Wildlife Monographs No. 163. 48 p.

Burnham, K.P.; Anderson, D.R. 2002. Model selection and multimodel inference: a practical information theoretical approach. 2nd ed. New York, NY: Springer-Verlag. 488 p.

Burnham, K.P.; Anderson, D.R.; White, G.C. 1996. Meta-analysis of vital rates of the northern spotted owl. Studies in Avian Biology. 17: 92–101.

Courtney, S.P.; Blakesley, J.A.; Bigley, R.E.; Cody, M.L.; Dumbacher, J.P.; Fleischer, R.C.; Franklin, A.B.; Franklin, J.F.; Gutiérrez, R.J.; Marzluff, J.M.; Sztukowski, L. 2004. Scientific evaluation of the status of the northern spotted owl. Portland, OR: Sustainable Ecosystem Institute. 348 p. + appendixes.

Davis, R.; Lint, J. 2005. Habitat status and trend. In: Lint, J., tech. coord. Northwest Forest Plan–the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 21–82.

Fleming, T.L.; Halverson, J.L.; Buchanan, J.B. 1996. Use of DNA analysis to identify sex of northern spotted owls (*Strix occidentalis caurina*). Journal of Raptor Research. 30: 18–122.

Forsman. E.D.; Anthony, R.G.; Reid, J.A.; Loschl, P.J.; Sovern, S.G.; Taylor, M.; Biswell, B.L.; Ellingson, A.; Meslow, E.C.; Miller, G.S.; Swindle, K.A.; Thrailkill, J.A.; Wagner, F.F.; Seaman, D.E. 2002. Natal and breeding dispersal of northern spotted owls. Wildlife Monograph No. 149. Washington, DC: The Wildlife Society. 35 p.

Forsman, E.D.; Anthony, R.G.; Dugger, K.M.; Glenn, E.M.; Franklin, A.B.; White, G.C.; Schwarz, C.J.; Burnham, K.P.; Anderson, D.R.; Nichols, J.D.; Hines, J.E.; Lint, J.B.; Davis, R.J.; Ackers, S.H.; Andrews, L.S.; Biswell, B.L.; Carlson, P.C.; Diller, L.V.; Gremel, S.A.; Herter, D.R.; Higley, J.M.; Horn, R.B.; Reid, J.A.; Rockweit, J.; Schaberl, J.; Snetsinger, T.J.; Sovern, S.G. 2011. Population demography of northern spotted owls. Studies in Avian Biology 40. 106 p.

Forsman, E.D.; DeStefano, S.; Raphael, M.G.; Gutíerrez, R.J., eds. 1996. Demography of the northern spotted owl. Studies in Avian Biology. No. 17.

Franklin, A.B.; Anderson, D.R.; Forsman, E.D.; Burnham, K.P.; Wagner, F.F. 1996a. Methods for collecting and analyzing demographic data on northern spotted owl. Studies in Avian Biology. 17: 12–20.

Franklin, A.B.; Burnham, K.P.; White, G.C.; Anthony, R.G.; Forsman, E.D.; Schwarz, C.; Nichols, J.D.; Hines, J. 1999. Range-wide status and trends in northern spotted owl populations. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, Colorado, USA. 72 p. http://warnercnr.colostate.edu/~alanf/reprints/abf_ea99nsometa.pdf. (18 December 2010).

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

Franklin, A.B.; Gutiérrez, R.J.; Noon, B.R.; Ward, J.P. 1996b. Demographic characteristics and trends of northern spotted owl populations in northwestern California. Studies in Avian Biology. 17: 83–91.

Garman, S.L.; Cissel, J.H.; Mayo, J.H. 2003. Accelerating development of late-successional conditions in young managed Douglas-fir stands: a simulation study. Gen. Tech. Rep. PNW-GTR-557. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 119 p.

Lebreton, J-D.; Burnham, K.P.; Clobert, J.; Anderson, D.R. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs. 62: 67–118.

Lint, J.; Noon, B.; Anthony, R.; Forsman, E.; Raphael, M.; Collopy, M.; Starkey, E. 1999. Northern spotted owl effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-440. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 43 p.

DRAFT

Lint, J.B., tech. coord. 2005. Northwest Forest Plan–the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 176 p.

Muir, P.S.; Mattingly, R.L.; Tappeiner, J.C. II; Bailey, J.D.; Elliott, W.E.; Hagar, J.C.; Miller, J.C.; Peterson, E.B.; Starkey, E.E. 2002. Managing for biodiversity in young Douglas-fir forests of western Oregon. U.S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR–2002-0006. 76 p. http://fresc.usgs.gov/products/papers/mang_bio.pdf. (18 December 2010).

Pradel, R. 1996. Utilization of capture-mark-recapture for the study of recruitment and population growth rate. Biometrics. 52: 703–709.

SAS Institute, Inc. 2008. SAS/STAT® 9.2 users guide. SAS Institute, Inc., Cary, NC.

White, G.C.; Burnham, K.P. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study. 46: 120–138.

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Chapter 3: Habitat Status and Trend

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Introduction

The first rangewide northern spotted owl (*Strix occidentalis caurina*) habitat map was developed for the Forest Ecosystem Management Assessment Team (FEMAT) in 1993. It was constructed through a combination of digital maps derived from satellite imagery and maps derived from aerial photo interpretation. The team used the best available data and geographical information system (GIS) technologies at that time to represent owl habitat conditions at the start of the Northwest Forest Plan (the Plan), which we call the "baseline." However, the authors acknowledged that the map was an estimate and had not been assessed for accuracy (FEMAT 1993). Six years later, the northern spotted owl effectiveness monitoring plan concluded that this map lacked the spatial resolution and accuracy needed for a baseline spotted owl habitat map for monitoring purposes (Lint et al. 1999). They proposed the development of a new rangewide baseline habitat map to "provide the landscape-scale view of habitat conditions at different resolutions."

Having a good baseline habitat map is essential to the effectiveness monitoring program because it provides a snapshot in time of what the conditions were like when the Northwest Forest Plan was implemented. Without an understanding of baseline conditions, we would not be able to answer the primary question of whether owl habitat and dispersal habitat are being maintained and restored under the Plan. The first rangewide baseline habitat monitoring map was developed by Davis and Lint (2005) for the 10-year monitoring report (Lint 2005). The data sources and methods used to develop that map are fully described in Davis and Lint (2005) and are not repeated in this report. Limitations in the first baseline map were noted by Davis and Lint (2005) and Raphael (2006) and are reviewed in the following discussion.

The Northwest Forest Plan effectiveness monitoring program was in its early stages of development at the time of the 10-year reporting analysis. A consistent rangewide vegetation data set as described in Lint et al. (1999) did not exist. Instead, two distinctly different vegetation data sources covered the owl's range: Interagency Vegetation Mapping Project data (IVMP) (Oregon and Washington) and Classification and Assessment With Landsat of Visible Ecological Groupings data (CALVEG) (California) (Davis and Lint 2005, Moeur et al. 2005). The choice of vegetation variables provided by these two sources were limited and included only tree size class and cover attributes, which were not mapped consistently between the two products. Other habitat mapping "core elements" discussed by Lint et al. (1999), such as stand age and tree species data, were not available, resulting in omission of important habitat relationship variables in the models used to create the first baseline map. To compensate for lack of tree species data, Davis and Lint (2005) used elevation as a variable in their habitat modeling and also built a "habitat-capable" GIS layer, largely based on a rangewide elevation isopleth that would "mask out" subalpine forests, in which spotted owls avoid nesting. There was no way to "mask" pine-dominated forests or to include evergreen hardwoods, which are important components of owl habitat in the southern physiographic provinces. As a result, where tree size and cover conditions were otherwise similar to those used by nesting and roosting territorial owls, the models classified them as suitable, even when they probably were not because of tree species composition.

Another problem was the coarse spatial resolution and lack of continuous attribution in the CALVEG data (Davis and Lint 2005). This resulted in poorer estimates of habitat in the California physiographic provinces and habitat maps that were not directly comparable to the Oregon and Washington maps. The lack of a consistent rangewide habitat map resulted in our inability to fully model associations between spotted owl demography rates and habitat during the 2009 population meta-analysis (Forsman et al. 2011).

Additional limitations of the 10-year report's baseline owl habitat map (Davis and Lint 2005) included the use of the median algorithm in the BioMapper habitat modeling software (Hirzel et al. 2002), which was the only algorithm available at the time (Davis and Lint 2005). This algorithm assumed species distribution along the environmental factors was normal (see fig. 3-8 on page 36 in the 10-year report); however, in reality, this is not always the case, and nonnormal relationships resulted in the overestimations of habitat suitability. In general, profile models like BioMapper are known to sometimes overpredict habitat suitability (Engler et al. 2004). To compensate for this, Davis and Lint (2005) provided a habitat map with a continuous scale from 0 to 100, where a value close to zero signified that an individual map unit (pixel) had little in common with the conditions found where territorial owls are present, and those with values close to 100 had much in common with sites having territorial owl presence. During this initial effort, a threshold value that designated a cutoff between "suitable" and "not suitable" habitat was not chosen. Instead, Davis and Lint (2005) reported on status and trend of the spectrum of habitat suitability (HS) divided into equal-interval bins, and areas with HS >40, which "had characteristics similar to areas where territorial owls have been found."

Based on our latest work (presented here), we now conclude that the baseline habitat map developed for the 10-year report did overestimate owl habitat suitability in portions of the range. Overestimations occurred within pine-dominated forests of the eastern Cascades for reasons discussed above, and, as noted by Raphael (2006), habitat suitability scores greater than 40 were achieved in stands as young as 30 years in the Coast Range of Oregon and 50 years in Oregon western Cascades, providing further evidence of profile model overpredictions. Based on visual comparisons of the former baseline maps and the new one, we also believe that the use of the coarser scale CALVEG data in the 10-year habitat modeling resulted in considerably more HS >40 estimated for California.

Since the 10-year report, much progress has been made in developing a consistent rangewide vegetation data layer, with a larger suite of vegetation attributes to be used as "core elements" for

habitat mapping, including tree species information (Ohmann and Gregory 2002). These new rangewide vegetation data are produced by the Landscape Ecology, Modeling, Mapping, and Assessment group (LEMMA) based at the Pacific Northwest Research Station in Corvallis, Oregon (link to Web page: http://www.fsl.orst.edu/lemma/). Detailed attributes of forest composition and structure were mapped for all forests in the Plan area for two "bookend" dates. The bookend dates were 1996 and 2006 in Washington and Oregon, and 1994 and 2007 in California. This marks the first application of using multiple satellite imagery dates to create "bookend" vegetation maps for habitat monitoring purposes (Ohmann et al. 2010).

In addition to improved vegetation map products, the science of habitat modeling has evolved since the 10-year report. Species distribution and habitat suitability modeling has been the subject of much current research and discussion in ecology (Elith et al. 2006, Guisan and Zimmermann 2000, Hirzel and Le Lay 2008), so we spent a substantial amount of time reviewing modeling options and testing several types of software used for habitat modeling before deciding on the approach presented here.

One thing we have observed through these efforts is that regardless of the methods used, the map products are visually similar at the rangewide scale (fig. 3-1). Therefore, it is important to test the map's accuracy with actual spotted owl nesting and roosting location data. This is one area where the population monitoring and habitat monitoring efforts connect, as we used different subsets of the demographic data to first train and then test the accuracy of our habitat model mapped predictions.

The use of the new rangewide vegetation data set and the latest habitat modeling software has resulted in an improved baseline habitat map that has tested well with actual owl pair location data (including independent data sets). These improvements included better discrimination of habitat in the eastern Cascades, where pine-dominated forests mostly occur, and the use of the "habitat-capable" layer from Davis and Lint (2005) was no longer required for habitat modeling with the inclusion of a

subalpine forest type variable. We use this new baseline map (1994/96) and the other bookend map (2006/07) for conducting our habitat status and trend analysis.

The development of bookend maps was an innovative advancement in our monitoring methods, but aspects of it remain to be tested. Given its novelty, we restricted our use of the 2006/07 bookend to only inform us on habitat changes within areas that were identified as having experienced a disturbance by the LandTrendr data. It is important to make sure that the bookend maps used for later analyses are generated with the same data sets and methods, and tested so that the detection of change from one to the other is a fair comparison of "real'" change and not one caused by analytical or data differences. In future monitoring cycles, we anticipate more advancements in both vegetation data mapping and habitat modeling science; therefore, we anticipate that future modifications will be made to the baseline map, including the use of 1994 satellite imagery for the entire range. This is appropriate as the status and trend analysis is based on the use of the best available vegetation and change-detection data and technologies.

Habitat Monitoring Under the Plan

Under the monitoring plan, habitat status and trends are to be estimated approximately every 5 years after the baseline map was developed because it was believed that changes in forest vegetation conditions would not be discernable from the remote sensed vegetation data on more frequent intervals (Lint et al. 1999). The intent of habitat monitoring is to determine if assumptions made during the development of the Plan are holding true. Testing the assumption that habitat will not decline faster than predicted in the Final Environmental Impact Statement (USDA and USDI 1994) is of particular interest. The initial list of assumptions is as follows (Lint et al. 1999):

1. Habitat conditions within late-successional reserves (LSRs) will improve over time at a rate controlled by successional processes in stands that currently are not habitat. However, this is not expected to produce any significant changes in habitat conditions for several decades.
2. Habitat conditions outside of reserved allocations will generally decline because of timber harvest and other habitat-altering disturbances, but the vegetation structure across the landscape will continue to facilitate owl movements.
3. Catastrophic events are expected to halt or reverse the trend of habitat improvement in some reserves; however the repetitive design of reserves should provide resiliency, and not result in isolation of population segments.

Central to these questions is the federal network of reserved land use allocations designed to support groups of reproducing owl pairs across the species' range. These reserves include late-successional reserves, adaptive management reserves, congressionally reserved lands, managed late-successional areas, and larger blocks of administratively withdrawn lands. It is also important to monitor the lands between these reserves because they provide for recruitment of new owls into the territorial populations (see chapter 2, this report) and are important for dispersal and movement of owls between larger reserves. These dispersal habitats occur in a combination of matrix, adaptive management areas, riparian reserves, small tracts of administratively withdrawn lands, and other small reserved areas such as 100-ac owl core areas. To understand whether the Plan is contributing to the conservation and restoration of owl habitat, the condition and trends of owl habitat must be regularly assessed. The specific questions that were addressed in the 10-year report and that will be addressed here as well include:

1. What proportion of the total landscape on federal lands are owl habitat and dispersal habitat?

2. What are the trends in amount and changes in distribution of owl habitat, particularly in large, reserved blocks?
3. What are the trends in amount and distribution of dispersal habitat outside of the large, reserved blocks?
4. What are the primary factors leading to loss and fragmentation of both owl habitat and dispersal habitat?

Following the approach of Davis and Lint (2005), the condition of owl habitat will be reported at three broad geographic scales: (1) the physiographic province, (2) the state, and (3) the geographic range of the owl. However, because of changes that have occurred in federal land use allocations since the 10-year report (fig. 3-2), we will no longer report status and trends within every land use allocation. Instead, we will report by broad federal land use allocations representing "reserved" and "nonreserved" landscapes (fig. 3-3), which we feel is a more consistent and appropriate scale for monitoring. Because the "large block" reserves (see fig. 3-13, page 44 in the 10-year report) make up about 90 percent of the reserved landscape, we now consider our reporting of status and trend in the reserved landscape as one entity, whereas in the 10-year report we separated them. Although the effectiveness monitoring is focused to address questions about the Northwest Forest Plan, its developers realized that the status and trends of the subjects being monitored are often influenced by conditions on the surrounding nonfederal lands. Therefore, we will report on habitat conditions on nonfederal lands at the state and range scales, because these were included in the 10-year monitoring synthesis report by Raphael (2006).

As stated in the 10-year report, our objective was to produce maps of forest stands (regardless of patch size and spatial configuration) that showed the level of similarity to stand conditions known to be used for nesting and roosting by spotted owls. Forest stands with conditions most similar to what is used by nesting and roosting owl pairs are what we will refer to as "nesting/roosting habitat"

throughout this document. We will also report on forest stand conditions that are known to be used by dispersing owls, which we refer to as "dispersal habitat."

Methods and Data Sources

Land Use Allocation Data

An updated map of the Plan's land use allocations (LUA) was produced in 2002 for the 10-year monitoring reports (Huff et al. 2005, Lint 2005, Moeur et al. 2005). It updated the original 1994 version, which was mapped with older GIS technology and had a 40-ac resolution. This first update corrected some mapping inconsistencies, but more importantly, incorporated allocation changes that occurred between 1994 and 2002. Although this map was considered an improvement from the earlier version, some limitations still remained (Davis and Lint 2005, Huff et al. 2005). The major limitations were the inability to map riparian reserves (which can cover significant amounts of land where stream densities are high) and inconsistencies in how administratively withdrawn areas were delineated. Errors that remained after the 2002 update included the misidentification of a state-owned park in the redwood region of California as federally owned National Park Service land and inaccurate or missing boundaries of national wildlife refuges, mainly in Washington and Oregon. Other minor mapping issues included edge matching inconsistencies that caused "sliver gaps" and inconsistent attribution of large water bodies.

A second update of land use allocations performed in 2009 (fig. 3-2) produced a new version that is used for this 15-year report. The new version incorporates major land use allocation changes that occurred between 2002 and 2009, and it also corrects the errors identified above. Minor issues with inconsistent mapping of administratively withdrawn areas still remain, and a small amount (<1 percent) of federally administered lands are awaiting official land use allocation designations and identified as "not designated" in the 2009 map. Riparian reserves still remain unmapped because, as

Moeur et al. (2005) noted, "…at the Plan scale, they cannot be reliably distinguished from matrix because of a lack of consistency in defining intermittent stream corridors and varying definitions for riparian buffers."

The Plan allowed for land exchanges involving LSRs if they provide benefits equal to or better than current conditions, such as to improve area, distribution, and connectivity of the Late-Successional Reserve system (USDA and USDI 1994). It also acknowledges that future changes would occur for the administratively withdrawn allocation. At the end of the 15-year monitoring period, we note a net increase of about 25,000 ac in reserved allocations, and a net decrease of about 17,000 ac in nonreserved allocations. Most of the changes that occurred were designations of otherwise reserved allocations into 237,000 ac of congressionally designated reserves, and most of this (83 percent) occurred in northern California. Because some of the changes included land exchanges or acquisitions, the increase in reserved allocations and decrease in nonreserved allocations are not equal.

Land use allocations will continue to change, and we will continue to update this map with the intent of improving it for each monitoring effort. For monitoring purposes, we archive the previous versions and report vegetation and habitat changes for all monitoring modules within the reference frame of the most up-to-date allocation map. Major LUA changes that are important for us to note include changes that cover thousands of acres and involve gains or losses of reserved allocations. We will discuss these changes in relationship to the standard and guidelines within the record of decision (USDA and USDI 1994). Given the most recent information, the latest changes in reserved allocations (fig. 3-2) have resulted in a slightly increased area and improved distribution and connectivity of the reserved allocation system.

Vegetation Data

The vegetation data used for habitat modeling and mapping were developed through a method for predictive vegetation mapping using direct gradient analysis (Gauch 1982, ter Braak 1986) and nearest-neighbor imputation (Moeur and Stage 1995) to assign detailed forest vegetation plot information to every pixel in a GIS raster map. The combining of these methods to develop vegetation maps was termed "gradient nearest neighbor" (GNN) and is thoroughly described in Ohmann and Gregory (2002). The GNN maps developed in the Pacific Northwest have previously been applied to broad-scale vegetation mapping efforts across a wide range of forest ecosystems (Ohmann et al. 2007, Pierce et al. 2009). Forest attributes from regional inventory plots are assigned to map pixels where data are missing, on the basis of a modeled relationship between the detailed forest attributes from plots and a combination of spatial predictor variables derived from Landsat satellite imagery, climate variables, topographic variables, and soil parent materials. The assumption behind GNN methods is that two locations with similar combined spatial "signatures" should also have similar forest structure and composition. Plot data are from regional forest inventory plots: Forest Inventory and Analysis (FIA) periodic inventories on nonfederal lands, FIA annual inventory on all ownerships, and Current Vegetation Survey inventories. The GNN data used for habitat modeling and mapping covers the entire breadth of the owl's range from Washington to northern California for two points in time. We call these two data sets "bookends" because the changes in habitat that we analyzed and report on occurred between them. The satellite imagery from which GNN was created covers the period from 1994 to 2007 in California and 1996 to 2006 in Oregon and Washington. The on-the-ground plot data used to create the vegetation maps covers the period 1991 to 2000 for bookend 1, and 2001 to 2007 for bookend 2. The GNN products are 30-m (98.4-ft) grids that were specifically developed for mid- to large-scale spatial analysis (Ohmann and Gregory 2002).

The primary challenge was to develop GNN model-based maps for the two bookend dates that minimized spectral differences owing to different image dates that might produce false vegetation changes. To achieve this, the GNN models used Landsat imagery that was geometrically rectified and radiometrically normalized through time using the LandTrendr algorithms (Kennedy et al. 2007). A full description of the GNN bookends methodology can be found in Moeur et al. (2011).

The accuracy assessment for GNN continuous variables was based on the correlation of observed plot values against predicted (modeled) values. Ohmann et al. (2010) used a modified leave-one-out cross-validation approach that yields results similar to those of a true cross-validation approach, but probably slightly underestimates the true accuracy. The accuracy assessments are based on pooled plots for each modeling region. Canopy characteristics are usually the most easily determined via space-borne remote sensing instruments, and the most accurate GNN variable was conifer canopy cover, with an average plot correlation of 0.74 (±1 standard deviation [SD] = 0.07). Inferring vegetation characteristics underneath the canopy is more difficult, and the correlation coefficients for the structural and age vegetation variables we chose to use ranged from 0.38 to 0.82, with an average plot correlation of 0.63 (±1 SD = 0.12). The accuracy assessment for the species composition variables is based on Cohen's kappa coefficient, which is a measure of agreement between predicted and actual conditions (in this case dominant tree species), taking into consideration agreement occurring by chance (Cohen 1960). We combined several species to produce “forest type” basal area variables as shown in appendix A. The average kappas for these species groups, or forest-type, variables ranged from 0.30 to 0.46, with an average kappa of 0.40 (±1 SD = 0.07). Oak woodland was the most accurate species group, followed by subalpine, evergreen hardwoods, and pine.

Change-Detection Data

A new approach to monitoring landscape vegetation change was implemented to map forest disturbances in the owl's range. Landsat-based detection of trends in disturbance and recovery (LandTrendr) produces yearly maps of forest disturbance using a new analysis of annual Landsat Thematic Mapper satellite imagery (Kennedy et al. 2010). In general, LandTrendr detects spectral trajectories from Landsat time-series stacks and correlates them to land surface changes. The time series of Landsat imagery that was assembled for the Plan area was processed using basic atmospheric correction, cloud screening, and radiometric normalization to separate imagery noise (i.e., cloud cover, smoke, snow, or shadows) from actual vegetation change. Predictions of vegetation cover change were then evaluated using a statistical model of vegetation cover developed from photointerpreted plots (Cohen et al. 2010). The results of this evaluation found that LandTrendr detected vegetation disturbances as well or better than two-date change-detection methods, and that it detects with reasonable robustness a range of other dynamics such as insect-related disturbance and growth (Kennedy et al. 2010). Errors in LandTrendr predictions were generally confined to very subtle change phenomena (Kennedy et al. 2010). In summary, LandTrendr improved the temporal frequency of disturbance maps used for monitoring, better separates subtle changes from background noise, and detects a wider range of vegetation change phenomena than was possible with previous technologies (Kennedy et al. 2010, Moeur et al. 2011).

We used the LandTrendr data to verify habitat losses between our bookend maps and to attribute the most likely cause of habitat loss (fig. 3-4). The data covered the entire analysis area and period (1994-2007) and provided information by 30 by 30-m pixels on initial year of disturbance. LandTrendr classified the cause of disturbance (vegetation cover loss) into three types: (1) timber harvest, (2) insect and disease (can also include pathogens and other nonabrupt processes), and (3) wildfire. Fire locations were identified based on fire perimeter GIS data from Monitoring Trends in Burn

Severity (MTBS[1]) data, Geospatial Multi-Agency Coordination (GeoMAC[2]) data, and other sources (i.e., individual forest data). The remaining short-term disturbances were assigned "harvest" as the probable cause of disturbance, although wind may account for a small percentage.

Spotted Owl Presence Data

The owl survey data collected under the effectiveness monitoring program is important not only for population monitoring (chapter 2, this report), but also for monitoring suitable habitat. The owl pair location data (presence only spatial data) from demographic study areas are collected annually and are spatially very accurate. This made such data ideal for habitat suitability modeling; thus, we used them as the foundation for training our habitat models. However, the results of our preliminary model testing indicated that using only demographic study area data was problematic for modeling habitat in some modeling regions. Confining our model training data to the demography areas produced a "geographically clumped" distribution of model training points within the boundaries of our larger modeling regions. This clumping violated the basic assumption of habitat modeling methods that require independence and sampling without bias for presence data (training data) from the modeling region (Gillison and Brewer 1985, Phillips et al. 2009, Williams et al. 2002). We therefore matched our modeling regions to the boundaries of the demographic study areas, trained the habitat model to those areas, and then extrapolated the model results to the larger geographic regions. This produced mixed results, with some models testing well, while others could not be projected [extrapolated] successfully when the larger geographic area did not contain all the environmental variables that were used for habitat modeling. Our solution was to supplement the owl location data from demography study areas with the owl presence location from the broader geographic areas surrounding them to reduce sampling

[1] Data accessible thru the Forest Service's Remote Sensing Applications Center (RSAC) Web site http://www.fs.fed.us/eng/rsac/.

[2] Geospatial Multi-Agency Coordination Group or GeoMAC, is an Internet-based mapping application originally designed for fire managers to access online maps of current fire locations and perimeters in the conterminous 48 states and Alaska. Data are available at http://www.geomac.gov/.

bias issues and produce a training data set that was better distributed within the modeling region. To do this we used the data set used for the 10-year report (Davis and Lint 2005).

The first step in this process was to conduct a nearest neighbor distance analysis on owl pair site centers from study areas within each modeling region (app. B). We used the average nearest neighbor distances calculated from the 50-percentile harmonic cores (to remove outlier sites) from each of the study areas as a minimum distance parameter for randomly selecting a number (equal in size to the demographic study area data) of NSO pair sites from the 10-year report training data set (Davis and Lint 2005) that was outside of the study area boundaries. Both the demographic study area sites and the random selection of owl pair locations outside of them were combined to form the habitat suitability model training data set. This provided a well-distributed and nonclumped training data set for each modeling region.

We also attempted to match the date of our training data to the date of the satellite imagery used to create the vegetation data set that provided habitat variables for modeling. And finally, because we suspected interspecific competition between spotted owls and barred owls (*Strix varia*) to potentially confound the spotted owl/habitat use relationship, we used activity centers from the study areas based on surveys done between 1994 and 1996 because barred owl densities were lower than in 2006 and 2007. Our training data outside of the study area covers a broader period that roughly frames that period as discussed in Davis and Lint (2005).

Habitats, the Niche Concept, and Habitat Modeling

Understanding where animals live and the myriad factors associated with how and why they make those choices has been the subject of extensive research (Stauffer 2002). As stated by Morrison et al. (1992), "an animal's habitat is, in the most general sense, the place where it lives." This seems simple enough: but an animal can only live in an area that meets its basic needs for resources (food, water, nest

sites, etc.), includes competitors and predators with which it can coexist, and in climatic extremes it can withstand (Morrison et al. 1992). This is maybe best articulated within the niche concept, which has a long evolution in the science literature (see Morrison et al. 1992 for review) and has become a useful construct for conceptualizing and quantifying wildlife-habitat relationships. The multivariate, or n-dimensional, niche as defined by Hutchinson (1957) lends itself well to current attempts to model wildlife-habitat interactions, as it allows us to conceptualize all the complexities associated with how and why animals choose where they live. A species potential or "fundamental" niche includes a subset of all the environmental conditions required for a species long-term survival; however, this "fundamental niche" can be further restricted by predators and competitors resulting in a "realized niche" (Hutchinson 1957). This realized niche reflects a subset of the conditions found in the fundamental niche and is the set of environmental conditions that characterize the space a species actually occupies (Hutchinson 1957) and is reflected in the observed distribution of a species.

Many types of species distribution models are available for estimating a species realized niche (and producing a geographic distribution map of it) using species presence data that are correlated to environmental data of relevance to the species occurrence. For the 10-year report (Davis and Lint 2005) we used modeling software called BioMapper (Hirzel et al. 2002). However, species distribution modeling is a rapidly evolving field of study, so before conducting the spotted owl habitat modeling, we conferred with some of the species distribution modeling software developers (A. Hirzel and S. Phillips) and evaluated various habitat modeling methods (i.e., BioMapper: Hirzel et al. 2002; MaxEnt: Phillips et al. 2006, Phillips and Dudík 2008; Mahalanobis distance method: Jenness 2003; resource selection functions: Manley et al. 1993). We also ran comparison tests between BioMapper (all algorithms) and MaxEnt using "virtual species" data sets provided by Dr. Alexandre Hirzel (the developer of BioMapper) with known species occurrence and distributions. The details of these tests are not provided in this report; however, our conclusions were similar to those of Braunisch and Suchant (2010) who found that

BioMapper and MaxEnt produced models with similar accuracy, but that MaxEnt performed better when trained with systematically sampled data that were well-distributed within the modeling region. However, BioMapper outperformed MaxEnt when the model results were extrapolated to areas outside of the model training data area (Braunisch and Suchant 2010). In summary, our tests found that as long as species presence [training] data were fairly well distributed within a modeled region, MaxEnt outperformed the other modeling methods, and we selected it as the habitat modeling tool for this reporting cycle. Several other comparisons between MaxEnt and a number of other habitat modeling approaches are available in the scientific literature, and in most cases distribution models generated by MaxEnt performed as well or better than the other methods (Baldwin 2009).

Other notable factors associated with our selection of MaxEnt included its user-friendly interface, its ability to run replicated models for testing purposes and to provide information on the importance of the environmental variables used for modeling, and most importantly, its ability to "project" or "transfer" model results. Model transferability is the term given for applying the results of a model that is calibrated for specific location or period, to a different geographic location or period (Turner et al. 1989). The concept is based on the idea that calibrated model parameters from one area or time may provide useful information in estimating conditions in a different time or place. In our situation, we attempted to transfer our models, which were trained in 1994/96 to the same geographic location, but in a different period–2006/07. Model transferability is a fairly new concept, and one that is rarely assessed (Randin et al. 2006). Issues with MaxEnt projections documented by Braunisch and Suchant (2010), our model testing, and the current literature advise for caution in its use and interpretation (Peterson et al. 2007, Phillips 2008, Jiménez-Valverde et al. 2009).

Habitat Modeling Process

MaxEnt uses a machine learning process and a suite of potential response functions to estimate the most uniform distribution (maximum entropy) of the "average" environmental conditions at known species locations compared to what is available across the modeled area (background) (Phillips et al. 2006). The modeling process does not require an a priori specification of a set of models, but instead fits training data (presence locations of owl pairs) to environmental covariates using various combinations of response functions (features) such as linear, quadratic, product, hinge, and threshold structures. However, the use of all feature types may lead to model overfitting depending on the sample size of the training data (Phillips et al. 2006); therefore, the "auto feature" (default) restricts the model to simpler features, such as linear, quadratic, and hinge, for smaller sample sizes (Elith et al. 2011). In our preliminary model tests, overfitting seemed to occur from the use of the threshold feature, which requires a minimum of 80 training samples and produced sharp jumps (both up and down) in the variable response curves. Modeling with just the hinge feature produces models with simpler or smoother functions and is generally a useful simplification that can reduce overfitting (Phillips 2010). Our final selection incorporated a combination of linear, product, and hinge features because most of our hypothesized variable responses fit those choices. We considered using the quadratic feature; however, during our model testing, MaxEnt applied this feature to variables in which the response function did not make ecological sense (i.e., tree diameter). This was most apparent in modeling regions where the variables had outlier values at the extreme high end of the distribution histogram. The inclusion of the hinge and product features compensated for the omission of the quadratic feature, because in combination they can conform to a quadratic shape. We also selected the "auto features" option, which allows MaxEnt to further limit the subset of response features from those we selected above by retaining only those with some effect.

Other techniques can be used to control overfitting the data, such as reducing the number of parameters in the model. To do this, MaxEnt provides a "regularization feature" that performs a function similar to Akaike's information criterion (Akaike 1974) by penalizing the complexity of the model. The regularization multiplier affects the fit of the model training data to the modeling variable empirical means. A smaller value results in a tighter fit but potentially leads to overfitting the model to the data. The default setting of 1.0 is believed to be an appropriate setting for most modeling efforts (Phillips and Dudík 2008). A higher regularization multiplier setting reduces the number of model parameters, allowing for a more spread out fit around the mean, and simplifies the model.

Observing the statistical performance on test (versus training) data is the best approach to final model calibration (Phillips 2010). We therefore evaluated our model's performance beginning with the model test gain, which indicates how different the testing data are from the background data. It is similar to "deviance" as used in generalized linear modeling (Phillips et al. 2006) and higher gains indicate larger differences between occurrence location environmental conditions and average background environmental conditions. The exponent of gain produces the mean probability value of predicted species occurrence compared to a random location selected from the surrounding modeled landscape. Or in other words, an average testing gain of 0.80 indicates that the model predicted owl occurrence 2.2 times what would be expected by chance. In addition, observing the differences between model testing gain and regularized training gain can be used to control model overfitting, as a large difference between the two is an indication of model overfitting (Phillips 2010).

Using more than just one evaluation statistic to evaluate habitat model performance is highly recommended (Liu et al. 2005), so in addition to gain, we evaluated the area under the receiver operating curve (AUC) statistic to determine model accuracy and fit to the testing data (Fielding and Bell 1997). The AUC statistic is a measure of the model's predictive accuracy, and it was originally developed for evaluations using presence and absence data, producing an index value from 0.5 to 1 with values

close to 0.5 indicating poor discrimination and a value of 1 indicating perfect predictions. The AUC values can be interpreted similarly to the traditional academic point system where values between 0.9 and 1.0 indicate an excellent model (A), 0.8 to 0.9 is good (B), 0.7 to 0.8 is fair (C), 0.6 to 0.7 is poor (D), and AUC values between 0.5 and 0.6 represent failure (F), or models that don't predict much better than a random guess. Example of this interpretation in the field of niche-based species distribution models can be found in Araújo et al. (2005) and Randin et al. (2006). In our situation, MaxEnt uses 10,000 randomly selected background locations (map pixels) instead of true absence data, so it is not possible to achieve an AUC value of 1.0 (Wiley et al. 2003). However, interpretation is similar, with higher AUCs indicating better model predictions (Phillips et al. 2006). Specific to our case, AUC values represent the percentage of times a spotted owl nest site location would have a higher habitat suitability value than a randomly selected location from the modeling region.

Our third measure of model performance was the continuous Boyce index (CBI) as described by Hirzel et al. (2006). This index and methodology is designed specifically for testing habitat suitability models produced from presence only data. The index is based on the Spearman rank correlation coefficient (R_s) that compares the ranks of modeled species occurrence with the area available to "binned" modeled prediction ranks (Boyce et al. 2002). A good model would predict an increasing ratio of the percentage of species occurrence to the percentage of the modeled landscape in each model bin as the bin values increase. An R_s of 1.0 indicates a strong positive correlation (Boyce et al. 2002).

We produced 10 bootstrapped random replicates for each modeling region using 25 percent of the training data held out to test the model. We reviewed the jackknife graphs for mean test gain and AUC from these replicates, which are produced by MaxEnt. These graphs illustrated the contribution that each variable made to the overall model (Phillips et al. 2006). Based on these graphs, we dropped variables that significantly increased mean test gain and AUC when excluded. Once this decision was made, a final check for model overfitting (see above) was conducted. This process entailed increasing

the regularization multiplier by increments of 0.5 from the default setting of 1.0 (once the final list of variables was agreed to) until the highest CBI was achieved using 10 replicates.

The final models used for reporting status and trends are the average summary statistic model outputs from these replicates. MaxEnt also produced other summary statistic grids, such as the standard deviation for each cell within the modeling region. We used these maps to calculate a 95-percent confidence interval (CI) for each cell and produced upper and lower limit maps based on it. These summary maps were used to generate histograms of the model predictions uncertainty for each model region and for each bookend (app. C). The maps produced are also useful to see where within the modeling region the model predictions are less robust.

Environmental Variables

The environmental variables that influence the spotted owl's distribution in the Pacific Northwest have been well studied, and a wealth of information exists in the literature on important vegetation characteristics associated with owl habitat use. As previously noted, we were restricted to only a few basic factors (i.e., tree diameter, canopy cover) for the habitat modeling done in the 10-year monitoring cycle (Davis and Lint 2005); however, the GNN map products provided us a more extensive "menu" of forest vegetation variables to consider. Our initial selection of vegetation characteristics and environmental variables for habitat modeling was based on three things: (1) habitat relationship information in the literature expert knowledge, (2) on-the-ground plot accuracies of the variable, and (3) correlations between the covariates. We chose not to use any GNN structural or age variables that had plot correlations less than 0.3 for an individual modeling region and <0.5, averaged across all modeling regions. For species composition variables, we chose not to include any variables that had kappas <0.2 for individual modeling regions or <0.3, averaged (as a species group) across all modeling regions. In

cases where variables were highly correlated (Pearson correlation >0.7) with each other we dropped the variable with the lower plot accuracy.

From our initial list of GNN variables, we dropped basal area of conifers ≥20 in diameter at breast height (d.b.h.) because it was highly correlated with the mean stand conifer diameter, stand height, and the diameter diversity index, but had the lowest plot accuracies. We also dropped the standard deviation of d.b.h. of all live trees for similar reasons. We also did not include total canopy cover or stand density index variables because both had high correlations with conifer cover, which had the highest plot accuracy of all GNN variables. We considered, but did not use any GNN variables for snags and down wood because of low plot accuracies for those types of variables.

We ended up with a consistent set of five variables that reflected forest structure and one forest age variable that we included in all of our modeling regions. The accuracy of the variables we used is shown in appendix A (table A-2), along with Pearson correlations between covariates we selected for habitat modeling. We also developed five forest species composition variables (i.e., subalpine, pine, evergreen hardwoods, oak woodlands, and redwoods) and included them as appropriate for each modeling region (app. A, table A-2). For instance, we did not include a subalpine variable in the California Coast Range modeling region, because none exists in that area. Likewise, we did not include the redwood variable in the western Washington/Olympic Peninsula modeling region. The final list of variables used in each modeling region is provided in appendix C.

Modeling Regions

Based on recommendations from the 10-year report (Davis and Lint 2005), we developed habitat modeling regions that removed some administrative boundaries (i.e., state lines) and framed areas based more on ecological rather than sociopolitical divisions. Our modeling regions were modified versions of the standard physiographic provinces developed in FEMAT (1993) and used for reporting

monitoring results (fig. 3-5). Our intent was not to further split the existing delineations into smaller areas, but to combine the existing delineations based on two things: (1) ecological similarities between physiographic provinces and (2) occurrence and distribution of spotted owl location data being used for model training and testing. We used the ecological region (a.k.a. geographic region) information from the population monitoring work (app. A in Anthony et al. 2006, Forsman et al. 2011) to combine some provinces and Environmental Protection Agency level III ecoregions (Omernik 1987) to guide final delineations of modeling regions. Modeling regions were only used for habitat modeling purposes, we still report on habitat status and trend conditions within the physiographic provinces to maintain consistency with previous reports.

Within these modeling regions, our modeling background (the area for which MaxEnt compares the combinations of environmental variables that underlay owl locations to the broader area that is available for use) was based on a "habitat-capable" mask that we generated specifically for habitat modeling purposes. The GNN environmental data are modeled from detailed field plot data from forest-capable areas only, and a non-forest-capable "mask" is provided by GNN using ancillary land class data from the Gap Analysis Program (GAP) and National Land Cover Data (NLCD) data sets (Vogelmann et al. 2001). The GAP data are based on multiseason satellite imagery (Landsat ETM+) from 1999-2001 used in conjunction with other data sets (i.e., elevation, landform, aspect, etc.) to model the distribution of ecological systems (Comer et al. 2003) and land cover classes at a 1-ha (2.47-ac) resolution. However, upon review, the GNN mask included inconsistent masking of urban areas and roads, and also did not mask out areas that we felt were not capable of developing into habitat (i.e., subalpine parklands and steppes). Therefore, we used the "unmasked" GNN data set and applied our own customized mask specific to our purposes. The mask we developed included the use of the "impervious layer" from NLCD (Herold et al. 2003) to consistently exclude areas that have been converted into non-habitat-capable conditions (i.e., urbanized areas, major roads, etc.) and refined the developed open space designations.

We then modified the existing GNN mask classes to exclude a few additional land classes or ecological systems that we felt were not habitat-capable. Isolated areas less than 2/3 ac (pixel map noise) of both mask and nonmask were removed. The intent of our mask was to frame our modeling area such that it contained lands capable of producing closed canopy forests that could be potentially suitable for spotted owl nesting, roosting, foraging or dispersal; however, we suspect that this mask contains areas, especially in the higher elevations that might not actually be capable of developing habitat under the current climate.

Habitat Map Development and Evaluation

The MaxEnt model output is a logistic probability estimate of a site's suitability for species presence based on environmental conditions from where the species are found, and their differences from the surrounding background environmental conditions within the modeling region (Phillips and Dudík 2008). In our case, the environmental predictor variables used were based on stand-level structural and forest type species conditions associated with nesting and roosting use by spotted owls. Therefore, our raw model output maps show a scale of nesting/roosting suitability (from low to high) for forested stands based on the stand structure and species composition conditions described by the GNN data. The mapped logistic probability values will be higher where these stand-level conditions are more similar to the conditions observed where we have documented nests and territorial pair centers (i.e., the training data). A mapped logistic probability of 0.5 represents the "average" condition where the species occurred (Phillips 2008).

Our charge is to develop habitat maps that work well and to then measure and report on amounts and distribution of habitat. The latter requires that we select a threshold from the probability values described above to represent "suitable" owl nesting/roosting habitat for summarization purposes. In the 10-year report, we used the area-adjusted frequency (AAF) curves (Boyce et al. 2002)

associated with the habitat suitability output from BioMapper to evaluate our habitat models. These curves are among the few diagnostic measures designed specifically for measuring the accuracy of habitat models based on presence-only data (Hirzel et al. 2006). But in addition to model evaluation, these curves also provide information that can be used to reclassify habitat models into discrete habitat classes (Hirzel et al. 2006). To conform to the new terminology, we now refer to AAF curves as "continuous predicted versus expected (P/E) ratio curves" (Hirzel et al. 2006). The continuous P/E curves provide three indications of a model's performance (Hirzel et al. 2006):

1. For replicated model runs that use held-out testing methods (i.e., bootstrap or jackknife) the variance along the curve gives information about the model's robustness along its range of probabilities. Smaller variances indicate more reliable prediction points. Large variances indicate the range of prediction values that are the least robust. This information allows a better understanding of the model's strengths and weaknesses.
2. The shape of the curve provides clues about the model's predictive power. The Spearman rank correlation coefficient (R_s) is used to help us judge the shape of the curve and the model's performance. For fluctuating curves, each time the curve dips as the ranks increase, R_s decreases. A higher R_s indicates a consistently increasing larger proportion of species presence (versus available) being predicted as the model prediction output increases. This is indicative of a good model; however, note that one can get the same R_s for many different-shaped curves (i.e., linear, exponential, and sigmoid), and curves with flatter slopes can have the same ranks as curves with steep slopes. According to Hirzel et al. (2006), a perfect model would have a linear P/E curve that monotonically increases as probability increases because a perfectly straight line allows for an infinite number of classes along the scale of probability (i.e., "resolution"). A wavy line lowers the resolution because classifying the line depends on these changes in the shape and slopes. For exponential models (like MaxEnt), an exponentially increasing curve is indicative of a good model.

3. The maximum y-axis value reached by the P/E curve reflects how much the model differs from chance expectation, or deviation from randomness. This score reflects the model's ability to differentiate the species niche characteristics from those of the modeled region. Caution is needed, because this maximum value is sensitive to the species niche breadth within the context of the modeled region. In other words: Does the species just use a small percentage of what is available in the modeled region or is its habitat use more generalized within the modeling region? If there is abundant habitat available in the modeling region that is being used by the species, the model will usually produce a flatter curve with lower P/E values. Also, the selection and resolution of the environmental variables used for modeling can influence the maximum P/E value.

Once the habitat model evaluation process has been completed, the P/E curve provides a method for classification of a model into discrete habitat classes (Hirzel et al. 2006). The point along the model prediction axis (x-axis) where the curve crosses P/E = 1 along the y-axis (fig. 3-6) is the threshold where the model predicted species occurrence higher than would be expected if there were no selection (i.e., habitat use was random). This threshold is often used to classify habitat models into binary maps, where logistic probability values greater than the P/E = 1 threshold represent "suitable" habitat (Hirzel et al. 2006). We also note that in our case, the P/E = 1 threshold was similar to the "maximum specificity and sensitivity threshold"[3] (Phillips and Dudík 2008) for all model regions. We provide these and additional thresholds, that are commonly used, in appendix C. We also note that the 10-percentile threshold (app. C) is equivalent to where we reported that 90 percent of the owl training data occurred in the 10-year report habitat models (see fig. 3-11 and table 3-4 in the 10-year report).

We further divided the continuous scale of probability of occurrence from our habitat models into four habitat classes that represent from the least to the most suitable habitat conditions (fig. 3-6).

[3] Minimizes omission (false absence predictions) and commission (false presence predictions) errors.

This was done to produce histograms (appendix F) similar to the five-class histograms used to profile the continuum of habitat suitability in the 10-year report (Davis and Lint 2005). As in the 10-year report, tracking the changes in these habitat profiles (appendix F) is expected to provide useful information for visualizing where habitat may be recruited (first two habitat classes) via forest succession over the next few decades. The only difference between the two reports is that the classes in the 15-year report are based on commonly used thresholds and have more biological meaning. These habitat classes are defined as follows:

- Unsuitable–MaxEnt logistic output from zero to the mean value between zero and the P/E = 1 threshold. This habitat class represents the lowest suitability class and owls will normally avoid using it for nesting and roosting.
- Marginal–MaxEnt logistic output from the mean value between zero and the P/E = 1 threshold to the P/E = 1 threshold. This habitat class represents a condition approaching what owls will nest and roost in. Occasionally, these habitat characteristics are associated with nesting and roosting owls; however, this could be due to occurrence of legacy habitat features such as large trees, extreme rarity of suitable nesting/roosting habitat, or perhaps interspecific competition with barred owls.
- Suitable–MaxEnt logistic output from the P/E = 1 threshold to 0.5. A MaxEnt logistic output value of 0.5 represents the "average" environmental condition associated with the owl training data. This habitat class represents habitat conditions where the probability of owl presence is higher than expected by random chance and up to average conditions associated with nesting and roosting.
- Highly Suitable–MaxEnt logistic output from 0.5 to the highest output from the habitat model. This habitat class represents the most suitable, or "above average", conditions used by nesting and roosting territorial owl pairs.

In some of the modeled regions, the 10-percentile threshold occurs within the "marginal" habitat class indicating some owl nesting/roosting use of younger, mid-aged stands as noted by Thomas et al. (1990) who stated that as forests develop along the continuum from young to old, they gradually become more suitable for spotted owl nesting/roosting. To show this continuum of conditions, and to help interpret what these habitat classes represent on the ground, we also provide average stand structure and age attributes (table 3-1). It appears that the lowest class of habitat includes early to mid-successional forests and the highest suitability class includes the oldest and most structurally complex forests (table 3-1). However, we stress that these simple combinations of forest attributes do not fully describe habitat, and it is the complex interaction between them that does.

Nesting/Roosting Habitat

The importance of mature or late-successional forests for nesting, roosting, and foraging of owls in the Pacific Northwest is clear (see reviews in Thomas et al. 1990), with numerous studies documenting both selection of these habitats by owls (Carey et al. 1990, Forsman et al. 1984, Glenn et al. 2004, Gutiérrez et al. 1984, Hamer et al. 1989) and now more recent research linking greater amounts of older forest in owl territories to owl fitness (i.e., increased survival and/or reproductive success; Dugger et al. 2005, Franklin et al. 2000, Olson et al. 2004). High-quality owl habitat was described by Thomas et al. (1990) and generally includes older, multilayered, structurally complex forests characterized by large-diameter trees, high amounts of canopy cover, numerous large snags, and lots of downed wood and debris. Although late-successional and old-growth forests are often equated with spotted owl habitat, they are not always the same. As noted by Thomas et al. (1990), the redwood zone in northwestern California is unique in terms of owl habitat development. In that portion of the owl's range, the structural conditions that constitute nesting/roosting habitat develop quicker, with suitable conditions occurring in 40 to 60 years on some sites and superior conditions in 80 to 100 years.

Habitat development is not a mechanistic process, and there is considerable variability in predictions of habitat (Courtney et al. 2004). As can be seen in table 3-1 and appendix C, the transition from unsuitable to suitable conditions is more complex than a simple increase in a stand's average tree diameter and canopy closure. In addition, species composition is also important; for instance, late-successional/old-growth ponderosa pine forests do not function as nesting/roosting habitat, nor do older subalpine forests.

We consider our "suitable" and "highly suitable" habitat classes, as described above, as nesting/roosting habitat. It is important to emphasize that our maps are not attempting to predict owl occupancy or other demographics across the landscape, but rather describe stand-level habitat characteristics that are associated with owl pair use that approximates a species realized niche within a specific environmental space (Phillips et al. 2006).

Dispersal Habitat

Dispersal habitat is used by juvenile owls moving away from natal areas or by subadults and adults moving between territories (Forsman et al. 2002). Spotted owls are capable of dispersing long distances, and gene flow from one portion of the range to another can occur in a few generations (Forsman et al. 2002). The network of large reserves established under the Plan appeared suitable for maintaining interconnected populations of spotted owls (Lint et al. 2005); however, concern remained for disjunct small populations that are isolated by large nonforested areas or expanses of young managed forests (Forsman et al. 2002).

Thomas et al. (1990) predicted that much of the forested area between owl conservation areas would be suitable for passage by dispersing spotted owls as long as at least 50 percent of the landscape was forested with conifer stands with an average d.b.h. of ≥11 inches with at least 40 percent canopy closure. This definition of a dispersal-capable landscape became known as the "50-11-40 rule" (Thomas

et al. 1990) and was based on information of habitat conditions for dispersing juvenile owls (Miller 1989). Older forest habitat is more frequently used for natal dispersal, but closed-canopy (>60 percent cover) younger forests are also used whereas younger open-canopied (<40 percent cover) forests are generally avoided (Miller et al. 1997). Dispersal distance is also negatively associated with the amount of clearcut forest in the landscape, and large urban and agricultural areas appear to be barriers to dispersal (Forsman et al. 2002, Miller et al. 1997). Spotted owls use a wide variety of forest habitats for dispersal and will traverse very fragmented landscapes (Forsman et al. 2002), but little information exists on how the amount or fragmentation of habitat influences dispersal. The results of the latest meta-analysis suggest that recruitment into the territorial breeding population may depend on the presence of sufficient amounts of high-quality dispersal habitat, enough to ensure survival of dispersing owls until they recruit into the territorial population (Forsman et al. 2011).

We did not use presence locations and MaxEnt to model dispersal habitat. Instead we developed dispersal habitat maps for both bookend periods using simple GIS queries of our GNN variables for conifer d.b.h. ≥11 in and conifer cover ≥40 percent, similar to what was done in the 10-year report (Davis and Lint 2005). We also included both suitable habitat classes from our nesting/roosting habitat models, because owls obviously disperse through nesting/roosting habitat. We then analyzed the status and trend of this habitat within federal reserved and nonreserved land use allocations, as well as nonfederal lands. To detect changes in amounts of dispersal habitat that might affect owl movement across the landscape, we conducted a landscape-scale analysis using a spatial framework based on Forsman et al. (2002). Only 8.7 percent of dispersing individuals moved more than 31 linear mi and only "large expanses" of nonforested or younger forested areas appear to pose significant barriers to this movement (Forsman et al. 2002). We used this distance to define the radius (15.5 mi) for a circular analysis window within which we quantified the percentage of dispersal habitat for both bookend periods and included all land ownerships. This distance is also comparable to the root-mean-square

dispersal distance (a measure of gene flow) estimated by Barrowclough et al. (2005). We then overlaid linear owl dispersal paths from the 10-year report (Lint et al. 2005) on the baseline version to measure underlying percentages of dispersal habitat in the landscape through which they dispersed (fig. 3-7). The mean percentage of dispersal habitat for both juvenile and nonjuvenile owls was 55 percent. We combined results across age classes and used the 10-percentile value (40 percent) from all owl dispersal paths as a threshold to create binary maps from the roving window analysis maps. Thus, the binary maps show where there appears to be enough dispersal habitat at the landscape scale (≥40 percent within a 15.5 mi radius) to accommodate 90 percent of known owl movements. We call this footprint the "dispersal-capable landscape" and used it to identify potential disconnects or bottlenecks for owl movement between large block reserves. We also identified areas across the range of the owl where the footprint shrank or expanded between our bookends.

Habitat Fragmentation

Although large blocks of contiguous, high-quality habitat provide the best configuration for long-term persistence of owl populations (Thomas et al. 1990), smaller blocks or patches of owl habitat can also be important as dispersal habitat (Forsman et al. 2002). These smaller patches help to maintain connectivity between the larger blocks of habitat that will eventually develop in the reserve system designed under the Plan. At the time of the owl's listing, habitat fragmentation was believed to be a stressor for spotted owls because it is associated with habitat loss, and was also thought to improve habitat conditions for spotted owl predators, such as the great horned owl (*Bubo virginianus*) (Carey et al. 1992). There is no clear evidence of indirect effects of fragmentation through predation, but it remains as a possible threat (Courtney et al. 2004). A compilation of the recent research on this subject shows that habitat fragmentation can affect occupancy and other demographic factors, and may result in isolated populations and interruption of gene flow (Courtney et al. 2004).

In a general sense, habitat can be divided into two broad landscape morphological categories: (1) core habitat, which occurs only in larger habitat patches and is some distance away from the patch edge (sometimes referred to as "interior habitat") and (2) edge habitat, which occurs along the margins of larger habitat patches surrounding the core habitat or occurs in patches that are too small to contain core habitat.

It is not clear how habitat fragmentation affects owl demographics; however, survival and reproduction are higher on owl territories with more old-forest habitat centered on the nest tree or activity center (Dugger et al. 2005, Franklin et al. 2000, Olson et al. 2004). Edge habitat also appears to be important to spotted owls in some portions of their range, probably as a source of prey (Franklin et al. 2000, Olson et al. 2004; but see exception in Dugger et al. 2005).

Here we define core habitat as the internal portion of a stand of nesting/roosting habitat that is farther than 100 m from the stand edge. Edge habitat is defined as all noncore nesting/roosting habitat and is always adjacent to nonhabitat. We do however, distinguish between two types of edge habitat: (1) core-edge habitat, which is the amount of nesting/roosting habitat adjacent to and surrounding core patches (i.e., the edges of large habitat patches), and (2) all other edge habitat that is not directly adjacent to core habitat (i.e., small, isolated habitat patches). In juxtaposition together, core and core-edge habitat reflect more contiguous habitat blocks, whereas large amounts of non-core-edge habitat occur in landscapes that are highly fragmented, with patch sizes too small to contain core habitat.

We used GUIDOS v1.3 (Soille and Vogt 2009) to conduct a morphological spatial pattern analysis (MSPA) on 100-m (2.47-ac) resolution binary raster (grid) maps of nesting/roosting habitat for both 1994/96 and 2006/07 to assess status and trend in habitat configurations. GUIDOS was specifically developed for analysis of forest spatial patterns extracted from satellite images (Soille and Vogt 2009, Vogt et al. 2007). It produces simple-to-interpret maps of core and edge patterns from binary raster maps, and the outputs are pixels with specific core or edge classifications (fig. 3-8). From this product,

we conducted an area analysis that quantifies the area represented by both types of pixels ("core" or "edge"); thus, in our analysis, edge is not quantified as a perimeter. Specifically, edge habitat only occurs within 1 pixel width, or 100 m (328 ft), from a nonhabitat pixel, and, therefore, core habitat pixels are greater than 328 ft from nonhabitat pixels. This distance is similar to that used by Franklin et al. (2000) and Zabel et al. (2003) to define their core habitat. Using 100-m (2.47-ac) resolution maps requires a patch of contiguous habitat to be greater than 22 ac before it can contain core habitat. Therefore, the combination of core plus core-edge pixels shows patterns of habitat patches that are at least that large. All patches of nesting/roosting habitat smaller than that are essentially edge habitat. We report on the status and trend of core habitat and changes in the percentage of the sum of [core] + [core-edge] habitat to all nesting/roosting habitat. This percentage can serve as an index of landscape habitat fragmentation, as the higher the percentage, the more contiguous the habitat is within the landscape and the lower the percentage, the more fragmented the habitat (fig. 3-8).

Results

Habitat Suitability Modeling

Our final habitat models and map products (fig. 3-9) represent the mean from 10 bootstrapped replicates. We decided to use the means as our product, because the P/E curves that are generated for the means provide the users with valuable information on how to interpret the model (see the "Habitat Map Development and Validation" section and fig. 3-6). We also provide the summary statistic maps (i.e., 95-percent CI) to supplement this interpretation with area-specific information as discussed in the methods section.

Performance of bookend 1 (1994/96) models was fair to good (i.e., C+ to B+ grades) with AUCs ranging from 0.78 to 0.88 and Spearman rank correlation coefficients >0.9 ($P < 0.001$) (app. C). Our lowest performing models occurred in the Oregon and California Klamath and California Coast modeling

region and our best models were in the Washington Coast and Cascades and Oregon Coast modeling regions. We suspect this is because of the rich vegetative diversity in that area that: (1) confounds remotely sensed data development and (2) produces a more complex "definition" of habitat because of the complex variable interactions. Regardless of the reason, the model AUCs for these regions were 0.78 and 0.81, respectively, and therefore provide useful information (Swets 1988).

Our projected models (bookend 2, 2006/07) were tested using the 2006/07 owl location data sets not used for model training. Spearman ranks based on the continuous Boyce index (Hirzel et al. 2006) ranged from 0.63 to 0.98. The best model projection [extrapolation] occurred in the Oregon Cascades modeling region, followed in order by the Oregon Coast Range ($R_s = 0.95$), western Washington and Olympic ($R_s = 0.93$), and surprisingly the Klamath Mountain modeling region ($R_s = 0.92$). The poorest model projections occurred within the Washington Cascades modeling region ($R_s = 0.74$) and California Coast Range ($R_s = 0.63$). During this testing process we noted interesting differences between the average habitat suitability values where spotted owls in the demographic study areas occurred in 1994/96 compared to where they occurred in 2006/07 (fig. 3-10). We observed consistently lower than average habitat suitability values in 2006/07 compared to 1994/96; however, 95-percent CIs overlap between periods. We speculate that spotted owls might be using lower-quality habitat in 2006/07 because they are being displaced from higher-quality habitats by barred owls, whose density has increased steadily since the late 1990s (Forsman et al. 2011). The potential for displacement of spotted owls by barred owls in the current bookend is the reason we trained our models using the 1994/96 spotted owl locations. However, given the aforementioned issues on model projection [extrapolation], these results, based on our bookend 2 models, should be interpreted with some caution.

Nesting/Roosting Habitat

We estimate a rangewide gross loss of about 298,600 ac[4] of spotted owl nesting/roosting habitat on federal lands (app. D). This amounts to about 3.4 percent of what was present in 1994/1996 (bookend 1). Most of the loss (79 percent) occurred within the reserved allocations, which amounted to about 3.7 percent of the reserved areas under the Plan, whereas nonreserved allocations experienced a 2.7 percent loss of habitat. Wildfires remain the primary cause of habitat loss, accounting for about 90 percent of the loss in reserved allocation (203,900 ac), and about half of the loss in nonreserved allocations (32,600 ac). Timber harvesting accounts for about 45 percent of the loss in nonreserved allocations (37,400 ac) and 7 percent within reserved allocations (16,600 ac), and insects and disease outbreaks account for about 3 percent of the loss in all allocations (fig. 3-11). Relative to the baseline maps, and based on LandTrendr change-detection data, the physiographic province that experienced the greatest loss of habitat was the Oregon Klamath province because of the large Biscuit Fire that occurred in 2002. In general, the Klamath and eastern Cascades physiographic provinces experienced the largest percentage losses of habitat related to wildfires (fig. 3-12); however, in terms of absolute acreage of habitat lost, the Oregon Klamath ranked first (93,600 ac), California Klamath ranked second (71,600 ac), and the Oregon western Cascades ranked third (28,900 ac) (app. D). Most of the habitat loss in the Oregon western Cascades occurred in the southern half of that province.

Because wildfires appear to be the number one cause of habitat loss, we conducted a more in-depth analysis of the 20 largest wildfires that occurred within the owl's range between 1996 and 2006 (years with satellite data across the range). Table 3-2 lists these fires in descending order of estimated acres of owl habitat lost. Overall, these 20 fires accounted for almost 200,000 ac of habitat lost. The percentage of owl habitat lost within their fire perimeters differed among the east and west Cascades (Washington and Oregon) and the Klamath Mountains (Oregon and California) physiographic provinces

[4] Acres are rounded up to the nearest 100 ac.

(fig. 3-13). The percentage lost per fire in the Klamath Mountains and the west Cascade provinces were not significantly different (overlapping 90-percent CIs); however, percentage of habitat loss per fire was notably higher in the eastern Cascades. However, in terms of the amount of nesting/roosting habitat burned by these 20 fires, the vast majority of acres lost occurred in the Klamath Mountains (143,000 ac), followed by the east side of the Cascades (36,000 ac) and the western Cascades (20,000 ac).

Based on Climate, Ecosystem, and Fire Applications (CEFA) program data (Brown et al. 2002) and wildfire perimeter data (MTBS and GeoMac), wildfires burned an estimated 2.6 million ac within the owl's range between 1994 and 2007, which frames our analysis period. From our observations, it is clear that wildfires do not remove all owl nesting/roosting habitats within their perimeters. Fires of low to moderate severity can alter this habitat, but do not necessarily result in its loss. The commonly used term to define this effect is "habitat degradation". We estimated owl habitat degradation, as the number of acres that changed from the "highly suitable" to the "suitable" habitat class between our bookends (1994/96 to 2006/07). For habitat degradation, our analysis showed the reverse trend from what we observed for habitat loss (fig. 3-14). These results suggest that wildfires in the east Cascades have been more destructive (higher amount of habitat loss, lower amount of degradation) and that wildfires in the west Cascades and Klamath Mountains were less severe, producing a mosaic of fire effects indicative of a moderate severity regime.

For this report, we were cautious in our use of the new GNN/LandTrendr data for measuring gains in nesting/roosting habitat. Although the products we used for our analysis (and other remote sensing approaches) have demonstrated their ability to detect both losses and gains in forest cover (Coops et al. 2010; Hais et al. 2009; Kennedy et al. 2007, 2010; Staus et al. 2002), the underlying measurements from passive optical satellite sensors (i.e., those that take pictures of sunlight reflected from the Earth's surface) place constraints on the subtlety of coniferous forest change that can be reliably captured over a short period (i.e., 10 to 12 years). Disturbances that result in substantial

removal or reduction of vegetation cover (usually abrupt changes) are easier to discern during change-detection than minor disturbances that cause more subtle change, or gradual disturbances that occur over a longer period, such as insect and disease disturbances. Vegetation recovery can also be more difficult to detect (depending on the type of vegetation and timeframe), as it usually recovers gradually over a longer period. Increases in tree bole diameter and forest canopy cover happen at a faster rate in younger coniferous forests than in older forests, however, and the satellite-measured signal changes faster as well. Within the 10- to 12-year period of this investigation, mapping of such changes in early successional, pre-canopy-closure conditions are relatively robust (Kennedy 2010). Much more subtle, however, are the satellite signals associated with the structural changes as forests progress to maturity and old age. Moreover, small-scale forest canopy gap dynamics cannot be directly observed with the sensors used in our analysis (Frolking et al. 2009). Rather, all structural changes associated with maturing forests often must be inferred from changes in the spectral signal caused by proxy effects, such as within-canopy shadowing. Therefore, it is difficult to distinguish at a given location small changes in forest structure (and any associated variables, such as age) from background random noise caused by differing sun angles, atmospheric effects, and phenological differences, particularly when the interval of change is short (as for the 10- to 12-year period here) (Kennedy 2010).

During our analysis, we conducted visual and GIS examinations of our nesting/roosting habitat maps and variable maps using aerial imagery and noted that commercial thinning of young plantations created suspicious changes in some of our habitat modeling variables in the bookend 2006/07 data set. For instance, in some modeling regions, stand age increased by 3 to 5 decades, or density of large conifer (>30 in d.b.h) increased by as much as 3 to 4 trees per ac, which isn't likely within the timeframe of our analysis. We suspect that canopy shadowing increased owing to the thinning and may have caused some stands to appear older than they actually were, thus making them appear as habitat when the modeling results from the 1994/96 bookend were extrapolated [projected] to the 2006/07 bookend.

We also conducted an analysis of the regional inventory plot data, similar to what was done in the 10-year report (Davis and Lint 2005), to determine if there were significant gains of forest stand conditions that were similar to spotted owl nesting/roosting habitat (see table 3-5, page 47 in Davis and Lint 2005). The results of this analysis did not show any significant gains in "habitat classes" between the initial plot measurement and the remeasurement data, which roughly covers the same periods as our bookend models (app. H). In addition, the net changes between the bookend models were well within the 95-percent CIs between periods; therefore, it is not possible to state with certainty that we observed "real" net changes in nesting/roosting habitat between our bookend maps (app. C). For these reasons (plus the need for caution when transferring or projecting models discussed earlier), we focused on habitat losses, which are more accurately detected with current technologies and were verified by LandTrendr change-detection data. For the next round of monitoring (20-year report), we hope to use LandTrendr for verification of both nesting/roosting habitat losses and gains.

Dispersal Habitat

Although we were cautious in our interpretation of gains in nesting/roosting habitat, we feel that the GNN/LandTrendr data were better suited for detecting gains in younger forests (as described above), such as dispersal habitat, plus we did not develop and then project [extrapolate] a dispersal habitat model from one period to another as we did for nesting/roosting habitat (i.e., no model transferability issues). Examination of the bookend changes in the two variables that were used to define dispersal habitat (d.b.h. and conifer cover), and visual examination of the dispersal habitat maps overlaid on high-resolution color aerial imagery showed realistic changes that one might expect in a 10- to 12-year timeframe.

Rangewide, we report an estimated a gross loss of about 417,000 ac of dispersal habitat, most (82 percent) from wildfire (341,800 ac). The causes for dispersal habitat loss were similar to those for

nesting/roosting habitat losses, with wildfire being the main cause in reserved allocations and about half of the loss in nonreserved allocations (fig. 3-15). Timber harvesting accounts for the other half of the loss in nonreserved allocations, and insects and disease account for a small percentage of loss in all allocations (fig. 3-15). However, these losses were offset by a 1.26-million-ac gross gain in dispersal habitat on federal land from forest succession, resulting in a 5.2-percent overall net gain of dispersal habitat coverage across the owl's range (app. E). In general, the gains in dispersal habitat were higher in federal nonreserved allocations than in reserved allocations. Only the Oregon Klamath, experienced a net decrease in the amount of dispersal habitat (-2.6 percent) owing to the large Biscuit Fire, which removed more dispersal habitat than was recruited for this period (app. E). The biggest net gain (13.1 percent) in federal dispersal habitat occurred in the Oregon Coast Range, which has some of the most productive forests in the owl's range. An example of this recruitment is clearly seen in the maps from 1996 and 2006 for the large Oxbow Fire of 1966 (fig. 3-16). In 1996, this area was forested with stands just about 30 years of age. Based on tree diameter growth data for fully stocked, site class 1, Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) forests, stands of this age have an average d.b.h. of 9 in and can put on 3 in of diameter growth in one decade (McCardle et al. 1961), thus crossing the threshold from nondispersal to dispersal habitat in a relatively short timeframe. However, not all sources of gain for dispersal habitat come from forest succession. Sometimes disturbances, such as a moderate-severity wildfire, can alter (i.e., opening up the canopy) suitable nesting/roosting habitat, making it unsuitable for nesting and roosting, but still suitable enough for owl dispersal (see table 3-1).

At the landscape scale, we detected a 5-percent gross loss of dispersal-capable landscape, mostly around the periphery of the federal forests. We suspect this may be due to regeneration timber harvesting occurring in dispersal habitats on nonfederal lands that border federal lands. Large wildfires on federal lands played a role in this decrease in the eastern Cascade provinces and the Oregon Klamath Mountain province. We also detected a 4-percent gross gain in dispersal-capable landscapes along the

periphery of some federal forests caused by forest succession younger forests, resulting in an overall net decrease of 1 percent in dispersal-capable landscape area (fig. 3-17).

The most noticeable change in dispersal-capable landscapes, that we detected, occurred in the northeastern portion of the Washington eastern Cascades; the losses of dispersal-capable landscape caused by large wildfires in that area may have isolated some of the large LSRs established at the Plan's implementation (fig. 3-17). This may also be the case for the LSR just to the east of the B&B Fire where it appears that there has been a 3- to 6-mi contraction of dispersal-capable landscape in that area. Overall, the large reserved network still appears to be well connected, with the exception of three areas. Of primary concern are the federal reserved lands on the Olympic Peninsula, which are separated from the Cascades by about 75 mi of landscape with poor dispersal conditions (fig. 3-17). These federal lands are also separated to the south by about 90 mi from federal reserves that occur in the northern Oregon Coast Range physiographic province. The federal reserves in the most northern part of the Oregon Coast Range are the second area of concern. It appears that regeneration timber harvesting on nonfederal land may be narrowing the dispersal connection to the rest of the Coast Range's large federal reserved allocations. Finally, the southernmost large reserves, which are mainly located on the Mendocino National Forest in the California Klamath Mountains physiographic province, appear to occur in poor dispersal landscapes, and the Marin County northern spotted owl population, in particular, appears isolated at the extreme southern tip of the owl's range (fig. 3-17).

Habitat Fragmentation

At the range scale, core habitat accounted for about 19 and 29 percent of baseline nesting/roosting habitat within nonreserved and reserved allocations, respectively, indicating that reserved allocations contain larger patches of suitable habitat. Between 1994/96 and 2006/07, the amount of core habitat on federal lands decreased by 6 percent at the range scale, with 4.6 percent of

this decrease occurring in reserved allocations. The largest decrease (-20.6 percent) occurred in the Oregon Klamath province and was largely owing to the Biscuit Fire (fig. 3-18). The percentage loss of core habitat by physiographic province shown in figure 3-18 generally follows the same pattern among provinces as for nesting/roosting habitat loss (fig. 3-12); however, the percentage of loss is larger for core habitat, because it is a subset of nesting/roosting habitat and confined to a smaller portion of the landscape.

The combination of core and core-edge habitat constituted about 50 percent of the baseline nesting/roosting habitat in nonreserved allocations and 61 percent in reserved allocations at the range scale, indicating that reserved allocations contain more contiguous habitat than nonreserved allocations (table 3-3). We report an average rangewide decrease of 1 percent in these ratios, signifying a small but measureable increase in habitat fragmentation. The largest decreases occurred within the federally reserved portions of the Klamath provinces in Oregon (-4.3 percent) and California (-2.7 percent) as well as the California Cascades (-3.1 percent), again because of wildfires (table 3-3).

Discussion

Substantial progress has been made in 5 years to overcome some of the previous limitations of habitat monitoring (Davis and Lint 2005). Most importantly among these advancements is the development of a consistent set of vegetation data that now covers the entire range of the owl. As suspected by Davis and Lint (2005), the finer resolution (in both spatial scale and attributes) of this new vegetation data resulted in lower, but more accurate, estimates of the amount of northern spotted owl habitat in California. In addition, the development of bookend maps (using the same vegetation and modeling techniques) has increased our ability to detect trends of habitat losses and gains. For the first time, we can estimate not only habitat losses, but also habitat degradation–where habitat is altered by a disturbance, but still remains suitable for owl nesting and roosting. The new LandTrendr change-

detection data (Kennedy et al. 2010) were critical for verifying the habitat losses we detected with the bookends and also for assigning a cause for the habitat changes.

Although we were able to detect, measure, and report on nesting/roosting habitat loss and degradation, we were not able to detect and measure its recruitment during the 10- to 12-year timeframe of our analysis data. The expectation was that validation of habitat development would be part of the new habitat suitability maps developed by the interagency monitoring program (Courtney et al. 2004). However, validation of habitat development is a difficult task, and the transition of a forest age class or size class into the next higher class does not always equate to recruitment of owl habitat (Courtney et al. 2004). As seen from the combinations of vegetation variables we used for habitat modeling (app. A and table C-1 in app. C), the definition of nesting/roosting habitat is not a simple combination of one or two attributes. In reality, it is much more complex, and the transition of habitat from unsuitable to suitable likely happens over multiple decades (Courtney et al. 2004). This was not the case for the younger forest types through which owls can disperse. We cautiously accounted for gains in dispersal habitats after examination of the dispersal habitat maps on aerial imagery and through GIS analysis of changes in the tree diameter and canopy cover variables that were used in its definition.

So, although Raphael et al. (1994a, 1994b) and Lint et al. (1999) did not expect to see any significant gains in nesting/roosting habitat for a few decades, an examination of our habitat histograms (app. F) shows some gains in the "marginal" suitability class, which is similar to dispersal habitat (see table 3-1). Within the next three decades, the transition of habitat from the marginal suitability class to the suitable habitat class may be detectable given current remote sensing technology. In addition, the use of light detection and ranging (LIDAR) imagery, which is able to map forest canopy biomass, height, and vertical distribution, may provide us the ability to detect and monitor changes in the older stages of succession with improved accuracies (Falkowski et al. 2009).

Maintaining and restoring habitats that keep owl populations well connected across their range is a central goal of the Plan and should remain a priority. Our dispersal-capable landscape analysis was based on known linear dispersal distances (Forsman et al. 2002, Lint et al. 2005), and the analysis window we used to quantify amounts of dispersal habitat across the landscape had a diameter of 31 mi. This distance exceeds both the mean natal dispersal distance for males and females (Forsman et al. 2002) and the root-mean-square dispersal distance, which may be the more appropriate measure of gene flow (Barrowclough et al. 2005). Thus, our results indicate that most of the large reserved network is currently well connected (fig. 3-17) with a few exceptions, such as the Olympic Peninsula, the northern Oregon Coast Range, and the California Klamath, which we suggest might serve as focal areas for future studies on population connectivity and genetics, particularly as recent genetic work suggests northern spotted owls have undergone population bottlenecks resulting in reduced genetic diversity in several parts of their range, including the northern Oregon Coast Ranges, and the Klamath Mountains (Funk et al. 2010). Strong evidence for population bottlenecks in the Washington eastern Cascades were also reported (Funk et al. 2010) consistent with recent population declines in that region (Anthony et al. 2006, Forsman et al. 2011), but there is no definitive evidence that dispersal habitat is limited (this study) or that gene flow is restricted in that region (Barrowclough et al. 2005).

Summary

Rangewide owl habitat losses on federal lands were expected to be about 5 percent per decade, with a loss of 2.5 percent from timber harvest (USDA and USDI 1994) and 2.5 percent from wildfire (FEMAT 1993). We report a rangewide loss of 3.4 percent, between 1994/97 to 2006/07 and conclude that [rangewide] habitat is not declining faster than predicted under the Plan. Timber harvesting accounted for 0.6 percent of this loss, insects and disease 0.1 percent, and wildfire 2.7 percent of the habitat loss. Loss from timber harvesting is occurring at a fraction of what was predicted at Plan

implementation, but habitat losses from wildfire are very close to what was predicted (FEMAT 1993). Although rangewide habitat losses have not exceeded what was anticipated under the Plan, the trend of habitat loss has been greater than 5 percent per decade in some physiographic provinces (i.e., Oregon Klamath). If localized habitat losses continue at the current rates within some provinces, it is unclear what affect this may have on the effectiveness of the Plan to maintain well distributed and connected populations of northern spotted owls throughout their entire range, specifically the assumption that the large reserve network is resilient enough to incur these losses and not result in isolation of population segments (Lint et al. 1999).

Since implementation of the Plan, the majority of habitat loss on federally administered lands has been caused by wildfire, and most of that loss has occurred in reserved allocations. This seems counter to the Plan's goal of habitat maintenance and restoration within the reserved network. However, the reserve network was designed to function despite losses to wildfire, which were anticipated (FEMAT 1993, Murphy and Noon 1992). Although Lint et al. (1999) assumed that habitat conditions within large reserves would improve over time at a rate controlled by successional processes in stands that are not currently nesting/roosting habitat, they did not expect it to happen quickly, but over a period of several decades (Lint et al. 1999). Our latest monitoring shows that maintenance of nesting/roosting habitat within some of the large reserves is being challenged by the occurrence of large wildfires, and also that large-scale restoration of reserved nesting/roosting habitat has not yet occurred.

The monitoring assumption that habitat conditions outside of reserved allocations would continue to decline because of timber harvesting and other habitat-altering disturbances but would still facilitate owl movement across the landscape (Lint et al. 1999) is validated by the latest monitoring. The rate of nesting/roosting habitat loss outside of the reserves from timber harvesting has been lower than expected, and we observed both losses and gains in dispersal habitat. In our monitoring, we did not observe any isolation of owl population segments caused by large-scale disturbance; however, we did

note both expansions and contractions of dispersal-capable landscape and that some large reserves in portions of the range have poor dispersal conditions and might be focal areas for further investigation of population isolation studies.

Although not included within the timeframe of this latest monitoring analysis, the southern portion of the owl's range experienced another 615,000 ac (approx.) of wildfire between 2008 and 2009, with most of it occurring within reserved land use allocations. If this trend persists, the actual decadal loss of habitat from wildfire will continue to push against the Plan's assumption of 2.5 percent per decade and, to reemphasize the point made at the beginning of this summary, may have unexpected consequences on the effectiveness of portions of the large reserved network. Outside of the reserved network, the lack of timber harvesting in the nonreserved allocations over the past 15 years has provided some cushion from these losses. And finally, although we still anticipate that recruitment of nesting/roosting habitat from forest succession will eventually begin to offset habitat losses from wildfire, forests grow slowly, and, where they occur in landscapes prone to wildfire, the nesting/roosting habitat conditions may take much longer to develop.

References

Akaike, H. 1974. A new look at the statistical model identification. IEEE Transactions on Automatic Control. 19(6): 716–723.

Anthony, R.G.; Forsman, E.D.; Franklin, A.B.; Anderson, D.R.; Burnham, K.P.; White, G.C.; Schwarz, C.J.; Nichols, J.D.; Hines, J.E.; Olson, G.S.; Ackers, S.H.; Andrews, L.W.; Biswell, B.L.; Carlson, P.C.; Diller, L.V.; Dugger, K.M.; Fehring, K.E.; Fleming, T.L.; Gearhardt, R.P; Gremel, S.A.; Gutiérrez, R.J.; Happe, P.J.; Herter, D.R.; Higley, J.M.; Horn, R.B.; Irwin, L.L.; Loschl, P.J.; Reid, J.A.; Sovern, S.G. 2006. Status and trends in demography of northern spotted owls, 1985–2003. Wildlife Monographs No. 163. Washington, DC: The Wildlife Society. 48 p.

Araújo, M.B.; Pearson, R.G.; Thuillers, W.; Erhard, M. 2005. Validation of species-climate impact models under climate change. Global Change Biology. (11): 1504–1513.

Baldwin, R.A. 2009. Use of maximum entropy modeling in wildlife research. Entropy. 11: 854–866.

Barrowclough, G.F.; Groth, J.G.; Mertz, L.A.; Gutiérrez, R.J. 2005. Genetic structure, introgression, and a narrow hybrid zone between northern and California spotted owls (*Strix occidentalis*). Molecular Ecology. 14: 1109–1120.

Boyce, M.S.; Vernier, P.R.; Nielsen, S.E.; Schmiegelow, F.K.A. 2002. Evaluating resource selection functions. Ecological Modelling. 157: 281–300.

Braunisch, V.; Suchant, R. 2010. Predicting species distributions based on incomplete survey data: the trade-off between precision and scale. Ecography. 33: 826–840.

Brown, T.J.; Hall, B.L.; Mohrle, C.R.; Reinbold, H.J. 2002. Coarse assessment of federal wildland fire occurrence data: report for the National Wildfire Coordinating Group. Reno, NV: CEFA Report 02-04. Program for Climate, Ecosystem and Fire Applications, Desert Research Institute, Division of Atmospheric Sciences. 31 p.

Carey, A.B.; Horton, S.P.; Biswell, B.L. 1992. Northern spotted owls: influence of prey base and landscape character. Ecological Monographs. 62(2): 223–250.

Carey, A.B.; Reid, J.A.; Horton, S.P. 1990. Spotted owl home range and habitat use in southern Oregon Coast Ranges. Journal of Wildlife Management. 54: 11–17.

Cohen, J. 1960. A coefficient of agreement for nominal scales. Educational and Psychological Measurement. 20(1): 37–46.

Cohen, W.B.; Zhiqiang, Y.; Kennedy, R.E. 2010. Detecting trends in forest disturbance and recovery using yearly Landsat time series: 2. TimeSync–tools for calibration and validation. Remote Sensing of Environment. 114(12): 2911–2924.

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Comer, P.; Faber-langendoen, D.; Evans, R.; Gawler, S.; Josse, C.; Kittel, G.; Menard, S.; Pyne, M.; Reid, M.; Schulz, K.; Snow, K.; Teague, J. 2003. Ecological systems of the United States: a working classification of U.S. terrestrial systems. Arlington, VA: NatureServe. 75 p. http://www.natureserve.org/library/usEcologicalsystems.pdf. (18 December 2010).

Coops, N.C.; Gillandersa, S.N.; Wulderb, M.A.; Gergelc, S.E.; Nelsond, T.; Goodwin, N.R. 2010. Assessing changes in forest fragmentation following infestation using time series Landsat imagery. Forest Ecology and Management. 259: 2355–2365.

Courtney, S.P.; Blakesley, J.A.; Bigley, R.E.; Cody, M.L.; Dumbacher, J.P.; Fleischer, R.C.; Franklin, A.B.; Franklin, J.F.; Gutiérrez, R.J.; Marzluff, J.M.; Sztukowski, L. 2004. Scientific evaluation of the status of the northern spotted owl. Portland, OR: Sustainable Ecosystem Institute. 348 p. + appendixes.

Davis, R.; Lint, J. 2005. Habitat status and trend. In: Lint, J., tech. coord. Northwest Forest Plan–the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 21–82.

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

Elith, J.; Graham, C.H.; Anderson, R.P.; Dudík, M.; Ferrier, S.; Guisan, A.; Hijmans, R.J.; Huettmann, F.; Leathwick, J.R.; Lehmann, A.; Li, J.; Lohmann, L.G.; Loiselle, B.A.; Manion, G.; Moritz, C.; Nakamura, M.; Nakazawa, Y.; Overton, J.Mc.; Peterson, A.T.; Phillips, S.J.; Richardson, K.; Scachetti-Pereira, R.; Schapire, R.E.; Soberón, J.; Williams, S.; Wisz, M.S.; Zimmermann, N.E. 2006. Novel methods improve prediction of species' distributions from occurrence data. Ecography. 29: 129–151.

Elith, J.; Phillips, S.J.; Hastie, T.; Dudík, M.; Chee, Y.E.; Yates, C.J. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions. 17: 43–57.

Engler, R.; Guisan, A.; Rechsteiner, L. 2004. An improved approach for predicting the distribution of rare and endangered species from occurrence and pseudoabsence data. Journal of Applied Ecology. 41: 263–274.

Falkowski, M.J.; Evans, J.S.; Martinuzzi, S.; Gessler, P.E.; Hudak, A.T. 2009. Characterizing forest succession with LIDAR data: an evaluation for the inland Northwest, USA. Remote Sensing of Environment. 113: 946–956.

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination].

Fielding, A.H.; Bell, J.F. 1997. A review of methods for assessment of prediction errors in conservation presence/absence models. Environmental Conservation. 24: 38–49.

Forsman, E.D.; Anthony, R.G.; Dugger, K.M.; Glenn, E.M.; Franklin, A.B.; White, G.C.; Schwarz, C.J.; Burnham, K.P.; Anderson, D.R.; Nichols, J.D.; Hines, J.E.; Lint, J.B.; Davis, R.J.; Ackers, S.H.; Andrews, L.S.; Biswell, B.L.; Carlson, P.C.; Diller, L.V.; Gremel, S.A.; Herter, D.R.; Higley, J.M.; Horn, R.B.; Reid, J.A.; Rockweit, J.; Schaberl, J.; Snetsinger, T.J.; Sovern, S.G. 2011. Population demography of northern spotted owls. Studies in Avian Biology 40. 106 p.

Forsman. E.D.; Anthony, R.G.; Reid, J.A.; Loschl, P.J.; Sovern, S.G.; Taylor, M.; Biswell, B.L.; Ellingson, A.; Meslow, E.C.; Miller, G.S.; Swindle, K.A.; Thrailkill, J.A.; Wagner, F.F.; Seaman, D.E. 2002. Natal and breeding dispersal of northern spotted owls. Wildlife Monographs No. 149. Washington, DC: The Wildlife Society. 35 p.

Forsman, E.D.; Meslow, E.C.; Wight, H.M. 1984. Distribution and biology of the spotted owl in Oregon. Wildlife Monographs. 87: 1–64.

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

Franklin, J.F.; Dyrness, C.T. 1973. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 417 p.

Frolking, S.; Palace, M.W.; Clark, D.B.; Chambers, J.Q.; Shugart, H.H.; Hurtt, G.C. 2009. Forest disturbance and recovery: a general review in the context of spaceborne remote sensing of impacts on aboveground biomass and canopy structure. Journal of Geophysical Research. 114. 27 p.

Funk, W.C.; Forsman, E.D.; Johnson, M.; Mullins, T.D.; Haig, S.M. 2010. Evidence for recent population bottlenecks in northern spotted owls (*Strix occidentalis caurina*). Conservation Genetics. 11: 1013–1021.

Gauch, H.G. 1982. Multivariate analysis in community ecology. Cambridge, England: Cambridge University Press. 312 p.

Gillison, A.N.; Brewer, K.R.W. 1985. The use of gradient directed transects or gradsects in natural resource surveys. Journal of Environmental Management. 20: 103–127.

Glenn, E.M.; Hansen, M.C.; Anthony, R.G. 2004. Spotted owl home range and habitat use in young forests of western Oregon. Journal of Wildlife Management. 68: 33–50.

Guisan, A.; Zimmermann, N.E. 2000. Predictive habitat distribution models in ecology. Ecological Modelling. 135: 147–186.

Gutíerrez, R.J.; Solis, D.M.; Sisco, C. 1984. Habitat ecology of the spotted owl in northwestern California: implications for management. In: Proceedings of the 1983 Convention of the Society of

American Foresters. New forests for a changing world: Bethesda, MD: Society of American Foresters: 368–373.

Hais, M.; Jonášová, M.; Langhammer, J.; Kučera, T. 2009. Comparison of two types of forest disturbance using multitemporal Landsat TM/ETM + imagery and field vegetation data. Remote Sensing of Environment. 113: 835–845.

Hamer, T.E.; Seim, S.G.; Dixon, K.R. 1989. Northern spotted owl and northern barred owl habitat use and home range size in northwest Washington: preliminary report. 64 p. Unpublished report. On file with: Washington Department of Fish and Wildlife, 1111 Washington Street Southeast, Olympia, WA 98501.

Herold, N.D.; Koeln, G.; Cunnigham, D. 2003. Mapping impervious surfaces and forest canopy using classification and regression tree (CART) analysis. In: Proceedings of the American Society for Photogrammetry and Remote Sensing 2003 annual conference, Anchorage, Alaska. 7 p. http://nemo.uconn.edu/tools/impervious_surfaces/pdfs/Herold_etal_2003.pdf. (5 January 2011).

Hirzel, A.H.; Hausser, J.; Chessel, D.; Perrin, N. 2002. Ecological-niche factor analysis: how to compute habitat-suitability maps without absence data. Ecology. 83: 2027–2036.

Hirzel, A.H.; Le Lay, G. 2008. Habitat suitability modelling and niche theory. Journal of Applied Ecology. 45: 1372–1381.

Hirzel, A.H.; Le Lay, G.; Helfer, V.; Randin, C.; Guisan, A. 2006. Evaluating the ability of habitat suitability models to predict species presences. Ecological Modelling. 199: 142–152.

Huff, M.; Raphael, M.G.; Miller, S.L.; Nelson, S.K.; Baldwin, J., tech. coords. 2005. Northwest Forest Plan—the first 10 years (1994-2003): status and trends of populations and nesting habitat for the marbled murrelet. Gen. Tech. Rep. PNW-GTR-650. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 149 p.

Hutchinson, G.E. 1957. Concluding remarks. Cold Spring Harbor Symposium. Quantitative Biology. 22: 415–427.

Jenness, J. 2003. Mahalanobis distances (mahalanobis.avx) extension for ArcView 3.x, Jenness Enterprises. http://www.jennessent.com/arcview/mahalanobis.htm. (18 December 2010).

Jiménez-Valverde, A.; Nakazawa, Y.; Lira-Noriega, A.; Peterson, A.T. 2009. Environmental correlation structure and ecological niche model projections. Biodiversity Informatics. 6: 28–35.

Kennedy, R.E. 2010. Personal communication. Assistant Professor, Senior Researcher and Director, Laboratory for Applications of Remote Sensing in Ecology. Oregon State University, College of Forestry, Forest Ecosystems and Society. Corvallis, OR.

Kennedy, R.E.; Cohen, W.B.; Schroeder, T.A. 2007. Trajectory-based change-detection for automated characterization of forest disturbance dynamics. Remote Sensing of Environment. 110: 370–386.

Kennedy, R.E.; Yang, Z.; Cohen, W.B. 2010. Detecting trends in forest disturbance and recovery using yearly Landsat time series: 1. LandTrendr—temporal segmentation algorithms. Remote Sensing of Environment. 114(12): 2897–2910.

Lint, J.; Mowdy, J.; Ried, J.; Forsman, E.; Anthony, R. 2005. Owl movement. In: Lint, J., tech. coord. Northwest Forest Plan—the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 83–87.

Lint, J.; Noon, B.; Anthony, R.; Forsman, E.; Raphael, M.; Collopy, M.; Starkey, E. 1999. Northern spotted owl effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-440. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 43 p.

DRAFT

Lint, J.B., tech. coord. 2005. Northwest Forest Plan–the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 176 p.

Liu, C.; Berry, P.M.; Dawson, T.P.; Pearson, R.G. 2005. Selecting thresholds of occurrence in the prediction of species distributions. Ecography. 28: 385–393.

Manley, B.; McDonald, L.; Thomas, D. 1993. Resource selection by animals: statistical design and analysis for field studies. London: Chapman and Hall. 177 p.

McArdle, R.E.; Meyer, W.H.; Bruce, D. 1961. The yield of Douglas-fir in the Pacific Northwest. Rev. Tech. Bull. 201. Washington, DC: U.S. Department of Agriculture, Forest Service. 74 p.

Miller, G.S. 1989. Dispersal of juvenile northern spotted owls in western Oregon. Corvallis, OR: Oregon State University. 139 p. M.S. thesis.

Miller, G.S.; Small, R.J.; Meslow, E.C. 1997. Habitat selection by spotted owls during natal dispersal in western Oregon. Journal of Wildlife Management. 61: 140–150.

Moeur, M.; Spies, T.A.; Hemstrom, M.; Alegria, J.; Browning, J.; Cissel, J.; Cohen, W.B.; Demeo, T.E.; Healey, S.; Warbington, R. 2005. Northwest Forest Plan–the first 10 years (1994-2003): status and trend of late-successional and old-growth forest. Gen. Tech. Rep. PNW-GTR-646. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 142 p.

Moeur, M.; Ohmann, J.L.; Kennedy, R.E.; Cohen, W.B.; Gregory, M.J.; Yang, Z.; Roberts, H.M.; Spies, T.A.; Fiorella, M. 2011. Northwest forest plan–status and trends of late-successional and old-growth forests from 1994 to 2007. Gen. Tech. Rep. PNW-GTR-XXX. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. XX p.

Moeur, M.; Stage, A.R. 1995. Most similar neighbor: an improved sampling inference procedure for natural resource planning. Forest Science. 41: 337–359.

DRAFT

Morrison, M.L.; Marcot, B.G.; Mannan, R.W. 1992. Wildlife-habitat relationships: concepts and applications. Madison, WI: The University of Wisconsin Press. 364 p.

Murphy, D.D.; Noon, B.R. 1992. Integrating scientific methods with habitat conservation planning: reserve design for northern spotted owls. Ecological Applications. 2(1): 3–17.

Ohmann, J.L.; Gregory, M.J. 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest-neighbor imputation in coastal Oregon, U.S.A. Canadian Journal of Forest Research. 32: 725–741.

Ohmann, J.L.; Gregory, M.J.; Roberts, H.M. 2010. GNN "bookend" maps of forest vegetation for NWFP effectiveness monitoring. 4 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, 333 SW 1st Avenue, Portland, OR. 97208-3623.

Ohmann, J.L.; Gregory, M.J.; Spies, T.A. 2007. Influence of environment, disturbance, and ownership on forest vegetation of coastal Oregon. Ecological Applications. 17: 18–33.

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

Omernik, J.M. 1987. Ecoregions of the conterminous United States (map supplement) [1:750,000]. Annals of the Association of American Geographers. 77(1): 118–125.

Peterson, A.T.; Papeş, M.; Eaton, M. 2007. Transferability and model evaluation in ecological niche modeling: a comparison of GARP and MaxEnt. Ecography. 30: 550–560.

Phillips, S.J. 2008. Transferability, sample selections bias and background data in presence-only modeling: a response to Peterson et al. (2007). Ecography. 31: 272–278.

Phillips, S.J. 2010. Personal communication. Co-developer of MaxEnt. AT&T Labs–Research, 180 Park Avenue, Florham Park, NJ 07932.

Phillips, S.J.; Anderson, R.P.; Shapire, R.E. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling. 190: 231–259.

Phillips, S.; Dudík, M. 2008. Modeling of species distributions with MaxEnt: new extensions and a comprehensive evaluation. Ecography. 31: 161–175.

Phillips, S.J.; Dudík, M.; Elith, J.; Graham, C.H.; Lehmann, A.; Leathwick, J.; Ferrier, S. 2009. Sample selection bias and presence-only distribution models: implications for background and pseudo-absence data. Ecological Applications 19: 181–197.

Pierce, K.B.J.; Ohmann, J.L.; Wimberly, M.C.; Gregory, M.J.; Fried, J.S. 2009. Mapping wildland fuels and forest structure for land management: a comparison of nearest-neighbor imputation and other methods. Canadian Journal of Forest Research. 39: 1901–1916.

Randin, C.F.; Dirnbo, T.; Dullinger, S.; Zimmermann, N.E.; Zappa, M.; Guisan, A. 2006. Are niche-based species distribution models transferable in space? Journal of Biogeography. 33: 1689–1703.

Raphael, M. 2006. Conservation of listed species: the northern spotted owl and marbled murrelet. In: Haynes, R.; Bormann, B.; Lee, D.; Martin, J., eds. Northwest Forest Plan—the first 10 years (1994-2004): synthesis of monitoring and research results. Gen. Tech. Rep. PNW-GTR-651. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 117–144.

Raphael M.G.; Young J.A.; McKelvey K.; Galleher B.M.; Peeler K.C. 1994a. A simulation analysis of population dynamics of the northern spotted owl in relation to forest management objectives. Appendix J3. In: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management. Final supplemental environmental impact statement on management of late-successional and old-growth forests within the range of the northern spotted owl. 37 p.

Raphael M.G.; Young J.A.; McKelvey K.; Galleher B.M.; Peeler K.C. 1994b. Addendum to "A simulation analysis of population dynamics of the northern spotted owl in relation to forest management objectives. Appendix J3. In: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management. Final supplemental environmental impact statement on management of late-successional and old-growth forests within the range of the northern spotted owl. 16 p.

Soille, P.; Vogt, P. 2009. Morphological segmentation of binary patterns. Pattern Recognition Letters. 30: 456–459.

Stauffer, D.F. 2002. Linking populations and habitat: where have we been? Where are we going? In: Scott, J.M.; Heglund, P.; Morrison, M., eds. Predicting species occurrences: issues of accuracy and scale. Washington DC: Island Press. 53–61.

Staus, N.; Strittholt, J.; Dellasala, D.; Robinson, R. 2002. Rate and patterns of forest disturbance in the Klamath-Siskiyou ecoregion, USA between 1972 and 1992. Landscape Ecology. 17: 455–470.

Swets, J. 1988. Measuring the accuracy of diagnostic systems. Science. 240: 1285–1293.

ter Braak, C.J.F. 1986. Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology. 67: 1167–1179.

Thomas, J.W.; Forsman, E.D.; Lint, J.B.; Meslow, E.C.; Noon, B.R.; Verner, J. 1990. A conservation strategy for the northern spotted owl: a report of the Interagency Scientific Committee to address the conservation of the northern spotted owl. Portland, OR: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management, Fish and Wildlife Service, National Park Service. 427 p.

Turner M.G.; Dale V.H.; Gardner, R.H. 1989. Predicting across scales: theory development and testing. Landscape Ecology. 3: 245–52.

DRAFT

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management [USDA and USDI]. 1994. Final supplemental environmental impact statement on management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. Volumes I-II + Record of Decision.

Vogelmann, J.E.; Howard, S.M.; Yang, L.; Larson, C.R.; Wylie, B.K.; Van Driel, J.N. 2001. Completion of the 1990's national land cover data set for the conterminous United States. Photogrammetric Engineering and Remote Sensing. 67: 650–662.

Vogt, P.; Riitters, K.H.; Estreguil, C.; Kozak, J.; Wade, T.G.; Wickham, J.D. 2007. Mapping spatial patterns with morphological image processing. Landscape Ecology. 22: 171–177.

Wiley, E.O.; McNyset, K.M.; Peterson, A.T.; Robins, C.R.; Stewart, A.M. 2003. Niche modeling and geographic range predictions in the marine environment using a machine learning algorithm. Oceanography. 16: 120–127.

Williams, P.H.; Margules, C.R.; Hilbert, D.W. 2002. Data requirements and data sources for biodiversity priority area selection. Journal of Biosciences. (Suppl. 2). 27(4): 327–338.

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

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Chapter 4: Large Wildfires within the Owl's Range

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Introduction

When Franklin and Dyrness created their map of physiographic provinces in 1973, they noted that the lines drawn to reduce the complexity of large geographic areas into more manageable proportions are sometimes arbitrary, whereas in nature the transition from one condition to another is often gradual. A modified version of the Franklin and Dyrness (1973) physiographic provinces was used to divide the northern spotted owl's (*Strix occidentalis caurina*) range, which covers 57 million ac that stretch from Canada to northern California, into 10 areas that represented different forest vegetation and environmental characteristics (Thomas et al. 1990). Agee and Edmonds (1992) made the first attempt to delineate fire disturbance regimes within the owl's range during the initial stages of northern spotted owl recovery planning. The spotted owl recovery team (USDI 1992) used this and other information to further subdivide the range into 12 physiographic provinces, which currently provide the framework for monitoring the Northwest Forest Plan (the Plan) (FEMAT 1993, Lint et al. 1999). More recent attempts to map the "dry, fire-prone" portion of the owl's range (Healey et al. 2008, Rapp 2005, Spies et al. 2006) are mainly delineated along these physiographic province boundary lines, which were not drawn specifically to define the underlying nature of wildfire within the owl's range. The result is a line that often shifts, sometimes considerably, between mapping efforts (fig. 4-1).

This desire to map fire-prone areas in the owl's range stems from a concern by many that wildfire will destroy spotted owl habitat. The recent increase in frequency of large wildfire occurrence (and area burned) since the mid-1980s in the Western United States (Schwind 2008, Westerling et al. 2006), and within the owl's range (fig. 4-2) has only heightened this concern. There is also evidence that along with this increased frequency; there has also been an increase in the amount of high-severity

wildfire (Miller et al. 2009, Schwind 2008; but see Hanson et al. 2009). However, evidence from recent studies reveals that the effects of wildfire on owl habitat and demography are mixed (Bond et al. 2009, Clark 2007). In the short term, large wildfires may be detrimental to spotted owls by decreasing survival and occupancy rates because high-severity[1] fire that caused loss and fragmentation of suitable nesting and roosting habitat contributed to existing spotted owl sites becoming unoccupied (Clark 2007). In addition, California spotted owls avoided roosting [breeding season] in forests that had experienced moderate to high-severity[2] fire effects and nested only in stands that were unburned or had experienced low- to moderate-severity fire (Bond et al. 2009). However, spotted owls did forage in areas of high-severity fire, possibly because prey species are more abundant and accessible in these high-severity burn patches (Bond et al. 2009, Clark 2007, Franklin et al. 2000). Thus, although stand-replacing wildfires certainly remove nesting/roosting habitats described in chapter 3, they may not prevent foraging by owls, and only a very large fire that creates a large-scale loss of forest canopy and habitat would have a significant effect on owl demography and dispersal (see the discussion on dispersal habitat in chapter 3). Much more research is needed to fully understand the effects of wildfire frequency and severity on owls and their prey sources (see chapter 5 in this report), but some adaptation to wildfire is expected given that this species has evolved with it in some parts of its range.

Although the relationship between wildfire frequency and severity on owl demography is not fully understood, habitat loss is the primary reason for the owl's decline and subsequent listing as "threatened" under the endangered species act (USDI 1990). The habitat monitoring results presented in chapter 3 (this report) identified wildfire as the leading cause of current spotted owl nesting and roosting habitat loss (3.4 percent) and its future recruitment on federal lands. This was also the finding in the 10-year monitoring report (Davis and Lint 2005), and since completion of that report, several more large wildfires have occurred within the owl's range and more nesting/roosting habitat has been

[1] Clark (2007) defined high-severity as >70 percent of the overstory removed by fire.

[2] Bond et al. (2009) defined high-severity as areas where dominant vegetation had high to complete mortality owing to fire.

lost. Thus, loss of habitat to wildfire remains a significant concern for the management and conservation of the spotted owl. In response, the current species recovery planning process for the owl (USDI 2008) established working groups to develop recovery actions for fire-prone areas based on the current map of physiographic provinces (USDI 1992).

Here we present a novel modeling method to map areas within the owl's range that are prone to large wildfires. The result is a rangewide map of likelihood (or suitability) gradients for large wildfire occurrence. Instead of using physiographic province boundaries to define fire-prone areas within the owl's range, the gradient map is further classified into a binary map that we believe better represents the fire-prone areas. However, the raw model output (fig. 4-3) maintains the gradual transitions from one condition to another so succinctly alluded to by Franklin and Dyrness (1973).

Methods and Data Sources

There are several modeling approaches and methods available for modeling spatial distributions of environmental phenomenon, each with their own strengths and weaknesses (Guissan and Zimmermann 2000). A recent paper by Elith et al. (2011) summarizes many of these issues, including an ecological explanation of MaxEnt (Phillips and Dudík 2008, Phillips et al. 2006) and discussion on the issue of using presence-only versus presence-absence data (also see page 35 of Davis and Lint 2005). For consistency, we chose to use MaxEnt, the same modeling tool used for mapping spotted owl habitat suitability in chapter 3 (this report), to model and map wildfire suitability (fig. 4-3). This spatial distribution modeling software is commonly used to create predictive maps of habitat suitability (or likelihood of use) based on species location data and a set of environmental predictor variables that contribute to the definition of the species' niche (Phillips et al. 2006). The term "niche" is used to describe the environmental requirements needed for a species to exist (Grinnell 1917). It is the "hypervolume" in the multidimensional environmental space (the number of dimensions are based on

the number of environmental variables used to describe the niche) that permits positive growth (Hutchinson 1957). Habitat suitability models are operational applications of the ecological niche, and use multiple environmental variables to predict the likelihood of species occurrence (Hirzel and Le Lay 2008).

Based on our understanding of northern spotted owl ecology, we expect them to nest in landscapes that are heavily forested with older or structurally diverse stands of conifer with relatively closed canopies (see chapter 3 in this report). We call this combination of environmental conditions owl "habitat." Similarly, environmental conditions commonly associated with large wildfires include steep slopes, warm and dry aspects, hot and dry weather, and limited access for ground-based firefighting resources (hand crews, engines, etc.). These have long been identified in the literature as key elements in the development of large wildfires (Albini 1976, Albini et al. 1982, Brown and Davis 1973, Countryman 1964, Deeming et al. 1977, Garfin and Morehouse 2001, Gisborne 1936, Hayes 1941, Rothermel 1983, Schroeder and Buck 1970, Scott and Reinhardt 2001, Sugihara et al. 2006, Van Wagner 1977); in decision-support planning tools for wildfire response such as the National Fire Management Analysis System (NFMAS) and its successor, Fire Program Analysis (FPA); and in practice. It is no surprise that wildfires grow rapidly and become larger in landscapes that have an abundance of these conditions. The combination of these environmental conditions might also be considered a "habitat," not for an animal, but one that is suitable for large wildfires as alluded to by Pyne (2001, 2004). The analogy of wildfire as a "living organism" is not unheard of (Bond and Keeley 2005, Parisien and Moritz 2009), and it seems reasonable that the principles for describing the niche of a plant or animal species should be no different than for defining the "niche" of large wildfires, or for that matter any other natural phenomenon that is associated with unique combinations of environmental conditions.

Our ability to accurately map the environmental conditions that constitute the niche allows us to use modeling software to map the pattern of the relationship between these environmental factors

and large wildfire occurrence. This approach has been used recently to model wildfire's broad geographical distribution patterns across the conterminous United States, the state of California, and five wildfire-prone ecoregions within California (Parisien and Moritz 2009). To our knowledge, this marks the first time that "habitat suitability" software was used to map spatial patterns of wildfire likelihood over large landscapes as a function of multiple environmental variables. Coarse-scale maps of global fire patterns that discriminated between "fire-prone" and "fire-free" areas of the world were also produced using similar methods (Krawchuk et al. 2009). Maps produced by this method have been called "wildfire suitability" maps (Parisien and Moritz 2009), and this is the term we use to describe our map (fig. 4-3).

It is not uncommon for wildfires that range from 500 to 1,000 ac and greater to be defined as "large" in the recent fire ecology literature (Potter 1996; Westerling et al. 2003; Eidenshink et al. 2007; Preisler and Westerling 2007). In the 10-year report, a "large wildfire" was defined as a fire that would affect multiple owl territories (Davis and Lint 2005). Here we define "large wildfire" as one that exceeds 1,000 ac, which is larger than the estimated size of a northern spotted owl home range core area[3] throughout most of its range (Bingham and Noon 1997, Courtney et al. 2004, USDI USDA 2008).

Environmental Data

At an intermediate spatial scale, weather and topography make up two legs of the fire behavior (or environment) triangle (Agee 1993, Countryman 1966), whereas at the larger [regional] spatial scale, climate, ignitions, and broad vegetation patterns define fire regimes (see fig. 1 in Parisien and Mortiz 2009). Our spatial scale of modeling combines both the intermediate and regional scales, and our set of environmental data reflects this, with the exception of fuels and vegetation variable groups. We did not include any fuel variables in our modeling, but the model's geographic background consisted only of

[3] An area of concentrated use within a home range that commonly includes nest sites, roost sites, refuges, and regions with the most dependable food sources (Kaufmann 1962, Samuel et al. 1985).

forest-capable areas, which represents "vegetation" in the larger spatial scale. Because forest fires are what we were attempting to model, the use of this modeling background allowed us to confine the interactions of environmental variables to locations where forest vegetation and fuels occur. An advantage of not using a fuel variable is that we avoided the difficulties that arise in accurately mapping them (Stratton 2006). Fuels are a dynamic component of the ecosystem, very temporal in nature and always changing in response to forest succession and disturbances (Agee 1993). The inclusion of a fuel variable would produce a map that would only be good as long as the fuel condition remained exactly as modeled. Instead, we wanted to produce a model that was relatively stable, and based on the underlying conditions of topography and climate that support large wildfires.

The set of environmental variables we used for modeling were based on fire climate[4] and environment relationships in the literature and on expert advice (fig. 4-4, app. G). Matching the temporal scale of these environmental data with the fire training data was an important factor. Fire climate variables were derived from "parameter elevated regression on independent slope model" (PRISM) maps (Oregon Climate Service 2008) that provide averaged weather conditions between 1971 and 2000. This timeframe coincides with the 1970 to 2002 timeframe of the fire training data set. As our fire climate variables, we initially chose average maximum temperature in August and summer moisture stress (the ratio of summer temperature and precipitation). However, because of the high correlation between these two variables ($r > 0.7$), we replaced the moisture stress variable with a summer precipitation variable, which is the average amount of precipitation that fell between May and September, corresponding to the average fire season.

Lightning is the primary ignition source for wildfires around the world (Agee 1993) including the forested regions of the Pacific Northwest, especially when it occurs without significant rainfall (Rorig and Ferguson 1999). Based on data from the Climate, Ecosystem, and Fire Applications (CEFA) Program

[4] Defined by the National Wildfire Coordinating Group (NWCG) as a "composite pattern of weather elements over time that affect fire behavior in a given region."

(Brown et al. 2002), lightning was the cause for approximately 25,000 wildfires within the range of the owl from 1970 to 2002. Lightning accounted for 68 percent of the wildfires that grew to larger than 1,000 ac and accounted for 75 percent of the total area burned within the owl's range from 1994 through 2002 (Davis and Lint 2005). The geographic patterns of lightning-ignited wildfires in the Pacific Northwest are similar today to what they were throughout the 1900s (Agee 1993, Komarek 1967, Morris 1934, Rorig and Ferguson 1999, Sensenig 2002). Therefore, a lightning-ignited fire density map was created using the CEFA data from 1970 to 2002 and included as one of the environmental variables.

Topographic variables for elevation, slope, and aspect were also used in the model. Elevation provides an environmental gradient that relates to local climate conditions and vegetation zones, which can affect fire behavior and growth (Hayes 1941, Rothermel 1983). Slope is related to fire spread rate, and its orientation, or aspect, relates to the amount of solar radiation, which also affects the local microclimate and vegetation. Southerly aspects in the northern hemisphere usually receive more annual solar radiation and are hotter and drier than northerly aspects. We used the potential relative radiation (PRR) index developed by Pierce et al. (2005) as a more realistic measure for solar radiation than simple aspect.

The spatial resolution of our environmental data was 250-m by 250-m (15-ac) pixels, which was averaged within a 1,000-ac circular moving window to correspond with our minimum definition of a large wildfire. All "nonforested" (i.e., water, rock, etc.) areas were "masked out" to constrain the modeling background to only those areas where large wildfires are possible. All variables were analyzed for spatial correlations and one variable was dropped or replaced for Pearson correlations > 0.7.

Large Wildfire Data

We chose to train our model using historical occurrence data from only large wildfires (as defined above). Wildfires of this size are relatively rare occurrences, but are responsible for the vast

majority of area burned each year. For example, of the roughly 25,000 lightning-ignited wildfires recorded within the owl's range between 1970 to 2002, less than 1 percent were ≥1,000 ac; but these fires accounted for 96 percent of the total 2.5 million ac that burned (based on CEFA data) (Brown et al. 2002). This pattern of large areas of land being burned by a small percentage of large wildfires is a global phenomenon that fits power law distributions (Cui and Perera 2008, Stocks et al. 2003, Westerling and Bryant 2008). It therefore made more sense to focus our modeling on large wildfires because of their disproportionate effect on the environment.

To train the distributional model, the spatial point locations where large wildfires have occurred are linked to the underlying combinations of environmental variable grid cells over which they lay. This relationship between fire occurrence and environmental gradients is then extrapolated to the rest of the modeled region to "score" environmental conditions based on their similarity to where the training data occur. To create a point layer representing large wildfires, we assembled 250 polygons of large wildfire perimeters that, in total, burned about 2.6 million ac of forest lands across the owl's range between 1970 and 2002. Using a geographic information system (GIS), we overlaid these polygons on a grid of randomly generated points that was produced using Hawth's Tools (Beyer 2009). Each grid point was separated by 1.6 mi to reduce spatial autocorrelation issues, as the modeling environmental variables were averaged over a 0.7-mi radius that covered about 1,000 ac, representing a "large wildfire unit" (fig. 4-5). A total of 1,499 random grid points occurred within a large wildfire perimeter; of these, 104 (about 7 percent) were within overlapping wildfire perimeters, representing sites that had been burned twice during the 32 years represented by our training data. Because these points represent separate large wildfire occurrence from different years, they were included as additional points in the training data set for a total of 1,603 training points. We also generated an independent model-testing data set in the same manner, using 146 large wildfires that had burned 1.4 million acres between 2003 and 2009 (n = 903).

It is likely that without wildfire suppression, there would have been more large wildfires (Sensenig 2002) that burned between 1970 and 2002; thus our training data are likely biased. However, we are uncertain how this bias may have affected our model. It is possible that the training data better represent large wildfires that were more difficult to suppress or contain because of inaccessibility owing to geography or absence of roads. To address this issue, we also included a variable that represents distance from roads. We assumed that wildfires were more apt to get bigger when further away from a road because it was more difficult to get people and equipment into the area to fight the fire.

Wildfire Suitability Modeling

We chose the same modeling features in MaxEnt that we used for habitat modeling (linear, product, and hinge features) because this combination works well in fitting the environmental data to known or expected relationships between the environmental variables and wildfires based on visual review of response curves generated during the modeling procedure. This combination is also a compromise between using features that may be too restrictive for complex environmental relationships (i.e., only linear) while avoiding features that might allow overfitting the model to the data (i.e., threshold).

Phillips and Dudík (2008) defined the logistic output of their modeling software as an "estimate" of probability of presence, conditioned on the environmental variables used in the modeling. In our case, we used only training data from large wildfires and environmental variables that are commonly associated with wildfire ignition and growth (Albini 1976, Deeming et al. 1977 , Gisborne 1936, Hayes 1941, Rothermel 1991). Therefore, the model's logistic output represents a scale of probability (from low to high) of a large wildfire occurring as a function of physical, topographic, climatic, and fire ignition history patterns in the owl's range. Where combinations of these variables are more similar to where large wildfires have occurred in the past, the logistic probability values will be higher. Likewise,

underlying patterns of environmental variables that do not commonly occur where large wildfires have burned will have lower probability values.

We ran 10 bootstrapped model replicates using half of the training data set for each replicate, and holding out the other half to test the model's predictions. In other words, MaxEnt produced 10 models using 10 randomly generated subsets of the 1970-2002 large fire data, each consisting of 802 points. Then each of these models was tested using the subset of large-fire points held out (n = 801). During this process we varied the regularization multiplier, which helps to prevent model overfitting, by increments of 0.5 until we achieved the highest mean test gain, area under the curve (AUC) statistic and Spearman rank (R_s) correlation coefficient on our held-out test data. These three statistics (gain, AUC, and R_s) are commonly used to measure the discriminative and predictive power of these sorts of models (Boyce et al. 2002, Fielding and Bell 1997, Hirzel et al. 2006).

The gain relates to how different the training or testing data are from the background data. It is similar to "deviance" as used in generalized linear modeling (Phillips et al. 2006), and higher gains indicate larger differences between occurrence location environmental conditions and average background environmental conditions. The exponent of gain produces the mean probability value of occurrence compared to random locations selected from the surrounding modeled landscape. Large differences between the regularized training and testing gains indicates model overfitting.

The AUC statistic is a measure of the model's predictive accuracy, and it was originally developed for evaluations using presence and absence data, producing an index value from 0.5 to 1 with values close to 0.5 indicating poor discrimination and a value of 1 indicating perfect predictions. The AUC values can be interpreted similarly to the traditional academic point system where values between 0.9 and 1.0 indicate an excellent model (A), 0.8 to 0.9 is good (B), 0.7 to 0.8 is fair (C), 0.6 to 0.7 is poor (D), and AUC values between 0.5 and 0.6 represent failure (F), or models that don't predict much better than a random guess. Examples of this interpretation in the field of niche-based species distribution

models can be found in Araújo et al. (2005) and Randin et al. (2006). In our situation, MaxEnt uses 10,000 randomly selected background locations (map pixels) instead of true absence data, so it is not possible to achieve an AUC value of 1.0 (Wiley et al. 2003). However, interpretation is similar, with higher AUCs indicating better model predictions (Phillips et al. 2006). Specific to our case, AUC values represent the percentage of times a large wildfire location would have a higher wildfire suitability value than a randomly selected location from the modeling region.

The Spearman rank correlation coefficient is a nonparametric statistic that, in our situation, compares the ranks of large fire occurrence vs. area available to "binned" modeled prediction ranks (Boyce et al. 2002). A good model would predict an increasing ratio of the percentage of fire occurrence to the percentage of the modeled landscape in each model bin as the bin values increase, and an R_s of 1.0 indicates a strong positive correlation (Boyce et al. 2002).

The best model using the training data, and based on these statistics was produced using a regularization multiplier of 1.5. We then reran the same model, using the entire training data set (n = 1,603) and conducted a final test of the model using 7 years of independent test data from large fires that occurred between 2003 and 2009. Following the same rationale and modeling approach used in chapter 3 (this report), our final model product is the "average" model from our bootstrapped replicates. The predictive qualities of the "average" map can be better explained by the diagnostic predicted versus expected (P/E) curve (fig. 4.6) (Hirzel et al. 2006), and this curve allows users to better interpret the modeled values.

We also analyzed the importance of each environmental variable and its relationship with large wildfire occurrence by running jackknifed models (Phillips et al. 2006) for each of the 10 replicates. For each environmental variable, this jackknifing procedure produces a model that excludes the variable, and another model based on only that variable. The gain and AUC model performance statistics from

the jackknifed models then inform us on the relationship and importance of each variable in explaining large wildfire occurrence in the area being modeled.

Results

An average testing gain of 0.80 indicates that our model predicted large wildfire occurrence 2.2 times that expected by chance. The testing gain was also similar to the regularized training gain of 0.77 indicating that our model was not over-fit to the environmental data. The mean testing data AUC, based on 10 bootstrapped replicates, was 0.83, and using independent test data from large wildfires from 2003 to 2009, the AUC was 0.78. The replicate mean predicted versus expected (P/E) curve (Hirzel et al. 2006) had an $R_s = 1.0$ ($P < 0.001$) and the test data P/E curve had an $R_s = 0.987$ ($P < 0.001$). The highest mean logistic probability for our model was 0.90, which we converted into an integer value (90) for GIS mapping purposes by multiplying by a factor of 100. The threshold of 31 along this probability gradient marks where the predicted probability of large wildfire occurrence is greater than what would be expected by chance (fig. 4-6). One can use that threshold to define the owl's range in binary terms, where mapped values above this threshold represent geographic areas that are more prone to large wildfire occurrence, based on our 32-year training data timeframe, and areas below that threshold are not normally prone to large wildfires during that timeframe.

The strongest environmental variables were August maximum temperature, slope, and lightning ignition density, explaining 76 percent of the geographical patterns of large wildfires. Distance to roads contributed another 15 percent, and, together, these four variables account for 91 percent of the information that relates to wildfire suitability in our model. Response curves (app. G) suggest suitability for large wildfires increases (in almost a logistic fashion) as August maximum temperature and slope increases. The response curves for lightning ignition density and distance to road variable response curves are quadratic in shape, showing sharp increases in suitability as the variable value increases, but

then reaching a wide plateau and eventually decreasing (app. G). We suspect this decrease in suitability at the high end is related to elevation effects, which also exhibited a similar quadratic response curve. Extreme distances from roads occurred in many wilderness areas located along the Cascades crest, and these remote areas tend to be at the highest elevations where late snowmelt produces cooler and moister conditions during the fire season. Likewise, lightning ignitions tend to be highest at high elevations. Of the six model variables used, slope had the highest gain when modeled by itself. It also decreased the gain the most when omitted from the model, and therefore is an important variable in our model and appears to have the most information that is not present in the other environmental variables.

Discussion

Four decades of history on large wildfire occurrence fit well within our map of "wildfire suitability" gradients (fig. 4-7). The binary version of our map (fig. 4-8) has some distinct similarities to previously mapped versions of "fire-prone" areas in the owl's range, especially the map by Agee and Edmonds (1992). But, it also has some distinct differences; most notably, it includes the considerable portions of the western Cascades of Oregon, and it excludes large areas of the eastern Cascades that are commonly shown on previous map versions (fig. 4-1). Based on our map, only the northern half of the Washington Eastern Cascades physiographic province has substantial land area that appears suitable for large wildfire occurrence. South of this, our map indicates a patchy distribution of high-suitability areas along the eastern Cascades; yet, much of this area historically was covered with ponderosa pine forests, known for its dependency on wildfire. This, and recent occurrences of large wildfires in these areas (i.e., B&B Complex, Link Fire, Davis Lake Fire, and the Eyerly Fire) may point to potential model limitations, which we discuss below.

To begin with, our map represents suitability for what we defined as "large" wildfires, and perhaps ones that are harder to suppress and contain, given the potential bias of our training data. The map does not represent a suitability gradient for all wildfire occurrences, nor behaviors, such as fire severity. Secondly, our map was trained with about three decades of large wildfire data and therefore, represents the likelihood of large wildfire occurrence within that specific timeframe. If we go further back in time, the fire history record within the owl's range clearly shows the occurrence of large wildfires in the lower suitability areas ("bluer areas") of our map (fig. 4-3), such as the Yacolt and Columbia Fires of 1902, the Tillamook Fire of 1933, and the more recent Oxbow Fire of 1966 (see fig. 3-16 in chapter 3). As noted above, our model is based on climate and topographic variables that have been relatively stable over the last century. The large wildfires that have occurred within the lower suitability areas of our map have been consistently associated with extreme weather (i.e., high winds) or heavy, contiguous, dry fuel (McClure 2005, Morris 1935), which could not be included in the model. We suspect a map characterizing long-term means of these extreme, episodic climatic events would be even more difficult to produce than a rangewide fuel map. However, fire ecologists have recently divided the range of the owl into five "fire regime groups[5]," which represent a coarse spatial integration of fire frequency and severity (Keane et al. 2002, Morgan et al. 2001, Schmidt et al. 2002). Whereas fire regimes relate to the frequency, severity, and spatial distribution of historical wildfire in the ecosystem (Rollins et al. 2002), our map sheds light only on the latter of these three characteristics. However, it still shows spatial similarities to the fire regime group map, and, in particular, the lower suitability areas complement Fire Regime Group V, which represents infrequent fires (>200-year intervals) and mostly occurs in the coastal zones and highest elevations of the mountain ranges. These areas have been defined as incurring infrequent wildfires that, when they do happen, tend to be extremely large and severe (Agee 1993, 1998; Morgan et al. 2001; Noss et al. 2006)

[5] LANDFIRE data products and their descriptions are available online at http://www.landfire.gov/products_overview.php.

On the other end of the fire regime group spectrum, wildfires were more frequent (<35-year intervals) and less severe, maintaining open forests, or a mosaic of different-aged forest seral stages (Hann and Strohm 2003). On our map, portions of the Cascades east of the high-elevation crest, where ponderosa pine forests historically dominated, fit this description. These pine forests were once dependent on frequent surface fires that burned heterogeneously through the landscape, creating open, park-like distributions of trees that were often clumped into small groups (Agee 1994, Graham and Jain 2005). Historically, wildfires in ponderosa pine forests were relatively easy to contain (Munger 1917). Fire suppression and exclusion in ponderosa pine forests produced changes that have been well documented by scientists since the 1990s (Agee 1990, Deeming 1990, Kauffman 1990, Mitchell 1990, Mutch et al. 1993, Wickman 1992). The lack of natural wildfires allows understory development of shade-tolerant vegetation that produces resource-stressed stands, making them more susceptible to insects and disease. This, in turn, leads to weakened or dead trees, producing fuel loadings that are unnaturally heavy and also contiguous over large areas (Hessburg et al. 2005). The understory development also produces ladder fuels that can lead to crown fires, and this fuel combination produces conditions ripe for large wildfires (Hessburg et al. 2005). Today, these areas have developed fuel characteristics that support larger, and more severe, wildfires (Hessburg et al. 2005), and the recent wildfires in central eastern Oregon Cascades have been larger than those of historical records (Eckert et al. 2008).

To what extent fire suppression may have biased our map is uncertain. We suspect fire suppression has likely affected the frequency of large wildfires, but it is much less clear that it has affected the distribution of large wildfires on the landscape. Studies of large wildfires in the large wilderness areas of the Southwest and Northern Rockies (Rollins et al. 2002, Rollins et al. 2004) suggest there has not been an effect on the distribution, although that evidence is indirect as distribution on the landscape was not the focus of any of these studies. Because we have almost no data on how the

distribution of large fires might have differed in the absence of suppression actions within the study area, we cannot characterize any model bias in that regard.

Using forest health protection aerial survey data from 1983 to 2008 (USDA 2008), spatial patterns of recent western spruce budworm (*Choristoneura occidentalis*) and mountain pine beetle (*Dendroctonus ponderosae*) outbreaks become apparent (fig. 4-9). In 1983, the spruce budworm began expanding its distribution in the eastern Cascades of Oregon, spreading northward into Washington. It mostly ran its course in the eastern Oregon Cascades by 1993, and then became more active in the southern portions of the Washington Eastern Cascades province. The increased fuel loads created by severe insect outbreaks certainly increase suitability for large wildfires, especially if the fuels are concentrated in a contiguous fashion. In general, the spatial pattern of concentrated spruce budworm outbreaks correspond highly with the B&B Complex and Link Fires from 2003 (fig. 4-9), and also the Lake George, Puzzle, and Black Crater Fires from 2006, and the loss of owl habitat in these areas has largely been attributed to this spruce budworm epidemic and its contribution to the wildfire's size and severity (Courtney et al. 2004). In addition, the Davis Fire of 2003 occurred in a concentrated area of recent mountain pine beetle outbreaks, and we consider it is likely these episodic insect infections added to the suitability of those specific areas to support these large wildfires.

Agee (1993) pointed out that fire regimes are dependent on the interaction of all parts of the fire behavior triangle – weather, topography, and fuel. Parisien and Moritz (2009) described the fire regime triangle as the interaction of climate, ignitions, and vegetation. Our map spans both the spatial and temporal scales that these triangles represent (see fig. 1 in Parisian and Moritz 2009) and appears to reasonably reflect the last four decades of wildfire history within the range of the owl. However, we suspect that additional spatial information on long-term means of episodic climatic events or insect outbreaks would likely increase its accuracy.

Perhaps one of the most compelling validations of our wildfire suitability map is the relationship of the distributions of three fire-dependent pine species (Little 1971, USDI 1999) with our binary characterization of wildfire suitability (fig. 4-10). As a group in general, pines are associated with forests where wildfire is an integral part of the environment (Fonda 2001). In the range of the owl, sugar pine (*Pinus lambertiana* Dougl.), Jeffrey pine (*P. jeffreyi* Grev. & Balf.), and ponderosa pine (*P. ponderosa* P. & C. Lawson) are common associates with fire-prone ecosystems having shorter fire return intervals (Skinner and Chang 1996, Taylor and Skinner 1998). These species are members of the "fire-resistant" group of pines (McCune 1988) that evolved in fire-prone environments and developed characteristics like thick bark to insulate the cambium and long needles to insulate buds from the heat of wildfires. Using a map comparison technique[6] (Visser and De Nijs 2006), we found that their combined geographic distributions (Little 1971) coincide (cell to cell) moderately well (kappa = 0.46, K_{LOC} = 0.76, K_{HISTO} = 0.60) with the fire-prone areas of the binary version of our model. We believe the historical distributions of these fire-resistant conifers provide further evidence that our binary map effectively identifies portions of the owl's range that wildfire regularly "inhabits."

Countryman (1966) described "fire environment" as the complex of fuel, topographic, and weather [air mass] factors that influences the inception, growth, and behavior of fire. He realized that it was a "pattern phenomena," and advised that its pattern "must be considered in order to understand and predict a fire's behavior." Our map of wildfire suitability is essentially a modeling application of the concept Countryman first described over 40 years ago and is well-validated by almost 40 years of large wildfire data.

[6] This analysis was performed by using the Map Comparison Kit software (version 3.2) (Netherlands Environmental Assessment Agency) developed by the Research Institute for Knowledge Systems, and available online at http://www.riks.nl/mck/.

Summary

Our goal was to identify landscape-scale areas within the owl's range where large wildfires are more probable over time using factors that are mostly spatially and temporally stable. The use of topographic and climate variables that summarized weather patterns over multiple years (1970-2000) resulted in a map that we believe met this goal, as evidenced by the map's moderate to good correlations (AUC of 0.78 to 0.83 and $R_s \geq 0.987$) with large wildfire locations that post-date the wildfire data used to train the model as well as historical distribution maps of fire-dependent pine species (fig. 4-10). A binary classification of our map (based on the threshold where the map predicts large wildfires more often than would be expected by chance) provides a less arbitrary way to identify "fire-prone" areas of the northern spotted owl's range that normally experience large wildfires.

With this knowledge, we can overlay our wildfire suitability map on the current habitat suitability map produced in chapter 3, to confirm that the physiographic province with the most owl habitat in fire-prone landscapes is the California Klamath province (fig. 4-11). The next highest province is the Oregon western Cascades province. However, the recent occurrence and trends of insect outbreaks in the eastern Cascades needs to be considered as well. The effects of past management practices combined with these outbreaks have probably increased the suitability for large wildfires of areas that otherwise have underlying physical and climatic factors that are not suitable. If this is the case, our results suggest that once the current fuel build-ups in the eastern Cascade provinces are reduced to more natural levels, the occurrence of large wildfires in that area should decline.

The effects of wildfire on owl biology are difficult to assess and will likely remain a source of uncertainty (Courtney et al. 2004) for some time. Yet, the latest estimates of wildfire's effect on current and future owl habitat, as displayed in chapter 3, indicate wildfires are the major source of habitat loss and future recruitment on federal lands in certain parts of the owl's range. Fortunately, our capabilities to map owl habitat suitability, wildfire effects on vegetation, and wildfire suitability are improving;

informing us better on what the habitat effects might be and where this interaction is most likely to happen.

A limitation of our map is that, by itself, it does not provide information on where within the range, large wildfires may occur as a result of atypical or unusual, infrequent conditions or events such as extreme fire weather (Bessie and Johnson 1995, Westerling et al. 2003, 2006), fuel conditions, or a combination of the two. There are other tools available to monitor and track those conditions. However, our map can be used in conjunction with this ancillary data, such as insect outbreak maps, to better inform us on where the next large wildfires might happen.

Finally, the inclusion of climate variables that summarize fire weather in our model may give us the ability to explore climate change scenarios (Carroll 2010) and what effect they may have on patterns of wildfire suitability in the future.

References

Agee, J.K. 1990. The historical role of fire in Pacific Northwest forests. In: Walstad, J.D.; Radosevich, S.R.; Sandberg, D.V., eds. Natural and prescribed fire in Pacific Northwest Forests. Corvallis, OR: Oregon State University Press: 25–38.

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Washington, DC: Island Press. 493 p.

Agee, J.K. 1994. Fire and weather disturbances in terrestrial ecosystems of the eastern Cascades. Gen. Tech. Rep. PNW-GTR-320. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 52 p.

Agee, J.K. 1998. The landscape ecology of western forest fire regimes. Northwest Science. 72(Spec. issue): 24–34.

Agee, J.K.; Edmonds, R.L. 1992. Appendix F – forest protection guidelines for the northern spotted owl. In: Final draft recovery plan for the northern spotted owl. 419–480. Unpublished report. On file with: U.S. Fish and Wildlife Service, 2600 SE 98th Ave., Ste. 100 Portland, OR. 97266.

Albini, F. 1976. Estimating wildfire behavior and effects. Gen. Tech. Rep. INT-30. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 92 p.

Albini, F.A.; Latham, D.J.; Baughman, R.G. 1982. Estimating upslope convective wind speeds for predicting wildland fire behavior. Res. Pap. INT-257. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 19 p.

Araújo, M.B.; Pearson, R.G.; Thuillers, W.; Erhard, M. 2005. Validation of species-climate impact models under climate change. Global Change Biology. (11): 1504–1513.

Bessie, W.C.; Johnson, E.A. 1995. The relative importance of fuels and weather on fire behavior in subalpine forests. Ecology. 76: 747–762.

Beyer, H.L. 2009. Hawth's analysis tools (version 3.27) for ArcGIS. http://www.spatialecology.com/htools. (4 January 2011).

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

Bond, W.J.; Keeley, J.E. 2005. Fire as a global "herbivore": the ecology and evolution of flammable ecosystems. Trends in Ecology and Evolution. 20(7): 387–394.

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

Boyce, M.S.; Vernier, P.R.; Nielsen, S.E.; Schmiegelow, F.K.A. 2002. Evaluating resource selection functions. Ecological Modelling. 157: 281–300.

Brown, A.A.; Davis, K.P. 1973. Forest fire control and use. New York, NY: McGraw-Hill Book Company. 686 p.

Brown, T.J.; Hall, B.L.; Mohrle, C.R.; Reinbold, H.J. 2002. Coarse assessment of federal wildland fire occurrence data: report for the National Wildfire Coordinating Group. Reno, NV: CEFA Report 02-04. Program for Climate, Ecosystem and Fire Applications, Desert Research Institute, Division of Atmospheric Sciences. 31 p.

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

Clark, D.A. 2007. Demography and habitat selection of northern spotted owls in post-fire landscapes of southwestern Oregon. Corvallis, OR: Oregon State University. 218 p. M.S. thesis.

Countryman, C.M. 1964. Mass fires and fire behavior. Res. Rep. PSW-19. Berkley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 53 p.

Countryman, C.M. 1966. The concept of fire environment. Fire control notes. Berkley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 27(4): 8–10.

Courtney, S.P.; Blakesley, J.A.; Bigley, R.E.; Cody, M.L.; Dumbacher, J.P.; Fleischer, R.C.; Franklin, A.B.; Franklin, J.F.; Gutiérrez, R.J.; Marzluff, J.M.; Sztukowski, L. 2004. Scientific evaluation of the status of the northern spotted owl. Portland, OR: Sustainable Ecosystem Institute. 348 p. + appendixes.

Cui, W.; Perera, A.H. 2008. What do we know about forest fire size distribution, and why is this knowledge useful for forest management? International Journal of Wildland Fire. 17: 234–244.

Davis, R.; Lint, J. 2005. Habitat status and trend. In: Lint, J., tech. coord. Northwest Forest Plan–the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen.

Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 21–82.

Deeming, J.E. 1990. Effects of prescribed fire on wildfire occurrence and severity. In: Walstad, J.D.; Radosevich, S.R.; Sandberg, D.V., eds. Natural and prescribed fire in Pacific Northwest forests. Corvallis, OR: Oregon State University Press: 95–104.

Deeming, J.E.; Burgan, R.E.; Cohen, J.D. 1977. The national fire danger rating system. Gen. Tech. Rep. INT-39. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 63 p.

Eckert, B.E.; Walstad, J.D.; Tappeiner, J.C. II. 2008. An illustrated guide to fire in central Oregon forests. Contributions in Education and Outreach No. 1. Corvallis, OR: Forest Research Laboratory, Oregon State University. 40 p.

Eidenshink J.; Schwind, B.; Brewer, K.; Zhu, Z.L.; Quayle, B.; Howard, S. 2007. A project for monitoring trends in burn severity. Fire Ecology. 3: 3–21.

Elith, J.; Phillips, S.J.; Hastie, T.; Dudík, M.; Chee, Y.E.; Yates, C.J. 2011. A statistical explanation of MaxEnt for ecologists. Diversity and Distributions. 17: 43–57.

Fielding, A.H.; Bell, J.F. 1997. A review of methods for assessment of prediction errors in conservation presence/absence models. Environmental Conservation. 24: 38–49.

Fonda, R.W. 2001. Burning characteristics of needles from eight pine species. Forest Science. 47: 390–396.

Forest Ecosystem Management Assessment Team [FEMAT]. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Portland, OR: U.S. Department of Agriculture; U.S. Department of the Interior [and others]. [Irregular pagination].

DRAFT

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

Franklin, J.F.; Dyrness, C.T. 1973. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-8. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 417 p.

Garfin, J.E.; Morehouse, B., eds. 2001. Fire and climate workshop proceedings. Tucson, AZ: University of Arizona, Institute for the Study of Planet Earth, Climate Assessment for the Southwest: 75 p.

Gisborne, H.T. 1936. Measuring fire weather and forest inflammability. Circular No. 398. Washington, DC: U.S. Department of Agriculture. 59 p.

Graham, R.T.; Jain, T.B. 2005. Ponderosa pine ecosystems. In: Ritchie, M.W.; Maguire, D.A.; Youngblood, A., tech. cords. 2005. Proceedings of the symposium on ponderosa pine: issues, trends, and management. Gen. Tech. Rep. PSW-GTR-198. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 1–32.

Grinnell, J. 1917. Field tests of theories concerning distributional control. The American Naturalist. 51(602): 115–128.

Guisan, A.; Zimmermann, N.E. 2000. Predictive habitat distribution models in ecology. Ecological Modelling. 135: 147–186.

Hann, W.J.; Strohm, D.J. 2003. Fire regime condition class and associated data for fire and fuels planning: methods and applications. In: Omi, P.N.; Joyce, L.A., eds. Fire, fuel treatments and ecological restoration: conference proceedings. Proceedings RMRS-P-29. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 397–433.

Hanson, C.T.; Odion, D.C.; Dellasala, D.A.; Baker, B.L. 2009. Overestimation of fire risk in the northern spotted owl recovery plan. Conservation Biology. 23: 1314–1319.

DRAFT

Hayes, G.L. 1941. Influence of altitude and aspect on daily variations in factors of forest-fire danger. Circular No. 591. Washington, DC: U.S. Department of Agriculture. 38 p.

Healey, S.P.; Cohen, W.B.; Spies, T.A.; Moeur, M.; Pflugmacher, D.; Whitley, M.G.; Lefsky, M. 2008. The relative impact of harvest and fire upon landscape-level dynamics of older forests: lessons from the Northwest Forest Plan. Ecosystems. 11: 1106–1119.

Hessburg, P.F.; Agee, J.K.; Franklin, J.F. 2005. Dry forests and wildland fires of the inland Northwest USA: contrasting the landscape ecology of the pre-settlement and modern eras. Forest Ecology and Management. 211: 117–139.

Hirzel, A.H.; Le Lay, G. 2008. Habitat suitability modelling and niche theory. Journal of Applied Ecology. 45: 1372–1381.

Hirzel, A.H.; Le Lay, G.; Helfer, V.; Randin, C.; Guisan, A. 2006. Evaluating the ability of habitat suitability models to predict species presences. Ecological Modelling. 199: 142–152.

Hutchinson, G.E. 1957. Concluding remarks. Cold Spring Harbor Symposium. Quantitative Biology. 22: 415–427.

Kauffman, J.B. 1990. Ecological relationships of vegetation and fire in Pacific Northwest forests. In: Walstad, J.D.; Radosevich, S.R.; Sandberg, D.V., eds. Natural and prescribed fire in Pacific Northwest forests. Corvallis, OR: Oregon State University Press: 39–52.

Kaufmann, J.H. 1962. Ecology and social behavior of the coati, *Nasua nirica* on Barro Colorado Island Panama. University of California Publications in Zoology. 60: 95–222.

Keane, R.E.; Parsons, R.; Hessburg, P. 2002. Estimating historical range and variation of landscape patch dynamics: limitations of the simulation approach. Ecological Modeling. 151: 29–49.

Komarek, E.V. 1967. The nature of lightning fire. In: Komarek, E.V., ed. Proceedings, 7th Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station: 5–41.

Krawchuk, M.A.; Moritz, M.A.; Parisien, M.A.; Van Dorn, J.; Hayhoe, K. 2009. Global pyrogeography: the current and future distribution of wildfire. Public Library of Science O. 4(4):e5102. DOI: 10.1371/journal.pone.0005102.

Lint, J.; Noon, B.; Anthony, R.; Forsman, E.; Raphael, M.; Collopy, M.; Starkey, E. 1999. Northern spotted owl effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-440. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 43 p.

Little, E.L., Jr. 1971. Atlas of United States trees, volume 1, conifers and important hardwoods. U.S. Department of Agriculture Miscellaneous Publication 1146. 9 p., 200 maps.

McClure, R. 2005. Washington's "awful conflagration"—The Yacolt Fire of 1902. Fire Management Today. 65(1): 24–27.

McCune, B. 1988. Ecological diversity in North American pines. American Journal of Botany. 75(3): 353–368.

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

Mitchell, R.G. 1990. Effects of prescribed fire on insect pests. In: Walstad, J.D.; Radosevich, S.R.; Sandberg, D.V., eds. Natural and prescribed fire in Pacific Northwest forests. Corvallis, OR: Oregon State University Press: 111–116.

Morgan, P.; Hardy, C.C.; Swetnam, T.W.; Rollins, M.G.; Long, D.G. 2001. Mapping fire regimes across time and space: understanding coarse and fine-scale fire patterns. International Journal of Wildland Fire. 10: 329–342.

Morris, W.G. 1934. Lightning storms and fires. U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR. 27 p.

DRAFT

Morris, W.G. 1935. The details of the Tillamook fire from its origin to the salvage of the killed trees. 26 p. Unpublished report. On file with: National Archives Records Admin., Pacific Alaska Region, 6125 Sand Point Way NE, Seattle, WA. 98115-7999.

Munger, T.T. 1917. Western yellow pine in Oregon. Bulletin 418. Washington, D.C.: U.S. Department of Agriculture; 48 p.

Mutch, R.W.; Arno, S.F.; Brown, J.K.; Carlson, C.E. [and others]. 1993. Forest health in the Blue Mountains: a management strategy for fire-adapted ecosystems. Gen. Tech. Rep. PNW-310. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station: 14 p.

Noss, R.F.; Franklin, J.F.; Baker, W.L.; Schoennagel, T.; Moyle, P.B. 2006. Managing fire-prone forests in the Western United States. Frontiers in Ecology and the Environment. 4: 481–487.

Oregon Climate Service. 2008. Parameter-elevation regressions on independent slopes models (PRISM). http://www.ocs.oregonstate.edu/prism. (21 December 2010).

Parisien, M.; Moritz, M.A. 2009. Environmental controls on the distribution of wildfire at multiple spatial scales. Ecological Monographs. 79(1): 127–154.

Phillips, S.J.; Anderson, R.P.; Shapire, R.E. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modelling. 190: 231–259.

Phillips, S.; Dudík, M. 2008. Modeling of species distributions with MaxEnt: new extensions and a comprehensive evaluation. Ecography. 31: 161–175.

Pierce, K.B.; Lookingbill, T.R.; Urban, D.L. 2005. A simple method for estimating potential relative radiation (PRR) for landscape-scale vegetation analysis. Landscape Ecology. 20: 137–147.

Potter, B.E. 1996. Atmospheric properties associated with large wildfires. International Journal of Wildland Fire. 6(2): 71–76.

Preisler, H.K.; Westerling, A.L. 2007. Statistical model for forecasting monthly large wildfire events in Western United States. Journal of Applied Meteorology and Climatology. 46(7): 1020–1030.

Pyne, S.J. 2001. Fire: a brief history. Seattle, WA: University of Washington Press. 209 p.

Pyne, S.J. 2004. Tending fire: coping with America's wildland fires. Washington, DC: Island Press. 256 p.

Randin, C.F.; Dirnbo, T.; Dullinger, S.; Zimmermann, N.E.; Zappa, M.; Guisan, A. 2006. Are niche-based species distribution models transferable in space? Journal of Biogeography. 33: 1689–1703.

Rapp, V. 2005. Conserving old forest in landscapes shaped by fire. Science Update 11. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 11 p.

Rollins, M.G.; Keane, R.E.; Parsons, R.A. 2004. Mapping fuels and fire regimes using remote sensing, ecosystem simulation, and gradient modeling. Ecological Applications. 14(1): 75–95.

Rollins, M.G.; Morgan, P.; Swetnam, T. 2002. Landscape-scale controls over 20th century fire occurrence in two large Rocky Mountain (USA) wilderness areas. Landscape Ecology. 17: 539–557.

Rorig, M.L.; Ferguson, S.A. 1999. Characteristics of lightning and wildland fire ignition in the Pacific Northwest. Journal of Applied Meteorology. 38: 1565–1575.

Rothermel, R.C. 1983. How to predict the spread and intensity of forest and range fires. Res. Pap. INT-143. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 161 p.

Rothermel, R.C. 1991. Predicting behavior and size of crown fires in the northern Rocky Mountains. Res. Pap. INT-438. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 46 p.

Samuel, M.D.; Pierce, D.J.; Garton, E.O. 1985. Identifying areas of concentrated use within the home range. Journal of Animal Ecology. 54(3): 711–719.

DRAFT

Schmidt, K.M.; Menakis, J.P.; Hardy, C.C.; Hann, W.J.; Bunnell, D.L. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. Gen. Tech. Rep. RMRS-GTR-87. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 41 p.

Schroeder, M.J.; Buck, C.C. 1970. Fire weather: a guide for application of meteorological information to forest fire control operations. Agric. Handb. 360. Washington, DC: U.S. Department of Agriculture, Forest Service. 229 p.

Scott, J.H.; Reinhardt, E.D. 2001. Assessing crown fire potential by linking models of surface and crown fire behavior. Res. Pap. RMRSRP- 29. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 59 p.

Schwind, B., comp. 2008. Monitoring trends in burn severity: report on the Pacific Northwest and Pacific Southwest fires (1984 to 2005). Unpublished report. On file with: USDA Forest Service, Remote Sensing Applications Center (RSAC), U.S. Geological Survey, Center for Earth Resources Observations and Science (EROS). http://mtbs.gov/reports/MTBS_pnw-psw_final.pdf. (4 January 2011).

Sensenig, T.S. 2002. Development, fire history and current and past growth, of old-growth and young-growth forest stands in the Cascade, Siskyou and mid-Coast Mountains of southwestern Oregon. Corvallis, OR: Oregon State University. 180 p. Ph.D. dissertation.

Skinner, C.N.; Chang, C. 1996. Fire regimes, past and present. In: Sierra Nevada Ecosystem Project: final report to Congress. Volume II, assessments and scientific basis for management options. Davis, CA: University of California, Centers for Water and Wildland Resources: 1041–1069. http://ceres.ca.gov/snep/pubs/web/PDF/VII_C38.PDF . (18 December 2010).

Spies, T.A.; Hemstrom, M.A.; Youngblood, A.; Hummel, S. 2006. Conserving old-growth forest diversity in disturbance-prone landscapes. Conservation Biology. 20: 351–362.

DRAFT

Stocks, B.J.; Mason, J.A.; Todd, J.B.; Bosch, E.M.; Wotton, B.M.; Amiro, B.D.; Flannigan, M.D.; Hirsh, K.G.; Logan, K.A.; Martell, D.L.; Skinner, W.R. 2003. Large forest fires in Canada, 1959–1997. Journal of Geophysical Research. 108(D1, 8149): 1–12.

Stratton, R.D. 2006. Guidance on spatial wildland fire analysis: models, tools, and techniques. Gen. Tech. Rep. RMRS-GTR-183. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 15 p.

Sugihara, N.G.; van Wagtendonk, J.W.; Shaffer, K.E.; Fites-Kaufamn, J.; Thode, A.E. 2006. Fire in California's ecosystems. Berkley, CA: University of California Press. 596 p.

Taylor, A.H.; Skinner, C.N. 1998. Fire history and landscape dynamics in a late-successional reserve, Klamath Mountains, California USA. Forest Ecology and Management. 111: 285–301.

Thomas, J.W.; Forsman, E.D.; Lint, J.B.; Meslow, E.C.; Noon, B.R.; Verner, J. 1990. A conservation strategy for the northern spotted owl: a report of the Interagency Scientific Committee to address the conservation of the northern spotted owl. Portland, OR: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management, Fish and Wildlife Service, National Park Service. 427 p.

U.S. Department of Agriculture, Forest Service [USDA]. 2008. Forest health protection aerial survey data. http://www.fs.fed.us/r6/nr/fid/as/index.shtml. (4 January 2011).

U.S. Department of the Interior, Fish and Wildlife Service [USDI]. 1990. Endangered and threatened wildlife and plants: determination of threatened status for the northern spotted owl. Federal Register 55:26114- 26194.

U.S. Department of the Interior, Fish and Wildlife Service [USDI]. 1992. Final draft recovery plan for the northern spotted owl. Unpublished report. On file with: U.S. Fish and Wildlife Service, 2600 SE 98th Ave., Ste. 100 Portland, OR. 97266.

DRAFT

U.S. Department of the Interior, Geological Survey [USDI]. 1999. Digital representation of "Atlas of United States Trees" by Elbert L. Little, Jr. USDI Geological Survey, Earth Surface Processes. http://esp.cr.usgs.gov/data/atlas/little/. (4 January 2011).

U.S. Department of the Interior, Fish and Wildlife Service [USDI]. 2008. Final recovery plan for the northern spotted owl (*Strix occidentalis caurina*). 142 p. On file with: U.S. Department of the Interior, Fish and Wildlife Service, 2600 SE 98th Ave., Ste. 100 Portland, OR. 97266.

U.S. Department of the Interior, Fish and Wildlife Service; U.S. Department of the Interior, Bureau of Land Management; U.S. Department of Agriculture, Forest Service [USDI and USDA]. 2008. Methodology for estimating the number of northern spotted owls affected by proposed federal actions (version 2.0). Unpublished report. On file with: U.S. Fish and Wildlife Service, 2600 SE 98th Ave., Ste. 100 Portland, OR. 97266.

Van Wagner, C.E. 1977. Conditions for the start and spread of crown fire. Canadian Journal of Forest Research. 7: 23–34.

Visser, H.; De Nijs, T. 2006. The map comparison kit. Environmental Modelling and Software. 21(3): 346–358.

Westerling, A.L.; Bryant, B.P. 2008. Climate change and wildfire in California. Climatic Change. 87: 231–249.

Westerling, A.L.; Gershunov, A.; Brown, T.J. 2003. Climate and wildfire in the western United States. Bulletin of the American Meteorological Society. 84: 595–604.

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

Wickman, Boyd E. 1992. Forest health in the Blue Mountains: the influence of insects and diseases. Gen. Tech. Rep. PNW-GTR-295. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific

Northwest Research Station. 15 p. (Quigley, Thomas M., ed.; Forest health in the Blue Mountains science perspectives).

Wiley, E.O.; McNyset, K.M.; Peterson, A.T.; Robins, C.R.; Stewart, A.M. 2003. Niche modeling and geographic range predictions in the marine environment using a machine learning algorithm. Oceanography. 16: 120–127.

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Chapter 5: Emerging Issues, Related Research, and Research Needs

Katie M. Dugger and Raymond J. Davis

Emerging Issues

The 10-year report on the status and trends of northern spotted owl (*Strix occidentalis caurina*) populations and habitat recognized that the conservation and recovery of the owl is not solely related to the amount and quality of habitat across its range (Lint 2005). Other factors including interactions with prey and prey biology, competition with barred owls (*Strix varia*), and the emergence of West Nile virus in the Pacific Northwest were noted as emerging issues (Lint 2005). The potential threat of West Nile virus infections to spotted owl populations has not been realized, despite early evidence that owls in the wild were susceptible to natural infection (Fitzgerald et al. 2003). For unknown reasons, outbreaks of the West Nile virus in spotted owls that were anticipated five years ago have not occurred, although the virus is present throughout the owls range (Franklin 2010). Although West Nile virus has not developed into as much of a threat to owl populations as predicted previously (Lint 2005), documentation of the negative association between the invasive barred owl and spotted owl vital rates has continued over the last five years (Anthony et al. 2006, Dugger et al. 2008, Forsman et al. 2011, Glenn et al. 2010, Kroll et al. 2010). The barred owl is now found at significant densities throughout the entire range of the northern spotted owl (Livezey 2009), and the range expansion of this species constitutes a significant threat to northern spotted owl persistence, which was not evident when the spotted owl was first listed (Courtney et al. 2004). The proportion of spotted owl territories where barred owls have been detected has increased steadily since the early 1990s in the eight effectiveness monitoring areas administered under the Plan (fig. 5.1) along with increased evidence of negative interactions, presumably owing to competition or interference between the two species (Dugger et al. 2008, 2009; Kroll et al. 2010; Olson et al. 2005).

The invasion of barred owls into the range of the northern spotted owl has been associated with a decreased ability to detect and monitor spotted owls when barred owls are present (Dugger et al. 2009, Glenn et al. 2010, Kroll et al. 2010, Olson et al. 2005). In addition, the detection of barred owls on spotted owl territories is associated with decreased site occupancy by spotted owls and changes in extinction and colonization rates (Dugger et al. 2008, 2009; Kroll et al. 2010; Olson et al. 2005). The strongest association is between detections of barred owls and increased extinction rates across the entire range of the spotted owl, and decreased colonization rates have been reported for some study areas as well (Dugger et al. 2008, 2009; Kroll et al. 2010; Olson et al. 2005). The most recent meta-analysis of spotted owl population dynamics reports a clear negative association between barred owl presence and spotted owl survival (Forsman et al. 2011; chapter 2, this report). Effects on fecundity are less apparent, but declines in spotted owl recruitment on four demographic study areas (Olympic, H.J. Andrews, Coast Ranges, Tyee) in association with barred owl presence has been reported (Glenn et al. 2010). Thus, researchers continue to compile negative associations between barred owl presence and spotted owl vital rates strengthening the evidence that barred owls are negatively affecting spotted owl demography.

Climate change is another emerging issue that may affect spotted owl habitat, populations, and the functionality of the network of reserved land use allocations across the owl's range (Carroll 2010, Carroll et al. 2009, Glenn et al. 2010, Spies et al. 2010). Forest Service research objectives include developing projections for changes in fire regimes and shifts in habitat distributions because altered forest structures with increased threats from wildfire and insect and disease outbreaks are anticipated in association with predicted climate change (USDA 2009). Rate of change in spotted owl population was negatively associated with hot, dry growing seasons and wet, stormy winters (Glenn et al. 2010). Climate models for the first half of the 21st century predict warmer, wetter winters and hotter, drier summers, which could potentially have negative consequences for spotted owls (Glenn et al. 2010).

Considering the potential effects of different climate change scenarios in models predicting wildfire suitability (see chapter 4 in this report) may help estimate potential changes in the fire regime within the owl's range and thus potential threats to habitat. In addition, the inclusion of forest type variables in the owl habitat models can also be modified based on climate change scenarios and used to explore the effects of climate change on suitable owl habitat. As noted by Glenn et al. (2010), however, in the face of climate change and barred owl persistence, the best management strategy for conserving spotted owl populations is to maintain sufficient, high-quality, suitable habitat throughout the species' range.

Related Research and Research Needs

Current research efforts to further understand the competitive interactions between barred and spotted owls are ongoing by D. Wiens, an Oregon State University Ph.D. Student (D. Wiens unpublished data). In addition, the U.S. Fish and Wildlife Service (FWS) is proceeding with a proposal to clarify interactions between the two species using an experimental approach as part of Recovery Action 29 in the *Final Recovery Plan for the Northern Spotted Owl* (USDI 2008). This recovery action calls for the U.S. Fish and Wildlife Service to "Design and implement large-scale control experiments in key spotted owl areas to assess the effects of barred owl removal on spotted owl site occupancy, reproduction, and survival." By removing barred owls from spotted owl territories, researchers will be able to document a clear cause-effect relationship between barred owl presence and spotted owl demography (Gutiérrez et al. 2007). The information gained from this experiment may aid in the management and conservation of spotted owls in the face of the continued threat posed by the invasion and establishment of the barred owl in the Pacific Northwest. This proposed research may elucidate new management actions or clarify management and conservation limitations regarding the negative interactions of these two species.

The extent to which habitat management can affect interactions between barred and spotted owls is not clear, but barred owls are habitat generalists that can occupy a wide variety of forest conditions including late-successional forests (Herter and Hicks 2000, Pearson and Livezey 2003, Singleton et al. 2010). In addition, their territories are only 1/4 to 1/9 the size of spotted owl territories (Singleton et al. 2010), so the ratio of the number of barred to spotted owls can be as high as 9 to 1 in some areas. This argues for the increased importance of high-quality, contiguous blocks of nesting/roosting habitat for spotted owls, and the effects of habitat loss cannot be decoupled from the additional stressor imposed by the barred owl range expansion (Dugger et al. 2008).

In particular, the relationship between spotted owl fitness and habitat characteristics may have become disconnected through interspecific competition with barred owls in the landscape (Dugger et al. 2008). Our comparison of habitat suitability at spotted owl pair locations between 1994/96 and 2006/07 (see chapter 3 in this report) showed an average decrease in habitat suitability value of 9.4 percent across the owl's range, suggesting that the quality of habitat at spotted owl pair locations has decreased over time. As loss of suitable nesting/roosting habitat since 1994/96 has been low (3.4 percent), it is unlikely this decline in habitat quality of owl pair locations is the result of general habitat loss, so it is possible this change reflects competition for space with barred owls. Barred owls will use a wide variety of forested landscapes (Hamer et al. 2007, Singleton et al. 2010) and may be excluding spotted owls from the best spotted owl habitat in places where their densities are high (Dugger et al. 2008), but this hypothesis needs to be tested directly with barred owl removal experiments. It is possible that competition with barred owls also might be the reason we have had difficulty developing predictive models (see following discussion) that provide a clear understanding of the relationship between habitat characteristics and spotted owl demographics across the species' range (Anthony et al. 1998, 2002a, 2002b; but see Dugger et al. 2005, Olson et al. 2004).

The effectiveness monitoring plan for spotted owls recommended the development of predictive models linking survival, fecundity, and occupancy to observed vegetation characteristics of owl habitat (Lint et al. 1999). The expectation was that these predictive models could be validated and proved to generate owl vital rate predictions with acceptable error. If so, then there would be a shift from intensive collection of mark-recapture data via annual field surveys to the use of remotely sensed habitat data to monitor owl populations on at least some of the eight study areas (Lint et al. 1999). The spotted owl monitoring program funded a 5-year study to explore the development and feasibility of predicting occupancy and demographic performance of spotted owls using remotely sensed habitat data (Anthony et al. 1998), and most of that work has been completed (Anthony et al. 2002a, 2002b; Dugger et al. 2005, 2006, 2008; Olson et al. 2004, 2005).

Unfortunately, this component of the effectiveness monitoring program has produced mixed results, with only a few strong relationships between habitat characteristics and survival and fecundity noted for some of the demographic study areas (Dugger et al. 2005, Franklin et al. 2000, Olson et al. 2004). As noted by Lint (2005) in the 10-year report, results at that point did not warrant moving on to phase II monitoring, where models would be substituted for mark-recapture studies. However, although simple, universal models linking habitat characteristics to survival and fecundity of owls are likely not possible, these efforts have provided more insight into the effects of climate and habitat characteristics on owl demography. Some general findings include the strong positive effect of late-successional forest at the core of an owl's territory (around the nest site or activity center) on survival and fecundity (Dugger et al. 2005, Franklin et al. 2000, Olson et al. 2004). In addition, at least on some study areas in the southern portion of the owls' range, some component of edge habitat may be important, probably as a source of prey (Franklin et al. 2000, Olson et al. 2004).

Since the 10-year report, models for two study areas have been developed linking occupancy dynamics of spotted owls to habitat characteristics (Dugger et al. 2008; S. Sovern 2010). The effect of

barred owls and habitat characteristics on extinction and colonization rates can be modeled using multiseason, single-species occupancy models (MacKenzie et al. 2006) or even multiple-species models within seasons (Bailey et al. 2009, MacKenzie et al. 2006). Estimates of annual site occupancy can also be derived from these models, which rely on a mark-recapture framework with a "site" or owl territory the sample unit and presence/absence data across multiple visits within and between years to allow for the separation of occupancy dynamics and detection probabilities (MacKenzie et al. 2006). Accounting for variations in detection rates of spotted owls is important for developing accurate estimates of site occupancy (MacKenzie et al. 2006, Olson et al. 2005). In addition, understanding the mechanisms or processes that drive site occupancy, like the factors that affect the probability that an occupied site becomes unoccupied (i.e., local extinction rate) or the probability that an unoccupied site becomes occupied (i.e., local colonization rate) are proving vital to understanding the impact of barred owls and habitat characteristics on spotted owl persistence (Olson et al. 2005; Kroll et al. 2010; Dugger et al. in press). Based on these models, strong relationships between the amount of old-forest habitat at the core scale (410-ac circle around nest tree or activity center) and extinction rates were observed for the South Cascades study area; spotted owl territories with small amounts of old forest near the site center experienced higher extinction rates of owl pairs (Dugger et al. 2008). In addition, increased fragmentation of old forest at the home range scale (3,700-ac circle around nest site or activity center) decreased colonization rates by owl pairs, and both occupancy parameters were affected by barred owl presence as well (Dugger et al. 2008).

It is unclear why we observed stronger associations between habitat characteristics and occupancy parameters as compared to habitat characteristics and survival or fecundity (Anthony et al. 2002a, 2002b; Dugger et al. 2005, 2006, 2008; Olson et al. 2004, 2005), but it is possible that occupancy reflects the first level of selection by a species, and this is where the strongest selections for habitat are being made. In other words, an area of habitat selected for defense and maintenance of a territory by

an owl also meets some minimum standard of suitability for survival and reproduction; thus, habitat quality most strongly affects territory selection, but other factors (climate, age/experience of individuals, individual variation) are more important for explaining the variation in survival and fecundity.

Recent advances in the development of remotely sensed vegetation (Ohmann and Gregory 2002) and change-detection data (Kennedy et al. 2007) may provide an opportunity to investigate habitat relationships across the range of the species in conjunction with barred owl influences. Previous efforts included a range of map products based on a single point in time, or limited temporally and of varying quality (Glenn and Ripple 2004), precluding a meta-analysis using data from all the study areas. The development of this new vegetation layer will now allow us to search for and quantify consistent relationships between habitat characteristics and owl demography, particularly occupancy across the entire range of the species within a meta-analysis framework. In addition, the change-detection data provide an annual time sequence of vegetation changes that can now be linked to annual demographic data. This kind of analysis based on data from eight effectiveness monitoring areas and conducted in a workshop format as a meta-analysis following previous efforts for survival and fecundity (Anthony et al. 2006, Burnham et al. 1996, Forsman et al. 2011, Franklin et al. 1999) should be a priority for future research.

A better understanding of the population dynamics of many of the important spotted owl prey species across the range of the owl will likely be essential to understanding patterns and variation in spotted owl fecundity (Courtney et al. 2004, Forsman et al. 2011). New monitoring and research programs should be initiated to investigate prey cycles and their relationship to spotted owl demographics while incorporating the potential competitive effects of barred owls. This remains a large gap in our understanding of spotted owl ecology, and our lack of baseline information increases the

difficulty we face trying to manage spotted owl populations in conjunction with the barred owl, most likely a direct competitor for food resources.

Another area of much needed research includes the effect of fire on owls and their prey, and how fuel reduction treatments proposed to reduce wildfire risk affect owl demography. Fire suppression over the last century has reduced wildfire's presence in its "natural habitats" (Agee 1993, Atzet and Martin 1992, Sensenig 2002), and although wildfire risk has not increased dramatically in the moister/cooler forests, this suppression is believed to have increased the risk for severe wildfires in the fire-prone, or drier/warmer forests. The increased frequency of large wildfires since the mid-1980s in the Western United States (Westerling et al. 2006, Schwind 2008) and within the owl's range (see chapter 4 in this report) have created concern about how wildfires might affect efforts to conserve the owl. Hotter, drier climates associated with climate change are believed to be at least partially responsible for this increase in large-wildfire frequency (Westerling et al. 2006), and there is also evidence that the amount of high-severity wildfire has increased (Miller et al. 2009, Schwind 2008; but see Hanson et al. 2009), in some cases, as the result of accumulated fuels and higher stand densities (Sensenig 2002).

The relationship between wildfire and owl demography is not well understood, but likely includes a complex interaction of fire frequency and severity (Bond et al. 2009, Clark 2007). Owls use forest stands that have burned understories or partially removed overstories, but they tend to avoid areas of complete stand replacement for nesting and roosting (Clark 2007), although use of high-severity burn areas for foraging has been documented for the California spotted owl (*Strix occidentalis occidentalis*) (Bond et al. 2009). This species has likely evolved the ability to adapt and utilize forests that have been subjected to light to moderate fire severity, particularly in the fire-prone portions of its range (chapter 4, this report), but again short-term vs. long-term effects on demography and dispersal are unknown.

Although wildfire has long been a natural agent of disturbance, owls evolved with it in historically forested landscapes that could accommodate the habitat changes caused by it. Today, much of the spotted owl habitat that remains has been "squeezed" into federally managed lands, covers a much smaller portion of the owl's historical range, is highly fragmented (Davis and Lint 2005), and may no longer be able to accommodate large wildfires without incurring adverse consequences to the owl. To lessen the chances of adverse impacts from occurring, the *Final Recovery Plan for the Northern Spotted Owl* (USDI 2008) advocated landscape-level treatments to reduce the risk of large-scale habitat loss to high-severity wildfire for eastern Cascades and Klamath Provinces of the owl's range (USDI 2008). However, it is currently unclear what short- or long-term effects these forest thinning and fuel reduction treatments will have on northern spotted owl populations.

A case study on a single owl territory in second-growth forests in the northern Oregon Coast Range suggests commercial thinning may cause northern spotted owls to alter their habitat use and increase the size of their home ranges, particularly during the nonbreeding season (Meiman et al. 2003). This one case study suggested that thinning operations within core-use areas may be detrimental for northern spotted owls, at least in the short-term. But, the long-term effects of thinning are currently not known as to whether it produces long-lasting adverse impacts or long-term benefits associated with owl vital rates. No other published literature is available on thinning and the effects of fuel reductions on habitat use and demography of threatened spotted owls. Understanding the relationship between wildfire and owl demography and the effect of both commercial and noncommercial thinning activities to reduce fire fuel loads on owl vital rates should be a high research priority.

Summary

As we have summarized above, there are several large gaps in our understanding of spotted owl ecology, particularly in relation to cycles of prey distribution and abundance, disturbance by fire, and

forest management activities associated with developing future habitat or reducing fire risk. Emerging issues, primarily the competitive interactions with the barred owl, are also of very high concern, particularly as the negative effect of this invasive species may be in addition to, or somewhat independent of, maintenance of high-quality spotted owl habitat. The information we have on these issues is dependent on continued research and in particular, the continued long-term monitoring of owl vital rates throughout this species' range. The effectiveness monitoring program for spotted owls was designed to monitor the long-term results of the Plan and its effect on owl populations (Lint et al. 1999). This monitoring program has done much more; however, as the unique, large-scale demography data set resulting from this program has not only allowed resource managers to document the effects of management activities, but has also contributed valuable information regarding basic owl ecology and the factors that affect vital rates. In large part, the effectiveness monitoring program has been responsible for documentation of the barred owl expansion southward into the spotted owl's range and the negative effects of this invasion on spotted owls (Dugger et al. 2008, 2009; Olson et al. 2005). Recovery goals and actions associated with the *Final Recovery Plan for the Northern Spotted Owl* (USDI 2008) and proposed revisions have been informed directly by or are reliant on the demography data collected on the eight effectiveness monitoring study areas, as well as the remotely sensed data developed for habitat monitoring. Data from this long-term monitoring program have also aided researchers in the development of new analytical approaches for answering complex demography questions (Bailey et al. 2009, MacKenzie et al. 2006). These examples illustrate how the value of the spotted owl effectiveness monitoring program reaches far beyond the original objectives and is truly vital to management and conservation of this species.

References

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Washington, DC: Island Press. 493 p.

Anthony, R.G; Forsman, E.D.; Ripple, W.R. 1998. Research proposal: predicting abundance and demographic performance of northern spotted owls from vegetative characteristics. Unpublished research proposal. 20 p. On file with: Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331.

Anthony, R.G.; Forsman, E.D.; Ripple, W.R.; Glenn, E. 2002a. Predicting abundance and demographic performance of northern spotted owls from vegetative characteristics. Report on results of Western Oregon Cascades–H.J. Andrews Experimental Forest. 57 p. Unpublished progress report. On file with: Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331.

Anthony, R.G.; Forsman, E.D.; Franklin, A.B.; Anderson, D.R.; Burnham, K.P.; White, G.C.; Schwarz, C.J.; Nichols, J.D.; Hines, J.E.; Olson, G.S.; Ackers, S.H.; Andrews, L.W.; Biswell, B.L.; Carlson, P.C.; Diller, L.V.; Dugger, K.M.; Fehring, K.E.; Fleming, T.L.; Gearhardt, R.P; Gremel, S.A.; Gutiérrez, R.J.; Happe, P.J.; Herter, D.R.; Higley, J.M.; Horn, R.B.; Irwin, L.L.; Loschl, P.J.; Reid, J.A.; Sovern, S.G. 2006. Status and trends in demography of northern spotted owls, 1985–2003. Wildlife Monographs No. 163. 48 p.

Anthony, R.G.; Wagner, F.; Dugger, K.M.; Olson, G. 2002b. Identification and evaluation of northern spotted owl habitat in managed forests of southwestern Oregon and the development of silvicultural systems for managing such habitat. Report on step 2: analysis of habitat characteristics and owl demography on three density study areas. 77 p. Unpublished report. On file with: Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331.

DRAFT

Atzet, T.A.; Martin, R. 1992. Natural disturbance regimes in the Klamath province. In: Kerner, H.M., ed. Proceedings of the symposium on biodiversity of northwestern California. Berkeley, CA: University of California Wildland Resources Center Report 29: 40–48.

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

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

Burnham, K.P.; Anderson, D.R.; White, G.C. 1996. Meta-analysis of vital rates of the northern spotted owl. Studies in Avian Biology. 17: 92–101.

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

Carroll, C.; Dunk, J.R.; Moilanen, A. 2009. Optimizing resiliency of reserve networks to climate change: multispecies conservation planning in the Pacific Northwest, USA. Global Change Biology. 16: 891–904.

Clark, D.A. 2007. Demography and habitat selection of northern spotted owls in post-fire landscapes of southwestern Oregon. Corvallis, OR: Oregon State University. 218 p. M.S. thesis.

Courtney, S.P.; Blakesley, J.A.; Bigley, R.E.; Cody, M.L.; Dumbacher, J.P.; Fleischer, R.C.; Franklin, A.B.; Franklin, J.F.; Gutiérrez, R.J.; Marzluff, J.M.; Sztukowski, L. 2004. Scientific evaluation of the status of the northern spotted owl. Portland, OR: Sustainable Ecosystem Institute. 348 p. + appendixes.

DRAFT

Dugger, K.M.; Anthony, R.G.; Andrews, L.S. in press. Transient dynamics of invasive competition: barred owls, spotted owls, and the demons of competition present. Ecological Applications 00:000-000.

Dugger, K.M; Anthony, R.G.; Andrews, S.L.; Wagner, F. 2006. Modeling apparent survival and reproductive success of northern spotted owls relative to forest habitat in the southern Cascades of Oregon. 45 p. Unpublished report. Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331.

Dugger, K.M., R.G. Anthony, and E.D. Forsman. 2009. Estimating northern spotted owl detection probabilities: updating the USFWS northern spotted owl survey protocol. 55 p. Unpublished report. On file with: Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331.

Dugger, K.M.; Anthony, R.G.; Lawrence, L.S. 2008. Site occupancy dynamics of northern spotted owls relative to barred owl occurrence and forest habitat characteristics in the southern Cascades of Oregon. 40 p. Unpublished report. On file with: Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331.

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

Fitzgerald, S.D.; Patterson, J.S.; Kiupel, M.; Simmons, H.A.; Grimes, S.D.; Sarver, C.F.; Fulton, R.M.; Steficek, B.M.; Cooley, T.M.; Massey, J.P.; Sikarskie, J.G. 2003. Clinical and pathologic features of West Nile virus infection in native North American owls (Family Strigidae). Avian Diseases. 47: 602–610.

Forsman, E.D.; Anthony, R.G.; Dugger, K.M.; Glenn, E.M.; Franklin, A.B.; White, G.C.; Schwarz, C.J.; Burnham, K.P.; Anderson, D.R.; Nichols, J.D.; Hines, J.E.; Lint, J.B.; Davis, R.J.; Ackers, S.H.; Andrews, L.S.; Biswell, B.L.; Carlson, P.C.; Diller, L.V.; Gremel, S.A.; Herter, D.R.; Higley, J.M.; Horn, R.B.; Reid, J.A.; Rockweit, J.; Schaberl, J.; Snetsinger, T.J.; Sovern, S.G. 2011. Population demography of northern spotted owls. Studies in Avian Biology 40. 106 p.

Franklin, A.B. 2010. Personal communication. Project leader, Ecology of Emerging Viral and Bacterial Diseases in Wildlife Project. USDA/APHIS/WS National Wildlife Research Center, 4101 Laporte Avenue, Fort Collins, CO 80521–2154.

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

Franklin, A.B.; Burnham, K.P.; White, G.C.; Anthony, R.G.; Forsman, E.D.; Schwarz, C.; Nichols, J.D.; Hines, J. 1999. Range-wide status and trends in northern spotted owl populations. 71 p. Unpublished report. On file with: Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, 201 Wagar Building, 1484 Campus Delivery, Fort Collins, Colorado 80523. http://www.reo.gov/monitoring/reports/nso/N110202_3_1999-REPORT-FINAL-DRAFTREV.pdf. (4 January 2011).

Funk, W.C.; Forsman, E.D.; Johnson, M.; Mullins, T.D.; Haig, S.M. 2010. Evidence for recent population bottlenecks in northern spotted owls (*Strix occidentalis caurina*). Conservation Genetics. 11: 1013–1021.

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

Glenn, E.M.; Ripple, W.J. 2004. On using digital maps to assess wildlife habitat. The Wildlife Society Bulletin. 32: 852–860.

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

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

Hanson, C.T.; Odion, D.C.; Dellasala, D.A.; Baker, B.L. 2009. Overestimation of fire risk in the northern spotted owl recovery plan. Conservation Biology. 23: 1314–1319.

Herter, D.R.; Hicks, L.L. 2000. Barred owl and spotted owl populations and habitat in the central Cascade Range of Washington. Journal of Raptor Research. 34: 279–286.

Kennedy, R.E.; Cohen, W.B.; Schroeder, T.A. 2007. Trajectory-based change-detection for automated characterization of forest disturbance dynamics. Remote Sensing of Environment. 110: 370–386.

Kroll, A.J.; Fleming, T.L.; Irwin, L.L. 2010. Site occupancy dynamics of northern spotted owls in the eastern Cascades, Washington, USA, 1990–2003. Journal of Wildlife Management. 74: 1264–1274.

Lint, J.; Noon, B.; Anthony, R.; Forsman, E.; Raphael, M.; Collopy, M.; Starkey, E. 1999. Northern spotted owl effectiveness monitoring plan for the Northwest Forest Plan. Gen. Tech. Rep. PNW-GTR-440. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 43 p.

Lint, J.B., tech. coord. 2005. Northwest Forest Plan–the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 176 p.

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

DRAFT

MacKenzie, D.I.; Nichols, J.D.; Royle, J.A.; Pollock, K.H.; Bailey, L.L.; Hines, J.E. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. New York, NY: Academic Press. 344 p.

Meiman, S.; Anthony, R.; Glenn, E.; Bayless, T.; Ellingson, A.; Hansen, M.C.; Smith, C. 2003. Effects of commercial thinning on home-range and habitat-use patterns of a male northern spotted owl: a case study. Wildlife Society Bulletin. 31(4): 1254–1262.

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

Ohmann, J.L.; Gregory, M.J. 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest-neighbor imputation in coastal Oregon, U.S.A. Canadian Journal of Forest Research. 32: 725–741.

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

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

Pearson, R.R.; Livezey, K.B. 2003. Distribution, numbers, and site characteristics of spotted owls and barred owls in the Cascade Mountains of Washington. Journal of Raptor Research. 37: 265–276.

Schwind, B., comp. 2008. Monitoring trends in burn severity: report on the Pacific Northwest and Pacific Southwest fires (1984 to 2005). Unpublished report. On file with: USDA Forest Service, Remote Sensing Applications Center (RSAC), U.S. Geological Survey, Center for Earth Resources

Observations and Science (EROS). http://mtbs.gov/reports/MTBS_pnw-psw_final.pdf. (4 January 2011).

Sensenig, T.S. 2002. Development, fire history and current and past growth, of old-growth and young-growth forest stands in the Cascade, Siskyou and mid-Coast Mountains of southwestern Oregon. Corvallis, OR: Oregon State University. 180 p. Ph.D. dissertation.

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

Sovern, S.G. 2010. Personal communication. Wildlife biologist, Cle Elum demographic survey crew leader, Pacific Northwest Research Station, USDA Forest Service, 802 West Second Street, Cle Elum, WA 98922

Spies, T.A.; Giesen, T.W.; Swanson, F.J.; Franklin, J.F.; Lach, D.; Johnson, K.N. 2010. Climate change adaptation strategies for federal forests of the Pacific Northwest, USA: ecological, policy, and socio-economic perspectives. Landscape Ecology. 25: 1185–1199.

U.S. Department of Agriculture [USDA]. 2009. Forest Service global change research strategy: 2009–2019. Washington, DC:U.S. Department of Agriculture, Forest Service, Research and Development. 20 p. http://www.fs.fed.us/research/climate/strategy.shtml. (17 December 2010).

U.S. Department of the Interior [USDI]. 2008. Final recovery plan for the northern spotted owl (*Strix occidentalis caurina*). 142 p. On file with: U.S. Department of the Interior, Fish and Wildlife Service, 2600 SE 98th Ave., Ste. 100 Portland, OR. 97266.

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

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	25.4	millimeters (mm)
Inches (in)	2.54	Centimeters (cm)
Feet (ft)	.305	Meters (m)
Miles (mi)	1.609	Kilometers (km)
Square miles (mi^2)	2.59	Square kilometers (km^2)
Acres (ac)	.405	Hectares (ha)
Degrees Fahrenheit (°F)	(F-32)/1.8	Degrees Celsius (°C)

English Equivalents

When you know:	Multiply by:	To find:
millimeters (mm)	.0394	Inches (in)
Centimeters (cm)	.394	Inches (in)
Meters (m)	3.281	Feet (ft)
Kilometers (km)	.6215	Miles (mi)
Square kilometers (km^2)	.386	Square miles (mi^2)
Hectares (ha)	2.47	Acres (ac)
Degrees Celsius (°C)	1.8 C + 32	Degrees Fahrenheit (°F)

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Table A-1–Environmental variables that were used for habitat modeling.

Variable	Description	Units
Diameter diversity index	A measure of the structural diversity of a forest stand based on tree densities in different diameter at breast height (d.b.h.) classes. Calculation procedures are described in appendix 1 of McComb et al. (2002)[a]	Index
Canopy cover of all conifers	Percentage of conifer cover in the canopy as calculated using methods in the Forest Vegetation Simulator	Percentage
Stand height	Average height of dominant and codominant trees	Meters
Mean conifer diameter	Basal area weighted mean diameter of all live conifers	Cm
Density of large conifers	Estimated tree density for all live conifers >= 30 in d.b.h.	Trees/ha
Stand age (no remnants)	Average stand age based on field-recorded ages of dominant and codominant tree species, and excluding remnant trees	Years
Subalpine forest	Stand component of Pacific silver fir (*Abies amabilis*), subalpine fir (*Abies lasiocarpa*), noble fir (*Abies procera*), Shasta red fir (*Abies shastensis*), Alaska cedar (*Chamaecyparis nootkatensis*), Engleman spruce (*Picea engelmannii*), whitebark pine (*Pinus albicaulis*), and mountain hemlock (*Tsuga mertensiana*)	Percentage of total basal area
Pine forest	Stand component of lodgepole pine (*Pinus contorta*), Jeffrey pine (*Pinus jeffreyi*), Bishop pine (*Pinus muricata*), and ponderosa pine(*Pinus ponderosa*)	Percentage of total basal area
Oak woodlands	Stand component of blue oak (*Quercus douglasii*), Oregon white oak (*Quercus garryana*), and California black oak (*Quercus kelloggii*)	Percentage of total basal area
Evergreen hardwoods	Stand component of Pacific madrone (*Arbutus menziesii*), tanoak (*Lithocarpus densiflorus*), California live oak (*Quercus agrifolia*), Canyon live oak (*Quercus chrysolepis*), and California laurel (*Umbellularia californica)*	Percentage of total basal area
Redwood forest	Stand component of redwood (*Sequoia sempervirens*)	Percentage of total basal area

[a] **McComb, W.C.; McGrath, M.T.; Spies, T.A.; Vesely, D. 2002.** Models for mapping potential habitat at landscape scales: an example using northern spotted owls. Forest Science. 48(2): 203–216.

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Figure A-1–Stand structure and age habitat variable correlation matrix with averaged accuracy plot Pearson correlations (SD = standard deviation). These six environmental variables were used in all modeling regions.

Correlation coefficient (mean ±1SD) ⇨		0.739 ±0.065	0.567 ±0.133	0.574 ±0.135	0.585 ±0.081	0.677 ±0.093	0.559 ±0.132
⇩		**Canopy conifer cover**	**Stand height**	**Stand age**	**Large conifer density**	**Diameter diversity index**	**Mean conifer d.b.h.**
0.739 ±0.065	**Canopy conifer cover**	1.000	0.466	0.373	0.532	0.651	0.225
0.567 ±0.133	**Stand height**	0.466	1.000	0.489	0.649	0.633	0.593
0.574 ±0.135	**Stand age**	0.373	0.489	1.000	0.493	0.536	0.437
0.585 ±0.081	**Large conifer density**	0.532	0.649	0.493	1.000	0.659	0.555
0.677 ±0.093	**Diameter diversity index**	0.651	0.633	0.536	0.659	1.000	0.596
0.559 ±0.132	**Mean conifer d.b.h.**	0.225	0.593	0.437	0.555	0.596	1.000

Table A-2–Stand species composition variable groupings, with local scale accuracy assessments (kappa coefficients), used in applicable modeling regions (MR) (GNN DOM SPP = Gradient nearest neighbor, dominant species models).

	GNN DOM SPP	Scientific name	Common name	Washington Coast and Cascades (MR 221)	Washington Eastern Cascades (MR 222)	Oregon Coast Range (MR 223)	Oregon and California Cascades (MR 224)	Oregon and California Klamaths (MR 225)	California Coast (MR 226)	*Average kappa*
Subalpine forest	**ABAM**	*Abies amabilis*	Pacific silver fir	0.53	0.66	n/a	0.59	n/a	n/a	***0.59***
	ABLA	*Abies lasiocarpa*	Subalpine fir	0.48	0.58	n/a	0.39	n/a	n/a	***0.48***
	ABPRSH	*Abies procera/shastensis*	Noble fir/Shasta red fir	0.32	0.29	n/a	0.52	0.47	n/a	***0.40***
	CHNO	*Chamaecyparis nootkatensis*	Alaska cedar	0.28	0.29	n/a	0.19	n/a	n/a	***0.25***
	PIEN	*Picea engelmannii*	Engelmann spruce	0.38	0.38	n/a	0.22	n/a	n/a	***0.33***
	PIAL	*Pinus albicaulis*	Whitebark pine	0.32	0.46	n/a	0.34	n/a	n/a	***0.37***
	TSME	*Tsuga mertensiana*	Mountain hemlock	0.50	0.53	n/a	0.62	0.26	n/a	***0.48***
Pine forest	**PICO**	*Pinus contorta*	Lodgepole pine	n/a	0.26	n/a	0.57	0.28	0.21	***0.33***
	PIJE	*Pinus jeffreyi*	Jeffrey pine	n/a	n/a	n/a	0.27	0.28	0.14	***0.23***
	PIMU	*Pinus muricata*	Bishop pine	n/a	n/a	n/a	n/a	n/a	0.28	***0.28***
	PIPO	*Pinus ponderosa*	Ponderosa pine	n/a	0.62	n/a	0.58	0.34	0.48	***0.51***
Oak woodlands	**QUDO**	*Quercus douglasii*	Blue oak	n/a	n/a	n/a	n/a	0.68	0.41	***0.55***
	QUGA4	*Quercus garryana*	Oregon white oak	n/a	0.56	0.29	0.52	0.35	0.34	***0.41***
	QUKE	*Quercus kelloggii*	California black oak	n/a	n/a	0.27	0.53	0.38	0.52	***0.42***
Evergreen hardwoods	**ARME**	*Arbutus menziesii*	Pacific madrone	n/a	n/a	0.49	0.45	0.43	0.29	***0.41***
	LIDE3	*Lithocarpus densiflorus*	Tanoak	n/a	n/a	0.72	n/a	0.58	0.55	***0.61***
	QUAG	*Quercus agrifolia*	California live oak	n/a	n/a	n/a	n/a	n/a	0.31	***0.31***
	QUCH2	*Quercus chrysolepis*	Canyon live oak	n/a	n/a	0.46	0.17	0.35	0.22	***0.30***
	UMCA	*Umbellularia californica*	California laurel	n/a	n/a	0.43	n/a	0.29	0.30	***0.34***
Redwood forest	**SESE3**	*Sequoia sempervirens*	Redwood	n/a	n/a	n/a	n/a	n/a	0.59	***0.59***

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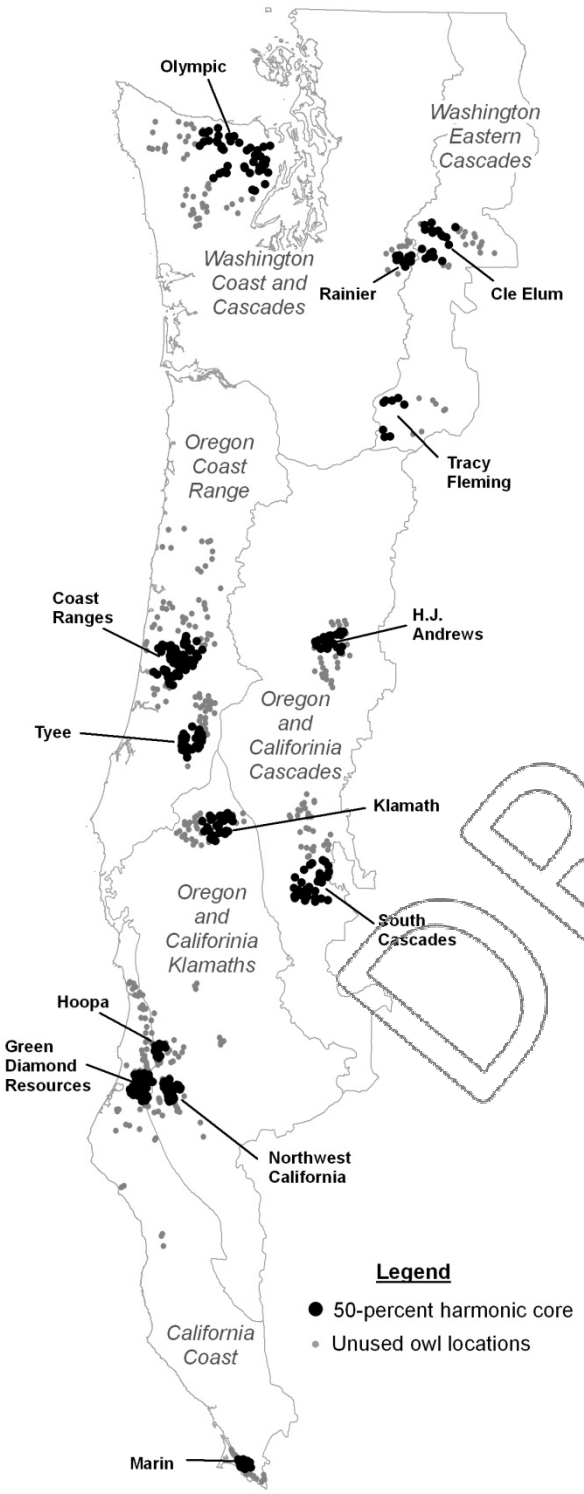

An analysis of nearest neighbor distances (Clark and Evans 1954) was conducted on several demographic study area owl pair location data sets from 1994 through 1997 to correspond with the baseline satellite imagery. The purpose of this analysis was to determine biologically relevant distances for use as minimum distance parameters in the random sampling of owl pair locations from the 10-year report owl presence data set (Davis and Lint 2005). The purpose of this sampling was to provide additional habitat model training data points, outside of demographic study areas, for the habitat modeling described in chapter 3.

Only one location was used to represent each owl territory center. To minimize erroneous results, we only used owl locations from the 50-percent harmonic mean core (Dixon and Chapman 1980) of each study area's data set. This removed outlier locations that would introduce errors in the analysis, especially for study areas that have disjunct areas or survey areas that are separated by several miles. The analysis was conducted in ArcView Spatial Analyst using the Animal Movement extension (v2.0) by Hooge and Eichenlaub (2000).

Results show a decreasing trend in distance between owl pair territories from north to south (fig. B-1). The greatest mean nearest neighbor distance occurs in the Washington eastern Cascades (4.5 km), and the shortest mean distance occurs within the California Coast (1.4 km). The longer distances in the northern portions of the range may relate to more limited prey resources. Likewise the shorter distances in the southern portion of the range may be due to increased prey base diversity and abundance associated with the presence of mast-producing evergreen hardwoods that occur in the coniferous forests of that region.

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Table B-1–Summary statistics from the nearest neighbor analysis for each habitat modeling region.

Modeling region	Data sets used	n[1]	Mean distance	Median distance	StDev
			---------- Kilometers ----------		
Washington Eastern Cascades	Cle Elum and T. Fleming study areas	26	4.5	3.9	2.4
Washington Coast and Cascades	Olympic and Rainier study areas	53	3.6	3.1	1.7
Oregon and California Cascades	H.J. Andrews and Southern Cascades study areas	57	3.1	2.9	1.5
Oregon Coast Range	Oregon Coast Ranges and Tyee study areas	79	2.7	2.5	1.2
Oregon and California Klamaths	Klamath, Northwest California, and Hoopa study areas	70	2.4	2.1	1.1
California Coast	Green Diamond Resources and Marin study areas	77	1.4	1.3	0.6

[1] Only locations from the 50-percent harmonic core of the study area data set were used.

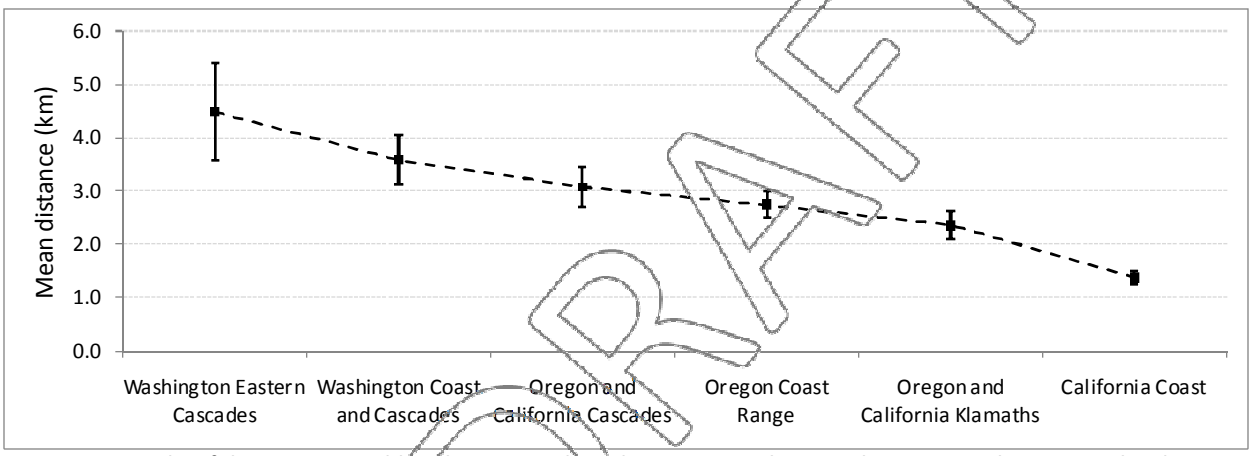

Figure B-1—Results of the nearest neighbor distance analysis showing mean distances between northern spotted owl territory centers with 95-percent confidence intervals for each habitat modeling region.

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References

Clark P.; Evans, F.C. 1954. Distance to the nearest neighbor as a measure of spatial relationship in populations. Ecology. 35: 445–453.

Davis, R.; Lint, J. 2005. Habitat status and trend. In: Lint, J., tech. coord. Northwest Forest Plan–the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 21–82.

Dixon, K.R.; Chapman, J.A. 1980. Harmonic mean measure of animal activity areas. Ecology. 61: 1040–1044.

Hooge P.N.; Eichenlaub, B. 2000. Animal movement extension to ArcView, 2.0. Anchorage, AK: Alaska Science Center—Biological Science Office, U.S. Geological Survey.

Table C-1–Results of the MaxEnt bootstrapped replicate habitat suitability models (10 replicates for each modeling region) showing mean percentage for environmental variable model contributions and changes in model test gain associated with inclusion or exclusion of specific environmental variables (d.b.h. = diameter at breast height)

Modeling region	Stand structure and age variables						Species composition variables					Highest gain by itself	Lowered gain the most when removed
	Conifer cover	Mean conifer d.b.h.	Large conifer density	Diameter diversity index	Stand height	Stand age	Subalpine forest	Pine forest	Oak woodland	Evergreen hardwood	Redwood forest		
	Percent contribution												
Washington Coast and Cascades	21.0	1.7	35.2	7.8	3.2	20.2	10.8	n/a	n/a	n/a	n/a	Diameter diversity index	Subalpine forest
Washington Eastern Cascades	34.6	0.5	11.0	6.0	7.4	2.7	31.8	4.9	1.3	n/a	n/a	Diameter diversity index	Subalpine forest
Oregon Coast Range	13.3	4.6	58.1	5.4	4.6	11.2	n/a	n/a	0.9	1.9	n/a	Stand age	Conifer cover
Oregon and California Cascades	15.6	5.2	33.4	21.7	3.8	4.7	6.3	5.5	1.1	2.6	n/a	Diameter diversity index	Subalpine forest
Oregon and California Klamaths	19.1	1.8	15.0	14.1	8.9	5.1	2.4	18.3	4.4	10.9	n/a	Diameter diversity index	Pine forest
California Coast	43.7	7.1	3.0	2.6	6.3	2.3	n/a	5.7	13.0	10.2	6.2	Conifer cover	Evergreen hardwood

Note: MaxEnt replicate variable response curve information for each modeling region is available upon request.

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The following sections in this appendix summarize the MaxEnt modeling regions and the modeling results of the bootstrapped replicates. Model region descriptions are largely based on information from the Landscape Ecology Modeling, Mapping and Analysis (LEMMA) Web site (http://www.fsl.orst.edu/lemma/main.php?project=nwfp&id=home).

Washington Coast and Cascades Modeling Region (MR 221)

This modeling region conforms to the Washington Douglas-fir ecological region used in the demographic meta-analyses, and contains the Olympic Peninsula and the Rainier demographic study areas. It encompasses the Washington Olympic Peninsula, Washington Western Lowlands, and the Washington Western Cascades physiographic provinces. The Olympic Peninsula is dominated by moist, productive coniferous rain forest on the western slope, and drier Douglas-fir forest in the rain shadow on the eastern slope. Wildfire frequency is very low. Federally managed lands occupy the interior half of the province, the core being Olympic National Park girded by the Olympic National Forest. Most of the Western Lowlands are in private and state ownership, with extensive urban and agricultural areas. It is dominated by wide, glaciated valleys, except for the Willapa Hills in the coastal section. Lowland coniferous forest, deciduous forest, and native prairie were its natural dominant vegetation types. The Western Cascades lower elevation forests are dominated by Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) grading into Pacific silver fir (*Abies procera*)at midelevations, and mountain hemlock (*Tsuga mertensiana*), and subalpine vegetation at higher elevations. Wildfire frequencies are low to moderate. About two-thirds of the province is administered by federal agencies.

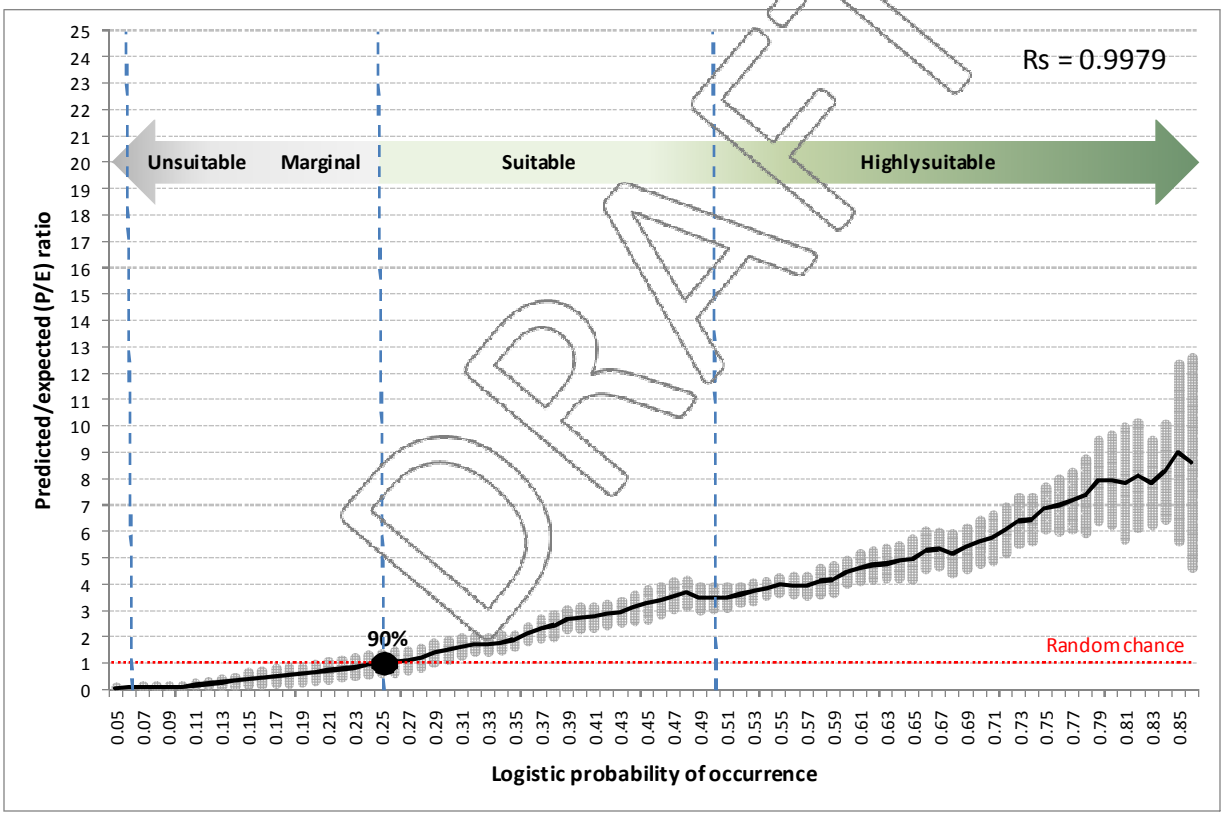

Figure C-2–The mean predicted vs. expected curve (solid black line) from the model replicates, showing 95-percent confidence intervals (gray-shaded vertical bars) for the Washington Coast and Cascades modeling region. The logistic thresholds used to define the four-class habitat map are represented by vertical blue-dashed lines. The P/E = 1 threshold is where the curve crosses the random chance line (red-dashed line). The solid black dot represents the 10-percentile threshold (see fig. C-2 below) indicating where 90 percent of the training data (owl pair site centers) occured above that threshold. The mean Spearman rank correlation (Rs) is shown in the upper right-hand corner. See Hirzel et al. (2006) for more information.

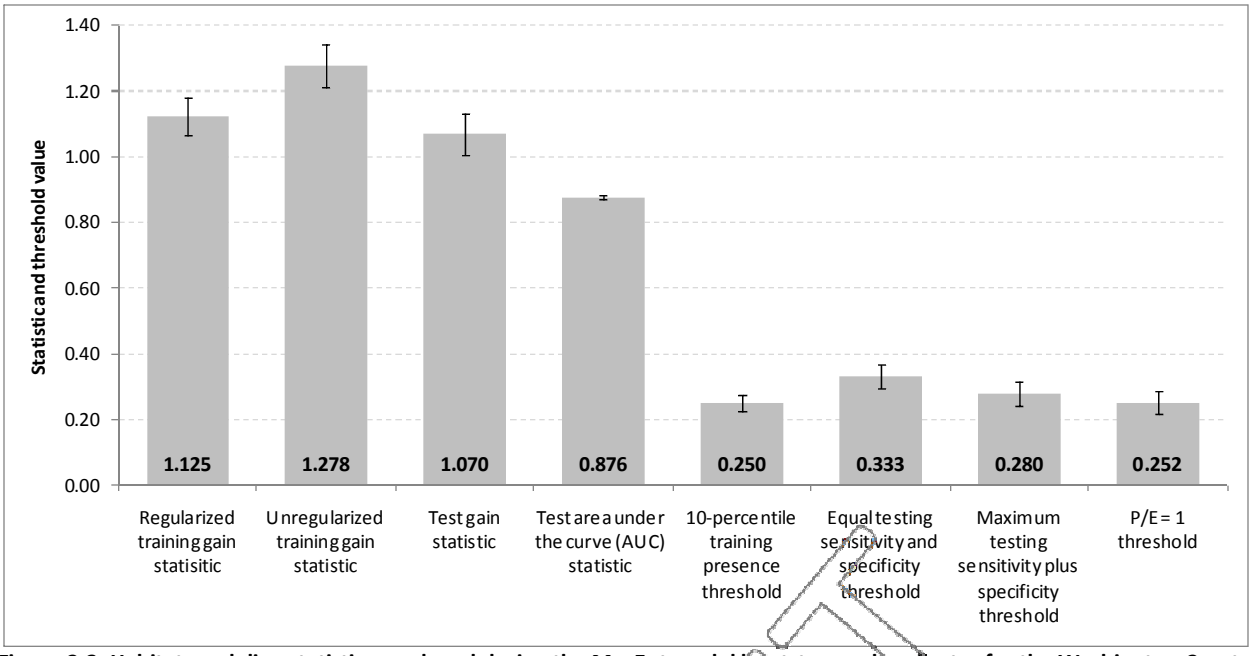

Figure C-3–Habitat modeling statistics produced during the MaxEnt model bootstrapped replicates for the Washington Coast and Cascades modeling region. Bars represent the mean statistic value and error bars show the 95-percent confidence intervals. The first four bars represent model fit and discrimination statistics; the last four bars are common "thresholds" used to classify continuous habitat suitability models into binary maps of "not-suitable" and "suitable" habitat.

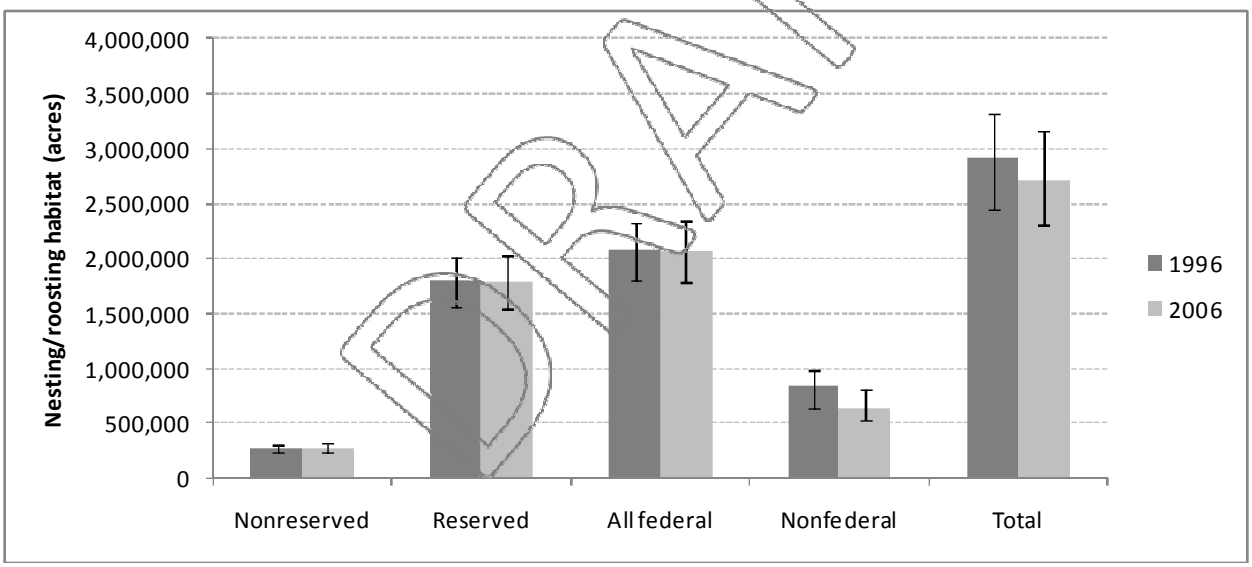

Figure C-4–Bookend habitat model area of suitable nesting/roosting habitat for northern spotted owls for the Washington Coast and Cascades modeling region. The bars represent the mean estimate of suitable habitat, and error bars show the 95-percent confidence intervals. This histogram shows net change (losses and gains) between 1996 and 2006.

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Washington Eastern Cascades Modeling Region (MR 222)

This modeling region conforms to the Washington Mixed-Conifer ecological region used in the demographic meta-analyses, and contains the Cle Elum demographic study area. It also conforms to the Washington Eastern Cascades physiographic province. The slopes of the Washington Eastern Cascades province are dominated by mixed-conifer forest and ponderosa pine (*Pinus ponderosa*) forest at lower to midelevations, and by true fir (*Abies* spp.) and mountain hemlock (*Tsuga mertensiana*) at higher elevations. Forest productivity is low in places owing to poor soils and high elevations. Historically, fire frequencies were high (≤35-year fire return intervals). Intensive fire suppression practices since the latter half of the 20th century have resulted in areas with significant accumulations of fuel and shifts in species composition and stand structure. About two-thirds of the area is federally managed.

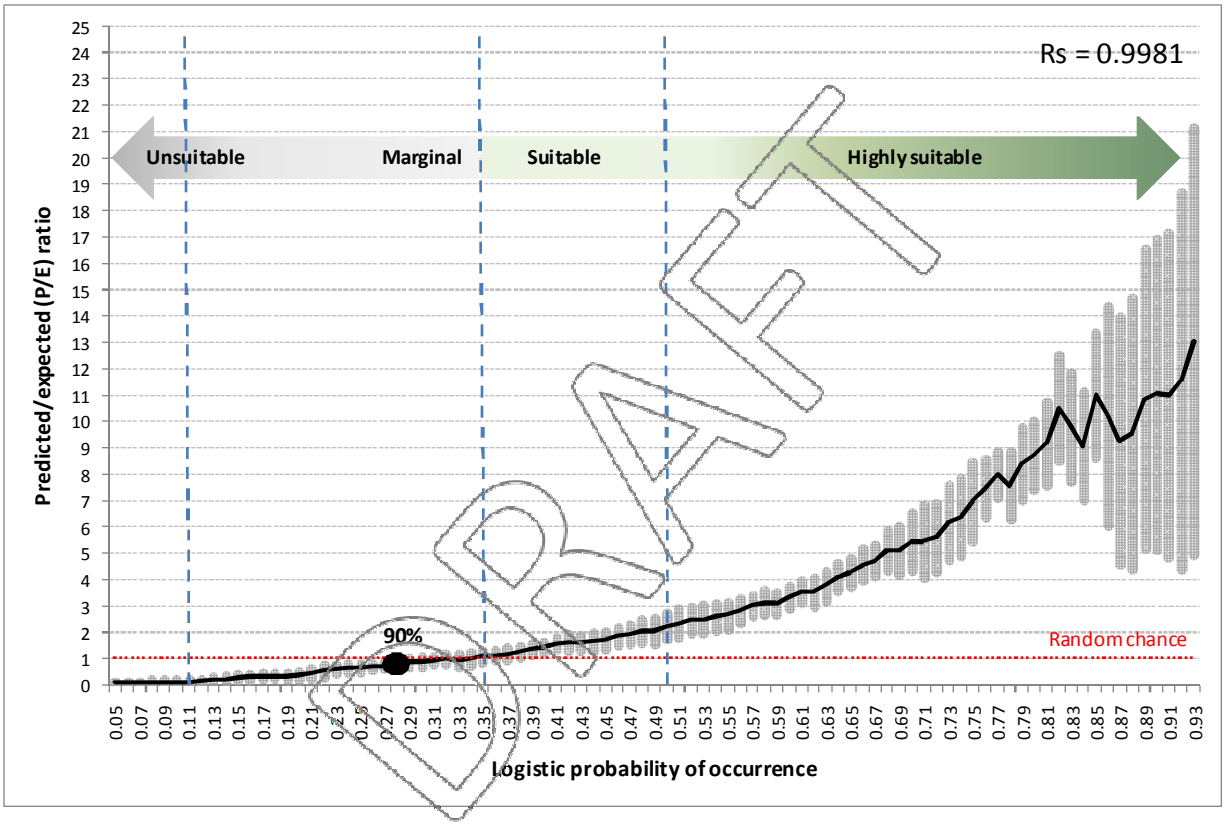

Figure C-5–The mean predicted vs. expected curve (solid black line) from the model replicates, showing 95-percent confidence intervals (gray-shaded vertical bars) for the Washington Eastern Cascades modeling region. The logistic thresholds used to define the four-class habitat map are represented by vertical blue-dashed lines. The P/E = 1 threshold is where the curve crosses the random chance line (red-dashed line). The solid black dot represents the 10-percentile threshold (see fig. C-5 below) indicating where 90 percent of the training data (owl pair site centers) occured above that threshold. The mean Spearman rank correlation (Rs) is shown in the upper right-hand corner. See Hirzel et al. (2006) for more information.

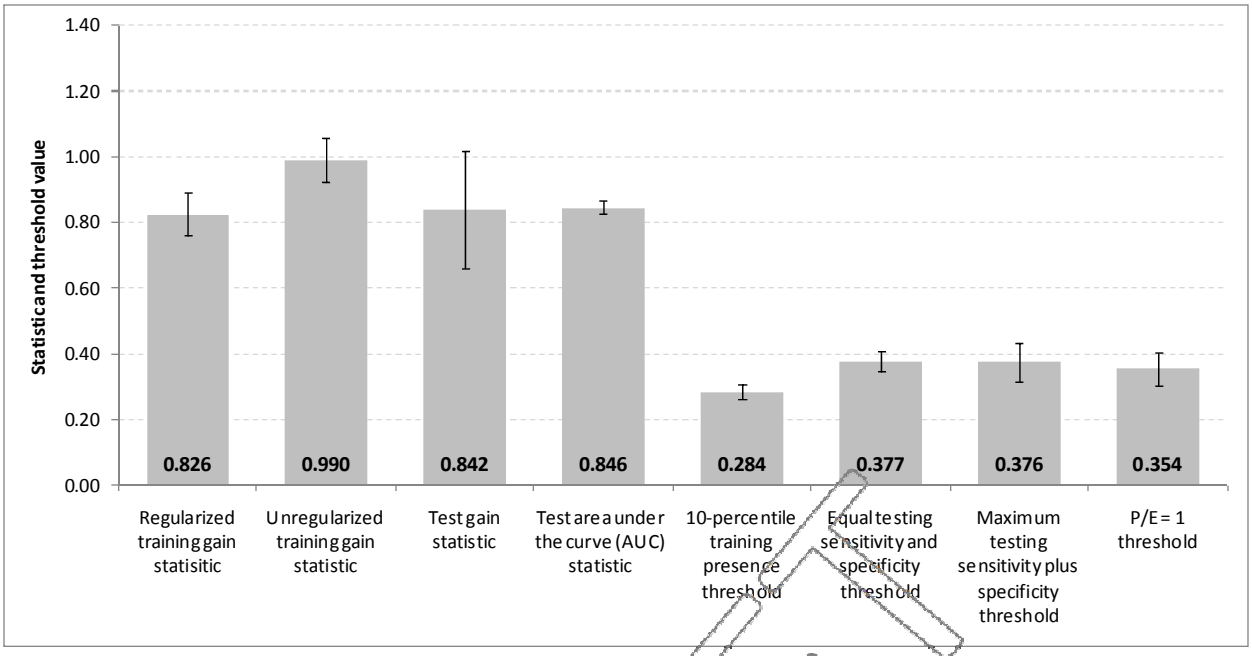

Figure C-6–Habitat modeling statistics produced during the MaxEnt model bootstrapped replicates for the Washington Eastern Cascades modeling region. Bars represent the mean statistic value and error bars show the 95-percent confidence intervals. The first four bars represent model fit and discrimination statistics; the last four bars are common "thresholds" used to classify continuous habitat suitability models into binary maps of "not-suitable" and "suitable" habitat.

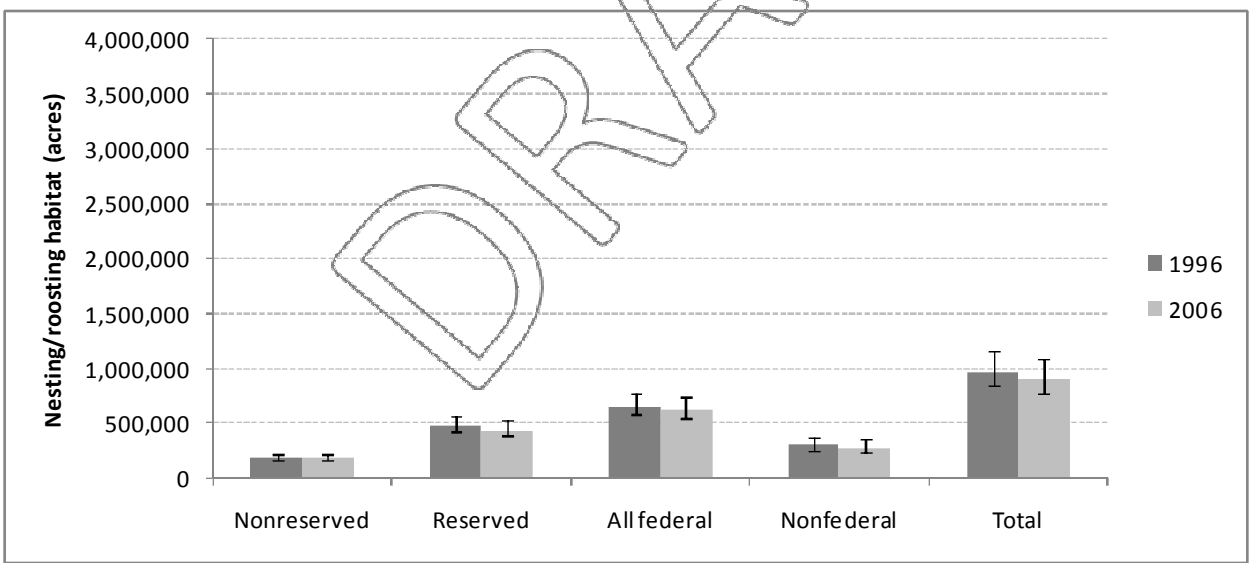

Figure C-7–Bookend habitat model area of suitable nesting/roosting habitat for northern spotted owls for the Washington Eastern Cascades modeling region. The bars represent the mean estimate of suitable habitat, and error bars show the 95-percent confidence intervals. This histogram shows net change (losses and gains) between 1996 and 2006.

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Oregon Coast Range Modeling Region (MR 223)

This modeling region conforms to the Oregon Coastal Douglas-fir ecological region used in the demographic meta-analyses, and contains the Oregon Coast Ranges and Tyee demographic study areas. It contains the Oregon Coast physiographic province, and also the Willamette Valley physiographic province west of the Willamette River, as well as the coastal margins of the Oregon Klamath physiographic province. The moist, productive forests in this modeling region are dominated by Douglas-fir, western hemlock, and western redcedar (*Thuja plicata*). The Forest Service and Bureau of Land Management together manage about one-quarter of the land in the region. Older forests are highly fragmented, largely as a result of infrequent but very large wildfires in the 1800s and 1900s, and heavy cutting, as well as checkerboard ownership patterns. Most of the Willamette Valley is in private ownership and includes extensive urban and agricultural areas. Lowland coniferous forest, deciduous forest, and native prairie were the natural dominant vegetation types.

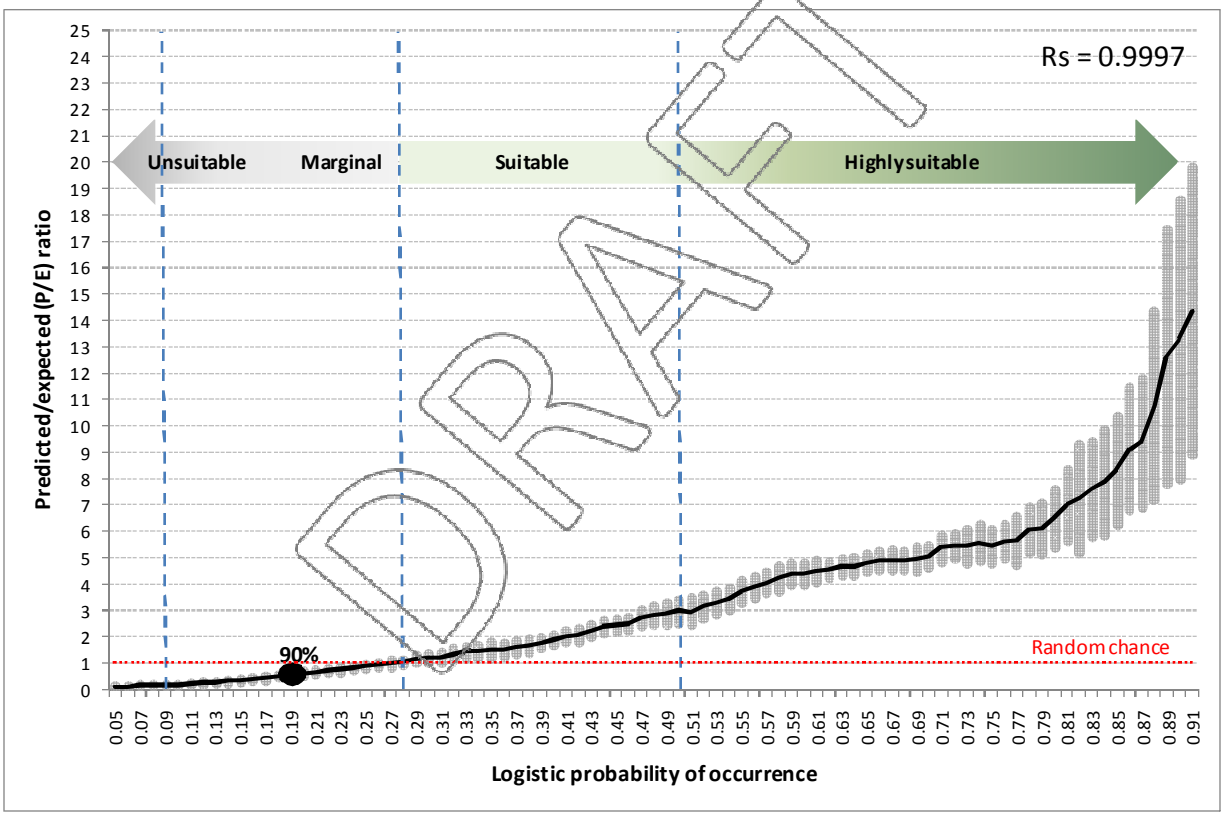

Figure C-8–The mean predicted vs. expected curve (solid black line) from the model replicates, showing 95-percent confidence intervals (gray-shaded vertical bars) for the Oregon Coast Range modeling region. The logistic thresholds used to define the four-class habitat map are represented by vertical blue-dashed lines. The P/E = 1 threshold is where the curve crosses the random chance line (red-dashed line). The solid black dot represents the 10-percentile threshold (see fig. C-8 below) indicating where 90 percent of the training data (owl pair site centers) occured above that threshold. The mean Spearman rank correlation (Rs) is shown in the upper right-hand corner. See Hirzel et al. (2006) for more information.

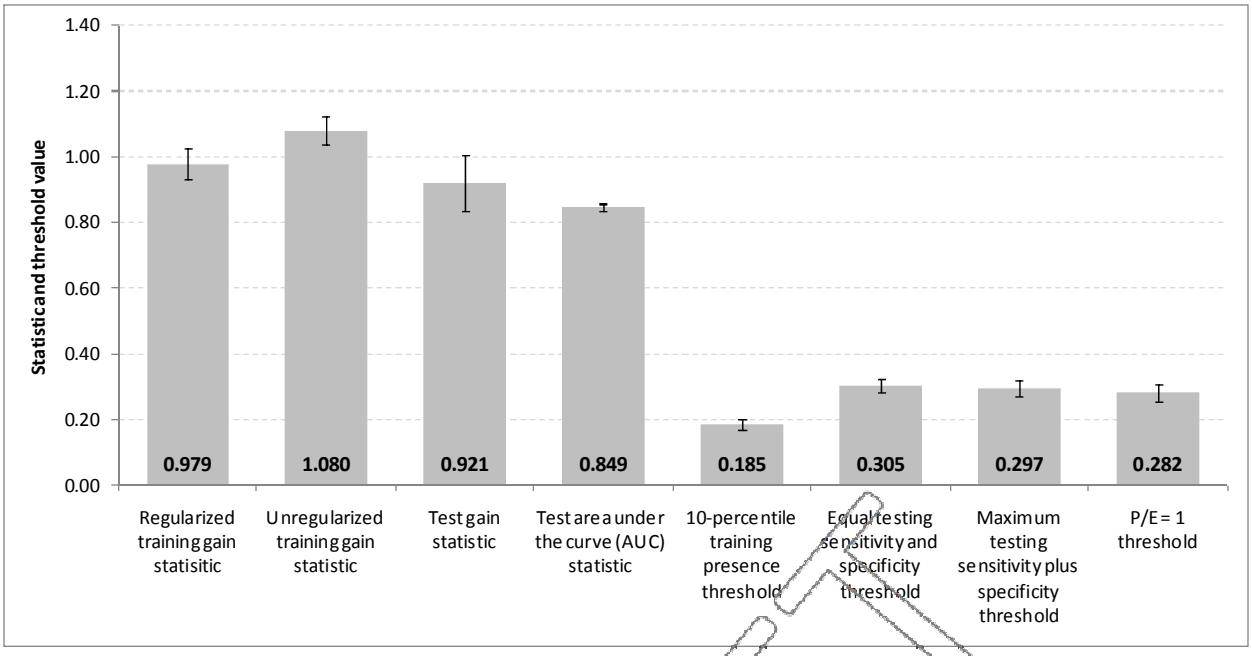

Figure C-9–Habitat modeling statistics produced during the MaxEnt model bootstrapped replicates for the Oregon Coast Range modeling region. Bars represent the mean statistic value and error bars show the 95-percent confidence intervals. The first four bars represent model fit and discrimination statistics; the last four bars are common "thresholds" used to classify continuous habitat suitability models into binary maps of "not-suitable" and "suitable" habitat.

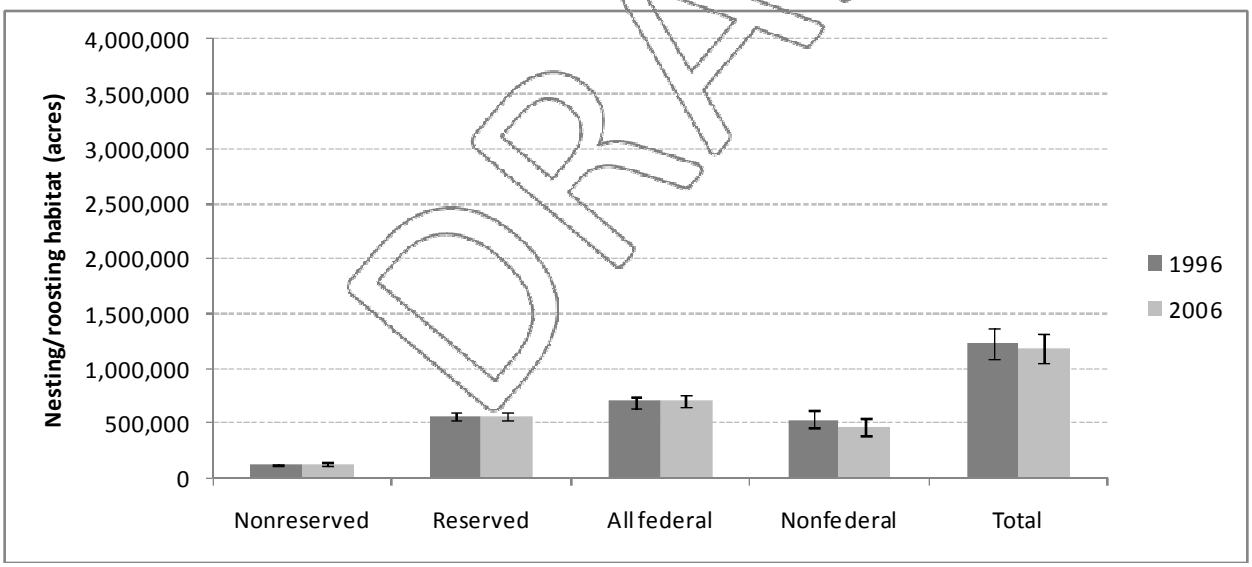

Figure C-10–Bookend habitat model area of suitable nesting/roosting habitat for northern spotted owls for the Oregon Coast Range modeling region. The bars represent the mean estimate of suitable habitat, and error bars show the 95-percent confidence intervals. This histogram shows net change (losses and gains) between 1996 and 2006.

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Oregon and California Cascades Modeling Region (MR 224)

This modeling region conforms to the Oregon Cascades Douglas-fir ecological region used in the meta-analyses, and contains the H.J. Andrews and South Cascades demographic study areas. It encompasses the east and west Cascades provinces in Oregon and portions of the California Cascades province as delineated along level III ecoregion lines. Although there are differences between the east and west Cascades, our decision to lump them into one modeling region was based on how the east Cascades province was originally drawn to define the eastern margin of the owl's range, which extends into the larger eastern Cascades ecoregion (as delineated by EPA). This thin delineation represents the ecotone between the east and west Cascades, and not the entire east Cascades province. On the west slope, Douglas-fir and western hemlock give way to Pacific silver fir at mid-elevations, and mountain hemlock and subalpine fir at high elevations. The east slope is covered by mixed-conifer and ponderosa pine forest at lower elevations, and true firs and mountain hemlock at higher elevations. The southern portion is mixed-conifer and pine forests in fire-adapted landscapes. Fire frequencies range from low to high along a north-to-south moisture gradient. Fire suppression has resulted in shifts in species composition and stand structure. About two-thirds of the land is administered by federal agencies.

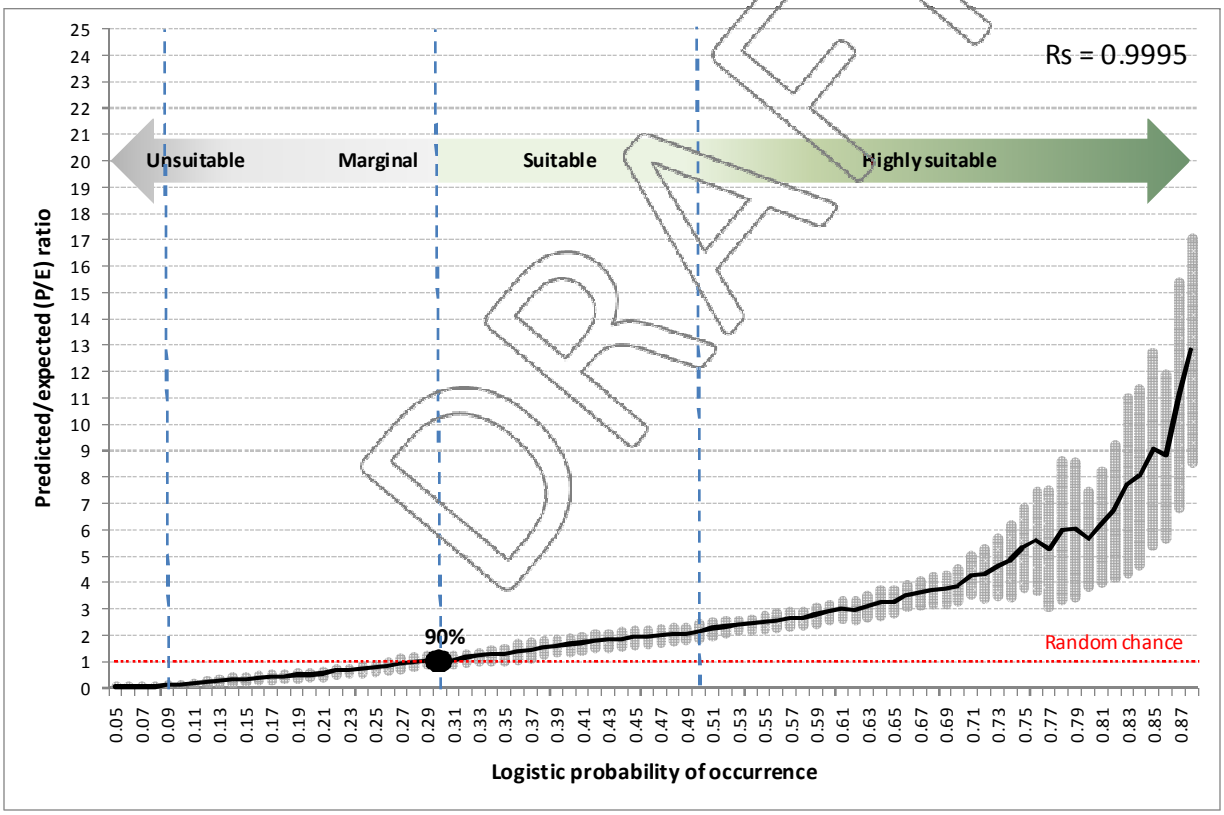

Figure C-11–The mean predicted vs. expected curve (solid black line) from the model replicates, showing 95-percent confidence intervals (gray-shaded vertical bars) for the Oregon and California Cascades modeling region. The logistic thresholds used to define the four-class habitat map are represented by vertical blue-dashed lines. The P/E = 1 threshold is where the curve crosses the random chance line (red-dashed line). The solid black dot represents the 10-percentile threshold (see fig. C-11 below) indicating where 90 percent of the training data (owl pair site centers) occured above that threshold. The mean Spearman rank correlation (Rs) is shown in the upper right-hand corner. See Hirzel et al. (2006) for more information.

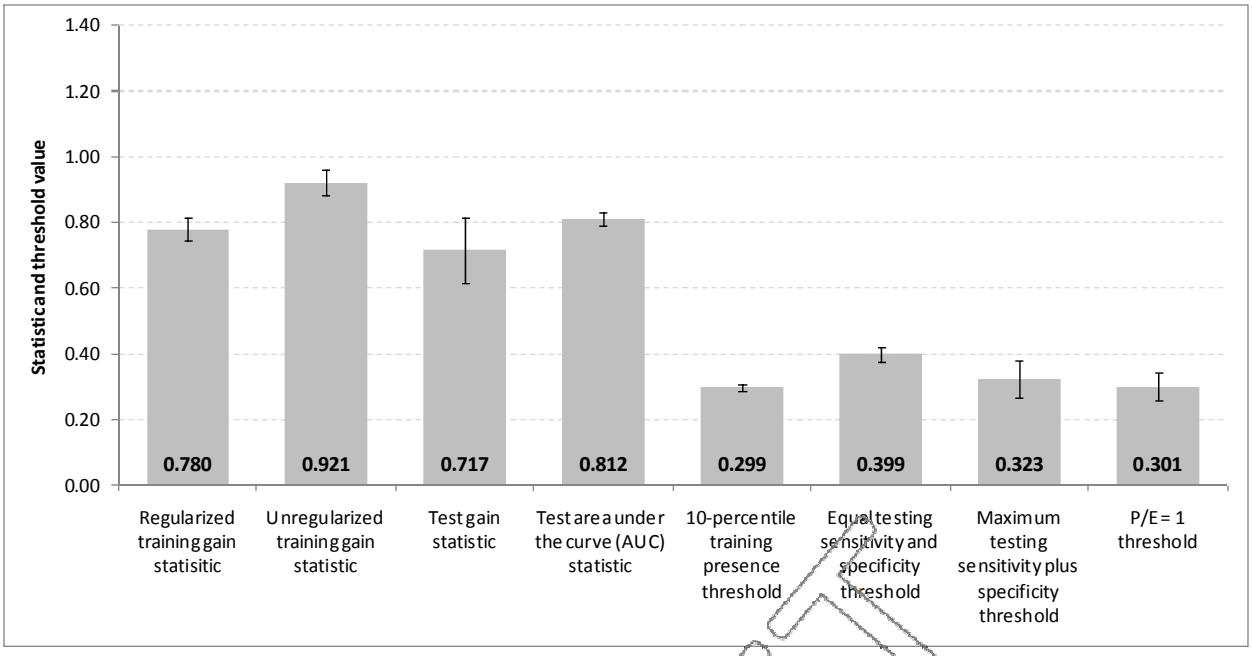

Figure C-12–Habitat modeling statistics produced during the MaxEnt model bootstrapped replicates for the Oregon and California Cascades modeling region. Bars represent the mean statistic value and error bars show the 95-percent confidence intervals. The first four bars represent model fit and discrimination statistics; the last four bars are common "thresholds" used to classify continuous habitat suitability models into binary maps of "not-suitable" and "suitable" habitat.

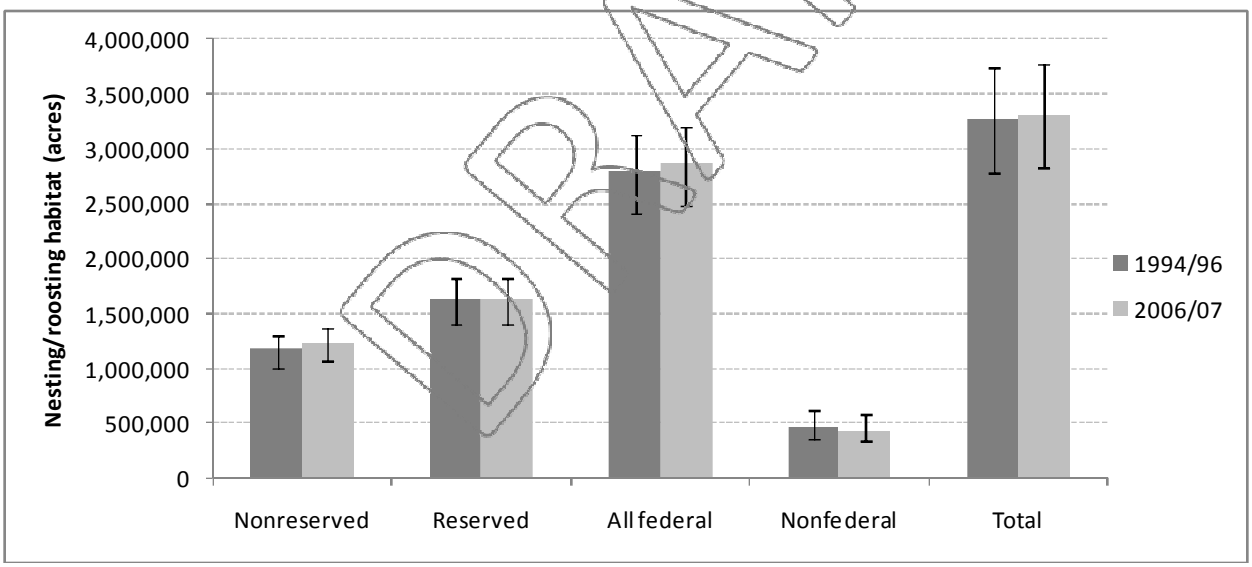

Figure C-13–Bookend habitat model area of suitable nesting/roosting habitat for northern spotted owls for the Oregon and California Cascades modeling region. The bars represent the mean estimate of suitable habitat, and error bars show the 95-percent confidence intervals. This histogram shows net change (losses and gains) between 1994/96 and 2006/07.

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Oregon and California Klamaths Modeling Region (MR 225)

This modeling region conforms to the Oregon/California Mixed-Conifer ecological region used in the demographic meta-analyses, and contains the Klamath and Northwest California demographic study areas. It encompasses the Klamath physiographic provinces of Oregon and California. It is influenced by unique geologic conditions. In many areas, serpentine soils formed by the accretion of rocks onto the continent control the native vegetation, which is dominated by mixed-conifer and mixed conifer and hardwood forest such as Douglas-fir mixed with tanoak (*Lithocarpus densiflorus*), and Pacific madrone (*Arbutus menziesii*). The region is characterized by historically high fire frequencies (≤35-year fire-return intervals), and fire suppression has resulted in areas with significant accumulations of fuel, shifts in species composition, and changes in stand structure. Forests are highly fragmented as a result of dry climate, poor soils, and past harvest practices, as well as ownership patterns, especially in areas of "checkerboard" ownership. Slightly over half of the province in Oregon is federally managed. In California National forests cover about three-quarters of the region.

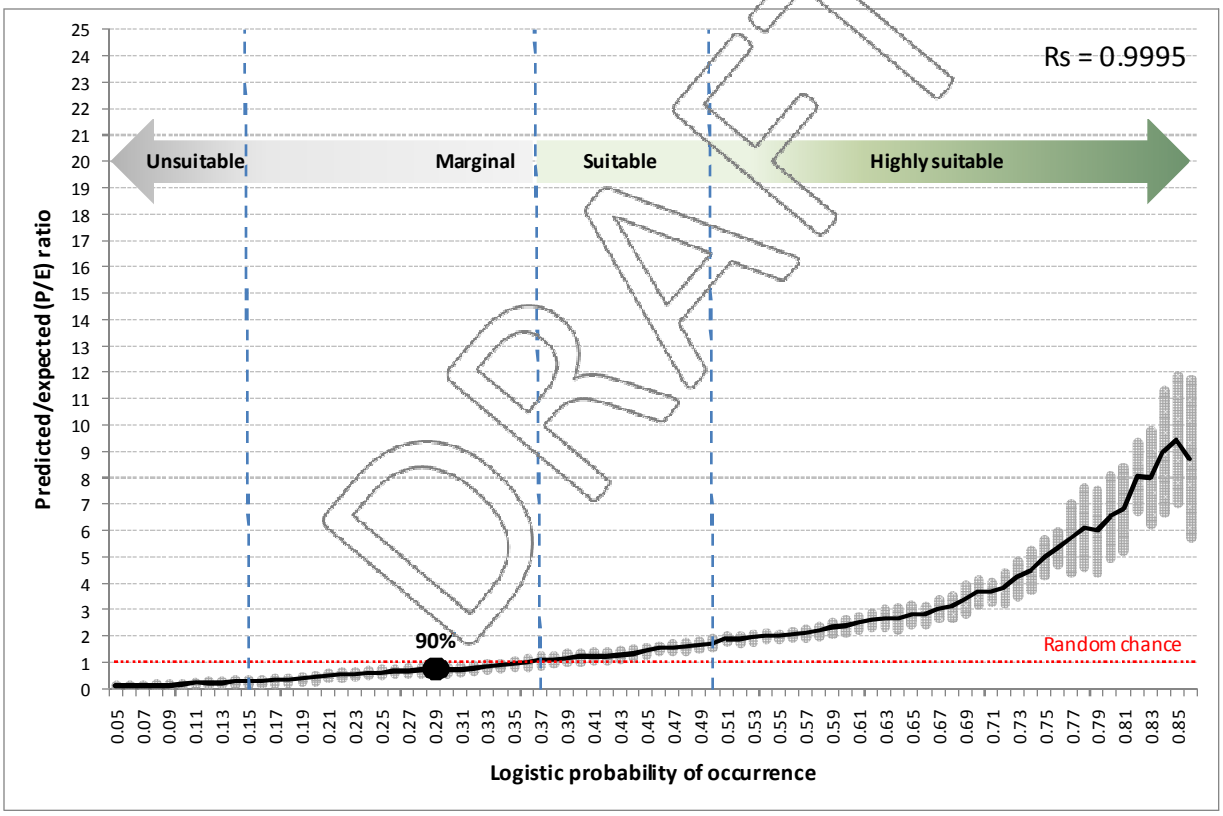

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Figure C-14–The mean predicted vs. expected curve (solid black line) from the model replicates, showing 95-percent confidence intervals (gray-shaded vertical bars) for the Oregon and California Klamaths modeling region. The logistic thresholds used to define the four-class habitat map are represented by vertical blue-dashed lines. The P/E = 1 threshold is where the curve crosses the random chance line (red-dashed line). The solid black dot represents the 10-percentile threshold (see fig. C-14 below) indicating where 90 percent of the training data (owl pair site centers) occured above that threshold. The mean Spearman rank correlation (Rs) is shown in the upper right-hand corner. See Hirzel et al. (2006) for more information.

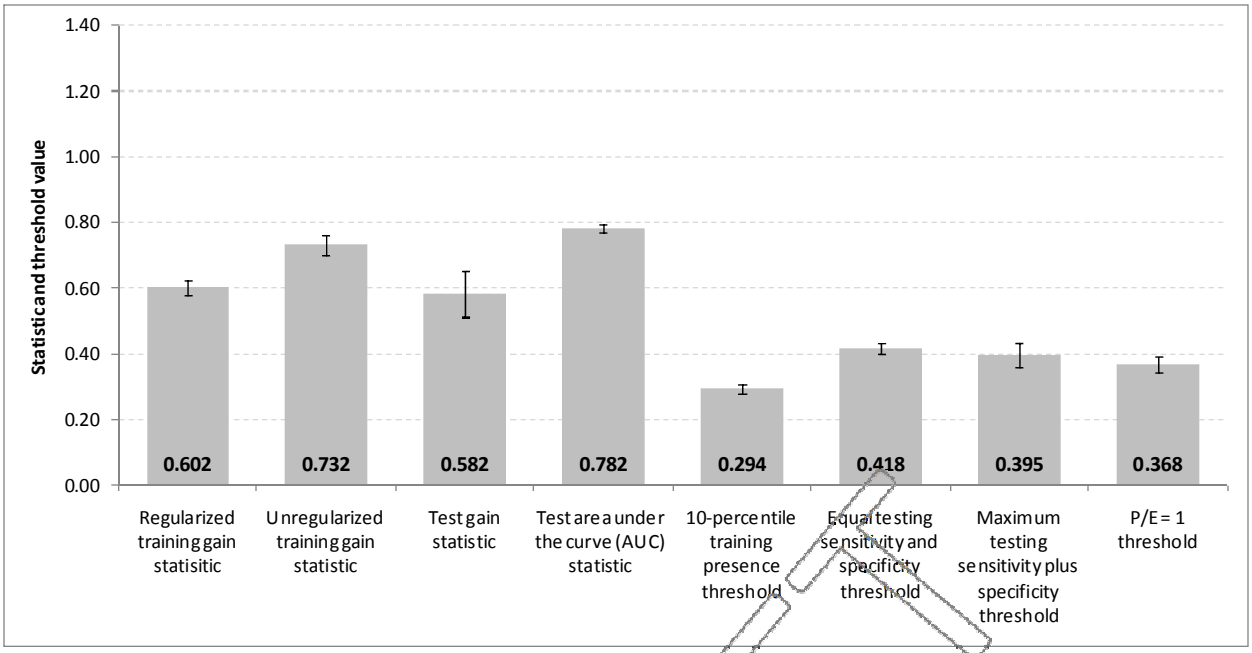

Figure C-15–Habitat modeling statistics produced during the MaxEnt model bootstrapped replicates for the Oregon and California Klamaths modeling region. Bars represent the mean statistic value and error bars show the 95-percent confidence intervals. The first four bars represent model fit and discrimination statistics; the last four bars are common "thresholds" used to classify continuous habitat suitability models into binary maps of "not-suitable" and "suitable" habitat.

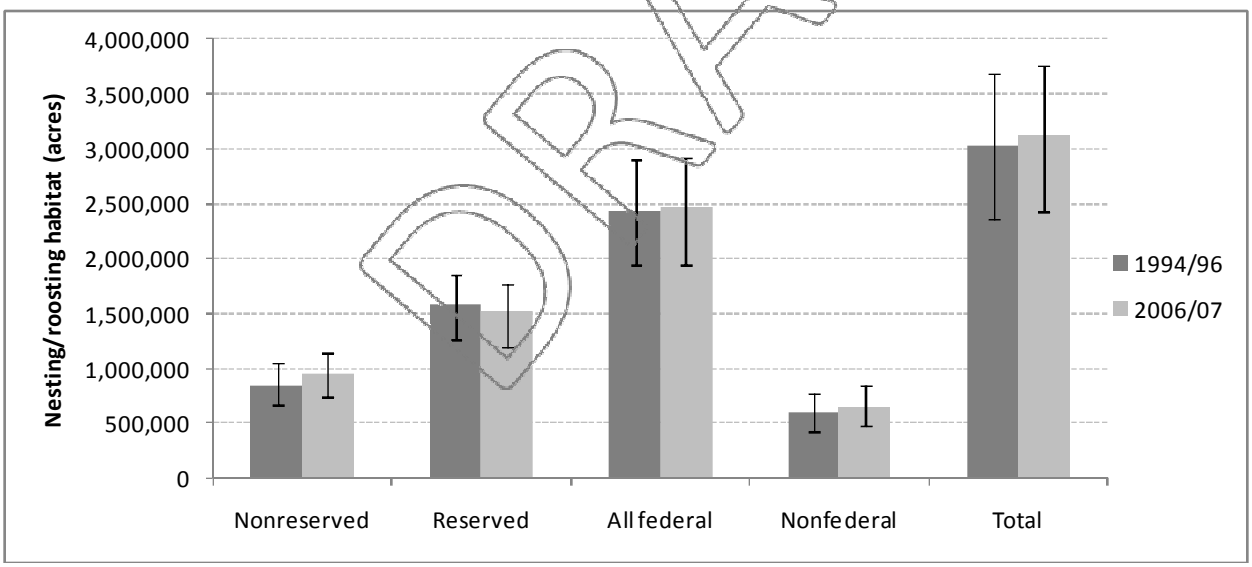

Figure C-16–Bookend habitat model area of suitable nesting/roosting habitat for northern spotted owls for Oregon and California Klamaths modeling region. The bars represent the mean estimate of suitable habitat, and error bars show the 95-percent confidence intervals. This histogram shows net change (losses and gains) between 1994/96 and 2006/07.

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California Coast Modeling Region (MR 226)

This modeling region conforms to the California Coast ecological region used in demographic meta-analyses, and contains the independently operated Green Diamond Resources and Hoopa Reservation demographic study areas. It conforms to the California Coast Range physiographic province, extending slightly into coastal Oregon Klamath physiographic province to encompass the coastal redwood forests in that area. Moist, productive forests in the California Coast region are dominated by Douglas-fir and western hemlock, and contain most of the coastal redwood forests. The southeastern portion of this modeling region falls within the Central California Chaparral and Oak Woodlands ecoregion. Only a small proportion of the California Coast region is administered by federal agencies.

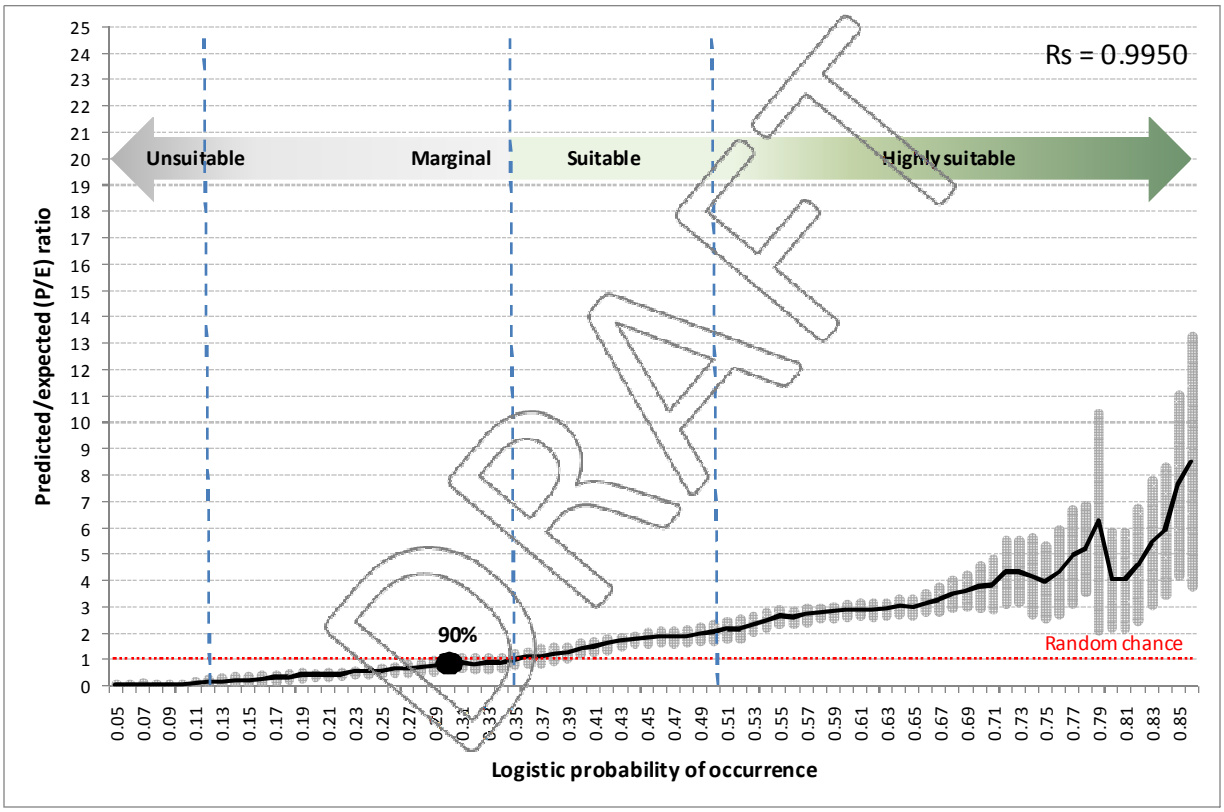

Figure C-17–The mean predicted vs. expected curve (solid black line) from the model replicates, showing 95-percent confidence intervals (gray-shaded vertical bars) for the California Coast modeling region. The logistic thresholds used to define the four-class habitat map are represented by vertical blue-dashed lines. The P/E = 1 threshold is where the curve crosses the random chance line (red-dashed line). The solid black dot represents the 10-percentile threshold (see fig. C-17 below) indicating where 90 percent of the training data (owl pair site centers) occured above that threshold. The mean Spearman rank correlation (Rs) is shown in the upper right-hand corner. See Hirzel et al. (2006) for more information.

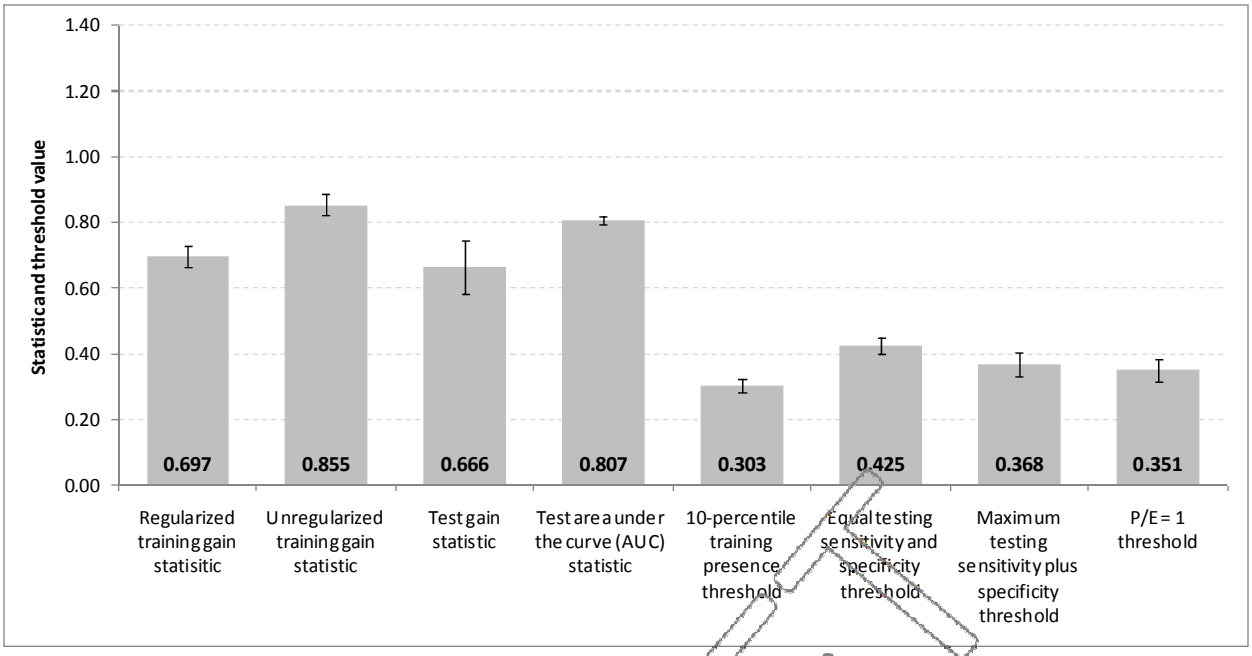

Figure C-18–Habitat modeling statistics produced during the MaxEnt model bootstrapped replicates for the California Coast modeling region. Bars represent the mean statistic value and error bars show the 95-percent confidence intervals. The first four bars represent model fit and discrimination statistics; the last four bars are common "thresholds" used to classify continuous habitat suitability models into binary maps of "not-suitable" and "suitable" habitat.

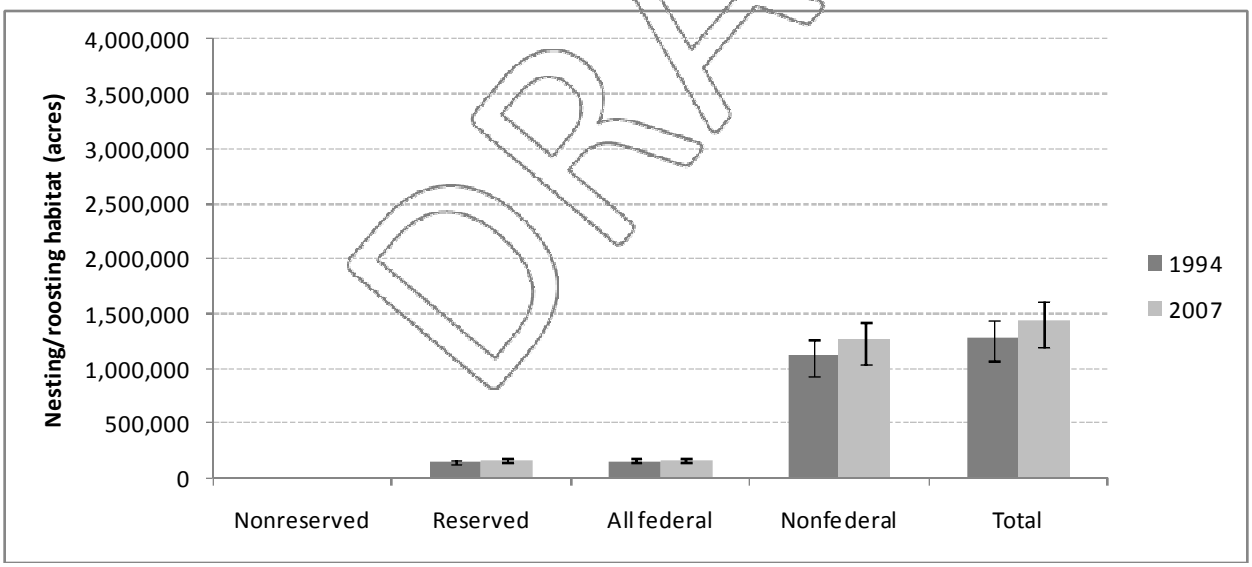

Figure C-19–Bookend habitat model area of suitable nesting/roosting habitat for northern spotted owls for the California Coast modeling region. The bars represent the mean estimate of suitable habitat, and error bars show the 95-percent confidence intervals. This histogram shows net change (losses and gains) between 1994 and 2007.

References

Hirzel, A.H.; Le Lay, G.; Helfer, V.; Randin, C.; Guisan, A. 2006. Evaluating the ability of habitat suitability models to predict species presences. Ecological Modelling. 199: 142–152.

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Table D-1–Estimates of nesting/roosting habitat loss on federal reserved lands using LandTrendr change-detection data.

Physiographic province	1994/96	Harvest	Insects and disease	Wildfire	Gross loss	2006/07	Percent change
	---------- acres ----------						--- percent ---
Washington:							
Olympic Peninsula	729,500	-300	0	-200	-500	729,000	-0.1
Western Lowlands	24,700	-400	0	0	-400	24,300	-1.6
Western Cascades	1,035,100	-2,400	-400	-700	-3,500	1,031,600	-0.3
Eastern Cascades	484,900	-4,800	-1,800	-15,900	-22,500	462,400	-4.6
State total:	**2,274,200**	**-7,900**	**-2,200**	**-16,800**	**-26,900**	**2,247,300**	**-1.2**
Oregon:							
Coast Range	495,700	-1,300	0	0	-1,300	494,400	-0.3
Willamette Valley	700	0	0	0	0	700	0.0
Western Cascades	1,302,200	-1,900	-600	-24,500	-27,000	1,275,200	-2.1
Klamath	636,200	-1,600	-200	-85,000	-86,800	549,400	-13.6
Eastern Cascades	264,800	-1,300	-1,700	-13,300	-16,300	248,500	-6.2
State total:	**2,699,600**	**-6,100**	**-2,500**	**-122,800**	**-131,400**	**2,568,200**	**-4.9**
California:							
Coast Range	135,200	-300	-100	-1,900	-2,300	132,900	-1.7
Klamath	975,500	-1,400	-1,500	-61,700	-64,600	910,900	-6.6
Cascades	103,300	-800	0	-800	-1,600	101,700	-1.5
State total:	**1,214,000**	**-2,500**	**-1,600**	**-64,400**	**-68,500**	**1,145,500**	**-5.6**
Range total:	**6,187,800**	**-16,500**	**-6,300**	**-204,000**	**-226,800**	**5,961,000**	**-3.7**

Note: Acres are rounded to the nearest 100 acres.

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Table D-2–Estimates of nesting/roosting habitat loss on federal nonreserved lands using LandTrendr change-detection data.

Physiographic province	1994/96	Harvest	Insects and disease	Wildfire	Gross loss	2006/07	Percent change
	---------- acres ----------						--- percent ---
Washington:							
Olympic Peninsula	33,600	-200	0	0	-200	33,400	-0.6
Western Lowlands	0	0	0	0	0	0	0.0
Western Cascades	247,900	-1,300	0	0	-1,300	246,600	-0.5
Eastern Cascades	188,700	-3,300	-200	-4,100	-7,600	181,100	-4.0
State total:	**470,200**	**-4,800**	**-200**	**-4,100**	**-9,100**	**461,100**	**-1.9**
Oregon:							
Coast Range	115,400	-2,000	0	0	-2,000	113,400	-1.7
Willamette Valley	2,700	-100	0	0	-100	2,600	-3.7
Western Cascades	956,500	-12,000	-500	-4,400	-16,900	939,600	-1.8
Klamath	348,800	-5,200	-100	-8,600	-13,900	334,900	-4.0
Eastern Cascades	138,000	-4,500	-600	-4,500	-9,600	128,400	-7.0
State total:	**1,561,400**	**-23,800**	**-1,200**	**-17,500**	**-42,500**	**1,518,900**	**-2.7**
California:							
Coast Range	10,300	0	0	-200	-200	10,100	-1.9
Klamath	514,200	-3,000	-100	-9,900	-13,000	501,200	-2.5
Cascades	109,900	-5,700	-300	-1,000	-7,000	102,900	-6.4
State total:	**634,400**	**-8,700**	**-400**	**-11,100**	**-20,200**	**614,200**	**-3.2**
Range total:	**2,666,000**	**-37,300**	**-1,800**	**-32,700**	**-71,800**	**2,594,200**	**-2.7**

Note: Acres are rounded to the nearest 100 acres.

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Table D-3–Estimates of nesting/roosting habitat loss on all federal lands using LandTrendr change-detection data.

Physiographic province	1994/96	Harvest	Insects and disease	Wildfire	Gross loss	2006/07	Percent change
	---------- acres ----------						--- percent ---
Washington:							
Olympic Peninsula	763,100	-500	0	-200	-700	762,400	-0.1
Western Lowlands	24,700	-400	0	0	-400	24,300	-1.6
Western Cascades	1,283,000	-3,700	-400	-700	-4,800	1,278,200	-0.4
Eastern Cascades	673,600	-8,100	-2,000	-20,000	-30,100	643,500	-4.5
State total:	**2,744,400**	**-12,700**	**-2,400**	**-20,900**	**-36,000**	**2,708,400**	**-1.3**
Oregon:							
Coast Range	611,200	-3,300	0	0	-3,300	607,900	-0.5
Willamette Valley	3,400	-100	0	0	-100	3,300	-2.9
Western Cascades	2,258,700	-13,900	-1,100	-28,900	-43,900	2,214,800	-1.9
Klamath	985,000	-6,800	-300	-93,600	-100,700	884,300	-10.2
Eastern Cascades	402,900	-5,800	-2,300	-17,800	-25,900	377,000	-6.4
State total:	**4,261,200**	**-29,900**	**-3,700**	**-140,300**	**-173,900**	**4,087,300**	**-4.1**
California:							
Coast Range	145,400	-300	-100	-2,100	-2,500	142,900	-1.7
Klamath	1,489,800	-4,400	-1,600	-71,600	-77,600	1,412,200	-5.2
Cascades	213,200	-6,500	-300	-1,800	-8,600	204,600	-4.0
State total:	**1,848,400**	**-11,200**	**-2,000**	**-75,500**	**-88,700**	**1,759,700**	**-4.8**
Range total:	**8,854,000**	**-53,800**	**-8,100**	**-236,700**	**-298,600**	**8,555,400**	**-3.4**

Note: Acres are rounded to the nearest 100 acres.

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Table D-4–Estimates of nesting/roosting habitat loss on all habitat capable lands within the owl's range using LandTrendr change-detection.

Land class	1994/96	Harvest	Insects/disease	Wildfire	Gross loss	2006/07	Change
Federal reserved:	---------- acres ----------						--- percent ---
Washington	2,274,200	-7,900	-2,200	-16,800	-26,900	2,247,300	-1.2
Oregon	2,699,600	-6,100	-2,500	-122,800	-131,400	2,568,200	-4.9
California	1,214,000	-2,500	-1,600	-64,400	-68,500	1,145,500	-5.6
Range total:	**6,187,800**	**-16,500**	**-6,300**	**-204,000**	**-226,800**	**5,961,000**	**-3.7**
Federal nonreserved:							
Washington	470,200	-4,800	-200	-4,100	-9,100	461,100	-1.9
Oregon	1,561,400	-23,800	-1,200	-17,500	-42,500	1,518,900	-2.7
California	634,400	-8,700	-400	-11,100	-20,200	614,200	-3.2
Range total:	**2,666,000**	**-37,300**	**-1,800**	**-32,700**	**-71,800**	**2,594,200**	**-2.7**
All federal:							
Washington	2,744,400	-12,700	-2,400	-20,900	-36,000	2,708,400	-1.3
Oregon	4,261,200	-29,900	-3,700	-140,300	-173,900	4,087,300	-4.1
California	1,848,400	-11,200	-2,000	-75,500	-88,700	1,759,700	-4.8
Range total:	**8,854,000**	**-53,800**	**-8,100**	**-236,700**	**-298,600**	**8,555,400**	**-3.4**
Nonfederal:							
Washington	1,258,900	-234,200	-6,000	-2,400	-242,600	1,016,300	-19.3
Oregon	1,382,400	-301,200	-2,700	-5,100	-309,000	1,073,400	-22.4
California	1,556,700	-90,200	-1,900	-5,600	-97,700	1,459,000	-6.3
Range total:	**4,198,000**	**-625,600**	**-10,600**	**-13,100**	**-649,300**	**3,548,700**	**-15.5**
All lands:							
Washington	4,003,300	-246,900	-8,400	-23,300	-278,600	3,724,700	-7.0
Oregon	5,643,600	-331,100	-6,400	-145,400	-482,900	5,160,700	-8.6
California	3,405,100	-101,400	-3,900	-81,100	-186,400	3,218,700	-5.5
Range total:	**13,052,000**	**-679,400**	**-18,700**	**-249,800**	**-947,900**	**12,104,100**	**-7.3**

Note: Acres are rounded to the nearest 100 acres.

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Table E-1–Estimates of gross loss, gross gain, and net change of dispersal habitat on federal reserved lands.

Physiographic province	1994/96	Harvest	Insects and disease	Wildfire	Gain	Net change	2006/07	Percent change
	acres							percent
Washington:								
Olympic Peninsula	1,052,600	-300	0	-400	46,100	45,400	1,098,000	4.3
Western Lowlands	61,800	-500	0	0	5,100	4,600	66,400	7.4
Western Cascades	1,889,300	-3,200	-400	-600	87,700	83,500	1,972,800	4.4
Eastern Cascades	1,428,400	-3,700	-1,300	-41,600	71,400	24,800	1,453,200	1.7
State total:	**4,432,100**	**-7,700**	**-1,700**	**-42,600**	**210,300**	**158,300**	**4,590,400**	**3.6**
Oregon:								
Coast Range	742,200	-1,700	0	-100	90,200	88,400	830,600	11.9
Willamette Valley	2,300	0	0	0	200	200	2,500	8.7
Western Cascades	1,963,800	-2,000	-600	-29,600	93,400	61,200	2,025,000	3.1
Klamath	903,700	-1,700	-400	-121,400	43,900	-79,600	824,100	-8.8
Eastern Cascades	661,500	-3,400	-3,100	-22,100	44,300	15,700	677,200	2.4
State total:	**4,273,500**	**-8,800**	**-4,100**	**-173,200**	**272,000**	**85,900**	**4,359,400**	**2.0%**
California:								
Coast Range	169,300	-300	-100	-2,300	14,600	11,900	181,200	7.0
Klamath	1,939,600	-2,500	-2,000	-67,600	127,000	54,900	1,994,500	2.8
Cascades	244,400	-700	0	-700	18,600	17,200	261,600	7.0
State total:	**2,353,300**	**-3,500**	**-2,100**	**-70,600**	**160,200**	**84,000**	**2,437,300**	**3.6**
Range Total:	**11,058,90**	**-20,000**	**-7,900**	**-286,400**	**642,500**	**328,200**	**11,387,10**	**3.0**

Note: Acres are rounded to the nearest 100 acres.

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Table E-2–Estimates of gross loss, gross gain, and net change of dispersal habitat on federal nonreserved lands.

Physiographic province	1994/96	Harvest	Insects and disease	Wildfire	Gain	Net change	2006/07	Percent change
	----------	----------	----------	acres	----------	----------	----------	--- percent ---
Washington:								
Olympic Peninsula	73,400	-200	0	0	15,700	15,500	88,900	21.1
Western Lowlands	200	0	0	0	100	100	300	50.0
Western Cascades	443,900	-1,500	0	0	48,900	47,400	491,300	10.7
Eastern Cascades	393,900	-3,500	-300	-9,200	45,100	32,100	426,000	8.1
State total:	**911,400**	**-5,200**	**-300**	**-9,200**	**109,800**	**95,100**	**1,006,500**	**10.4**
Oregon:								
Coast Range	260,800	-2,400	0	0	45,800	43,400	304,200	16.6
Willamette Valley	10,200	-100	0	0	1,300	1,200	11,400	11.8
Western Cascades	1,495,100	-11,000	-700	-4,200	167,100	151,200	1,646,300	10.1
Klamath	605,100	-5,800	-300	-16,100	62,200	40,000	645,100	6.6
Eastern Cascades	347,000	-6,500	-700	-6,800	57,600	43,600	390,600	12.6
State total:	**2,718,200**	**-25,800**	**-1,700**	**-27,100**	**334,000**	**279,400**	**2,997,600**	**10.3**
California:								
Coast Range	20,600	-100	0	-800	4,100	3,200	23,800	15.5
Klamath	996,000	-4,600	-300	-16,200	124,200	103,100	1,099,100	10.4
Cascades	333,800	-8,200	-4,000	-2,000	43,600	29,400	363,200	8.8
State total:	**1,350,400**	**-12,900**	**-4,300**	**-19,000**	**171,900**	**135,700**	**1,486,100**	**10.0**
Range Total:	**4,980,000**	**-43,900**	**-6,300**	**-55,300**	**615,700**	**510,200**	**5,490,200**	**10.2**

Note: Acres are rounded to the nearest 100 acres.

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Table E-3–Estimates of gross loss, gross gain, and net change of dispersal habitat on all federal lands.

Physiographic province	1994/96	Harvest	Insects and disease	Wildfire	Gain	Net change	2006/07	Percent change
	acres							percent
Washington:								
Olympic Peninsula	1,126,000	-500	0	-400	61,800	60,900	1,186,900	5.4
Western Lowlands	62,000	-500	0	0	5,200	4,700	66,700	7.6
Western Cascades	2,333,200	-4,700	-400	-600	136,600	130,900	2,464,100	5.6
Eastern Cascades	1,822,300	-7,200	-1,600	-50,800	116,500	56,900	1,879,200	3.1
State total:	**5,343,500**	**-12,900**	**-2,000**	**-51,800**	**320,100**	**253,400**	**5,596,900**	**4.7**
Oregon:								
Coast Range	1,003,000	-4,100	0	-100	136,000	131,800	1,134,800	13.1
Willamette Valley	12,500	-100	0	0	1,500	1,400	13,900	11.2
Western Cascades	3,458,900	-13,000	-1,300	-33,800	260,500	212,400	3,671,300	6.1
Klamath	1,508,800	-7,500	-700	-137,500	106,100	-39,600	1,469,200	-2.6
Eastern Cascades	1,008,500	-9,900	-3,800	-28,900	101,900	59,300	1,067,800	5.9
State total:	**6,991,700**	**-34,600**	**-5,800**	**-200,300**	**606,000**	**365,300**	**7,357,000**	**5.2**
California:								
Coast Range	189,900	-400	-100	-3,100	18,700	15,100	205,000	8.0
Klamath	2,935,600	-7,100	-2,300	-83,800	251,200	158,000	3,093,600	5.4
Cascades	578,200	-8,900	-4,000	-2,700	62,200	46,600	624,800	8.1
State total:	**3,703,700**	**-16,400**	**-6,400**	**-89,600**	**332,100**	**219,700**	**3,923,400**	**5.9**
Range Total:	**16,038,90**	**-63,900**	**-14,200**	**-341,700**	**1,258,200**	**838,400**	**16,877,30**	**5.2**

Note: Acres are rounded to the nearest 100 acres.

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Table E-4–Estimates of gross loss, gross gain, and net change of dispersal habitat on all habitat capable lands within the owl's range.

Land class	1994/96	Harvest	Insects/disease	Wildfire	Gross loss	Gross gain	2006/07	Net change
Federal reserved:	----------	----------	----------	acres	----------	----------	----------	--- percent ---
Washington	4,432,100	-7,700	-1,700	-42,600	-52,000	210,300	4,590,400	3.6
Oregon	4,273,500	-8,800	-4,100	-173,200	-186,100	272,000	4,359,400	2.0
California	2,353,300	-3,500	-2,100	-70,600	-76,200	160,200	2,437,300	3.6
Range Total:	**11,058,900**	**-20,000**	**-7,900**	**-286,400**	**-314,300**	**642,500**	**11,387,100**	**3.0**
Federal nonreserved:								
Washington	911,400	-5,200	-300	-9,200	-14,700	109,800	1,006,500	10.4
Oregon	2,718,200	-25,800	-1,700	-27,100	-54,600	334,000	2,997,600	10.3
California	1,350,400	-12,900	-4,300	-19,000	-36,200	171,900	1,486,100	10.0
Range Total:	**4,980,000**	**-43,900**	**-6,300**	**-55,300**	**-105,500**	**615,700**	**5,490,200**	**10.2**
All federal:								
Washington	5,343,500	-12,900	-2,000	-51,800	-66,700	320,100	5,596,900	4.7
Oregon	6,991,700	-34,600	-5,800	-200,300	-240,700	606,000	7,357,000	5.2
California	3,703,700	-16,400	-6,400	-89,600	-112,400	332,100	3,923,400	5.9
Range Total:	**16,038,900**	**-63,900**	**-14,200**	**-341,700**	**-419,800**	**1,258,200**	**16,877,300**	**5.2**
Nonfederal:								
Washington	4,359,100	-689,300	-14,700	-7,000	-711,000	993,000	4,641,100	6.5
Oregon	4,129,400	-760,700	-7,200	-10,000	-777,900	971,200	4,322,700	4.7
California	2,858,900	108,000	2,900	9,900	120,800	443,900	3,423,600	19.8
Range Total:	**11,347,400**	**-1,342,000**	**-19,000**	**-7,100**	**-1,368,100**	**2,408,100**	**12,387,400**	**9.2**
All lands:								
Washington	9,702,600	-702,200	-16,700	-58,800	-777,700	1,313,100	10,238,000	5.5
Oregon	11,121,100	-795,300	-13,000	-210,300	-1,018,600	1,577,200	11,679,700	5.0
California	6,562,600	91,600	-3,500	-79,700	8,400	776,000	7,347,000	12.0
Range Total:	**27,386,300**	**-1,405,900**	**-33,200**	**-348,800**	**-1,787,900**	**3,666,300**	**29,264,700**	**6.9**

Note: Acres are rounded to the nearest 100 acres.

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Appendix F–Crosswalk for Modifying Bookend 2 (2006/07) Map
For Making Habitat Suitability Histograms

As discussed in chapter 3, chose to not report on the highly-suspect suitable habitat gains in nesting/roosting habitat for this monitoring cycle given the short time span of our analysis and because of uncertainties with model transferability, bookend 2 (2006/07) map reviews with 1-m color aerial imagery (NAIP), geographic information system (GIS) analysis of model variable changes, and an inventory plot analysis (appendix H). However, we anticipate that our ability to measure these gains will improve with the passing of more time to separate the bookend maps, and with improved remote sensing technologies. This appendix presents the following table to describe the crosswalk we used for creating a modified bookend 2 map for the purpose of making "habitat suitability histograms" to help visualize shifts in habitat classes between bookend 1 (1994/96) and bookend 2. This approach is similar to what was done in the 10-year report, where we had only a baseline map and change-detection data to estimate habitat changes. The habitat suitability histograms on the following pages are formatted similar to the histograms in appendix G of the 10-year report. The modified bookend 2 map (as described below) is our best estimate of habitat classes as of 2006/07. It is conservative in nature, as it maintains suitable habitat classes (3 and 4) from bookend 1, and only shows loss in these suitable classes **if** verified by LandTrendr (LT) data. We allow for minor shifts within habitat classes that may represent subtle changes but do not result in a change between the broader categories of "unsuitable/marginal" (i.e., classes 1 and 2) to the "suitable" classes (i.e., classes 3 and 4).

Table F-1–Crosswalk table for modified bookend 2 map.

Bookend model habitat classes		Assumptions (based on aerial image review and GIS analysis of environmental variables)	Modified 2006/07 habitat class (modified bookend 2)
1994/6	2006/7		
1	1	Not suitable either period; no change	1
1	2	Not suitable either period; accept shift from unsuitable to marginal	2
1	3	Trend toward suitable, but highly uncertain gain; limit shift to marginal class	2
1	4	Trend toward suitable, but highly uncertain gain; limit shift to marginal class	2
2	1	Not suitable either period; accept shift from marginal to unsuitable	1
2	2	Not suitable either period; no change	2
2	3	Trend toward suitable, but highly uncertain gain; keep in marginal class	2
2	4	Trend toward suitable, but highly uncertain gain; keep in marginal class	2
3	1	If LT verified habitat loss, moved to unsuitable; otherwise no change	1 if LT verified, otherwise 3
3	2	If LT verified habitat loss, moved to marginal; otherwise no change	2 if LT verified, otherwise 3
3	3	Suitable habitat both periods; no change	3
3	4	Suitable habitat both periods; accept shift to highly suitable	4
4	1	If LT verified habitat loss, moved to unsuitable; otherwise no change	1 if LT verified, otherwise 4
4	2	If LT verified habitat loss, moved to marginal; otherwise no change	2 if LT verified, otherwise 4
4	3	Suitable habitat both periods; accept shift to suitable (degraded)	3
4	4	Suitable habitat both periods; no change	4

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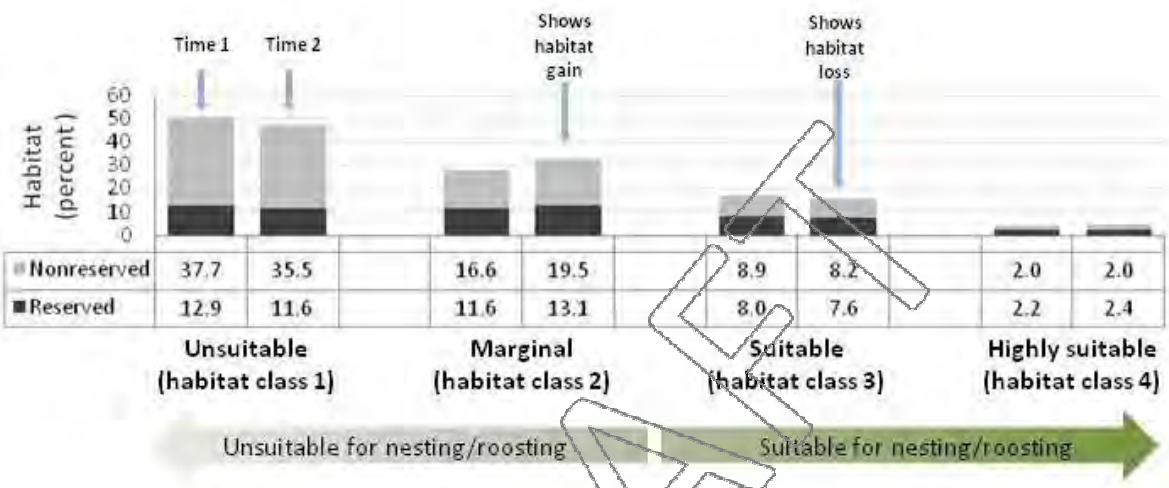
The histograms on the following pages establish the format we propose for visually representing status and trends in habitat classes for future monitoring efforts. They are based on habitat conditions at roughly the time of the Plan implementation (1994/96) to the end of our analysis data set in 2006/07. There are four pairs of histogram bars, one pair per habitat suitability class as described in chapter 3. The first bar in the pair shows conditions at time 1 (1994/96), the second bar shows conditions at time 2 (2006/07), based on our modified bookend 2 map. They also provide a visual on how owl habitat is distributed across reserved and nonreserved federal lands. The example histogram below is provided to help interpret the histograms provided for each physiographic province in the following pages.



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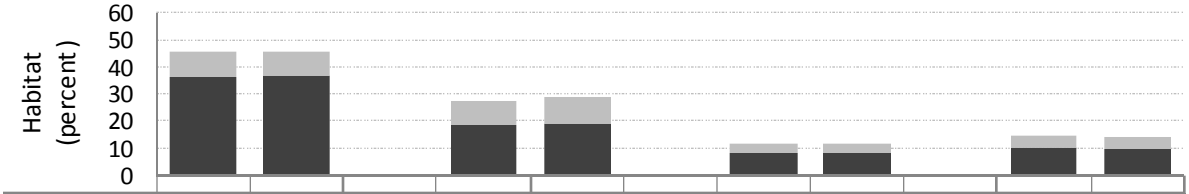
In the example above, we observe a slight decrease (3.5 percent) in unsuitable habitat class 1 between time 1 and time 2. We also observe a slightly larger (4.4 percent) increase in marginal habitat class (but still unsuitable for nesting/roosting). There has been a slight decrease in the suitable habitat class 3 (1.1 percent) with a very slight (0.2 percent) increase in the highly suitable habitat class. We can conclude that forest succession in habitat class 1 accounted for most of the increase in habitat class 2, but some of the loss in habitat class 3 may have also accounted for some of the changes in habitat class 2, or perhaps offset some of the decrease in habitat class 1. The slight increase in habitat class 4 may be a result of changes in habitat class 3, as seen in the plot analysis (appendix H) where there may have been some subtle changes. However, this does not result in a change in the broader "suitable" class. The simplest interpretation indicates that the increase in the marginal habitat class (class 2) will continue to progress to the suitable classes with time. This province has very little suitable nesting/roosting habitat.

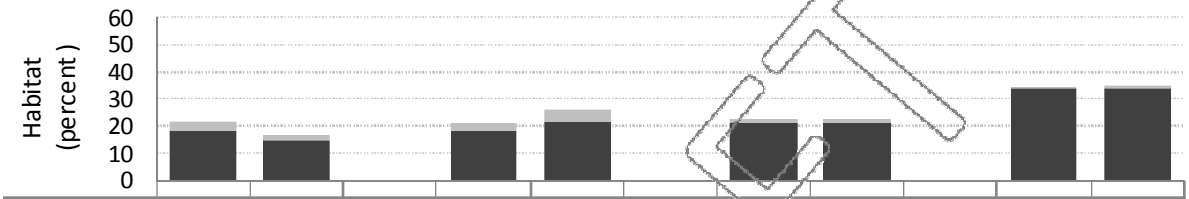
The table under the graphs shows the estimates of percentage of forest-capable land changes between habitat maps for both periods. The percentages are split into nonreserved and reserved land use allocations. The following graphs illustrate our best estimate of how habitat is changing (trending) at this early stage of Plan. These graphs are primarily for interpretive purposes. The observed change between the bookends is small, with the largest changes being increases in the marginal classes. We observed similar changes in dispersal habitat (see Chapter 3) and consider this an indication for noticeable future recruitment from marginal to suitable habitat within the next 2 to 3 decades.

Washington Eastern Cascades



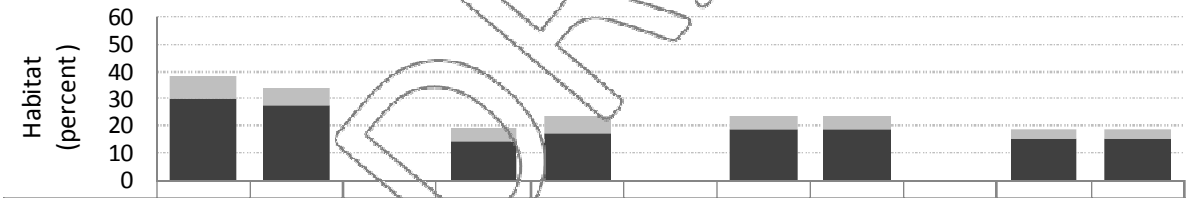
	Habitat class 1		Habitat class 2		Habitat class 3		Habitat class 4	
Nonreserved	9.9	9.3	8.9	9.8	3.3	3.2	4.1	3.9
Reserved	36.0	36.7	18.8	19.1	8.6	8.2	10.4	9.9

Washington Olympic Peninsula



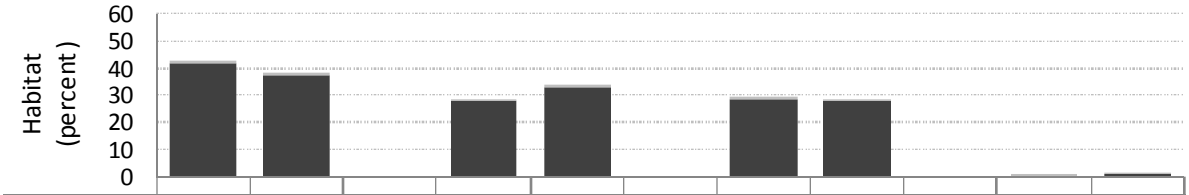
	Habitat class 1		Habitat class 2		Habitat class 3		Habitat class 4	
Nonreserved	3.5	2.5	3.2	4.2	1.5	1.4	1.0	1.1
Reserved	18.0	14.5	18.2	21.8	21.0	20.8	33.6	33.7

Washington Western Cascades



	Habitat class 1		Habitat class 2		Habitat class 3		Habitat class 4	
Nonreserved	7.9	6.4	5.3	6.7	4.9	5.0	3.3	3.2
Reserved	30.3	27.6	14.2	17.1	18.6	18.5	15.6	15.5

Washington Western Lowlands



	Habitat class 1		Habitat class 2		Habitat class 3		Habitat class 4	
Nonreserved	0.3	0.3	0.2	0.2	0.0	0.0	0.0	0.0
Reserved	42.1	37.7	28.0	32.9	28.8	28.2	0.5	0.6

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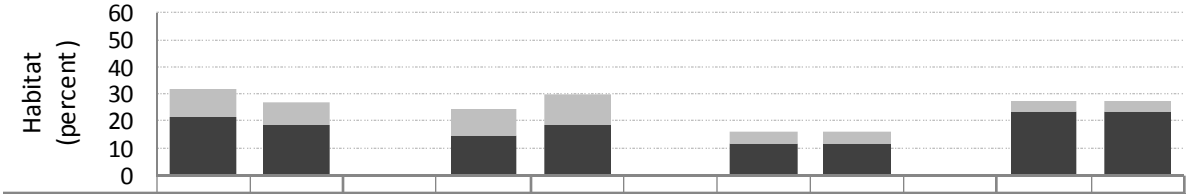
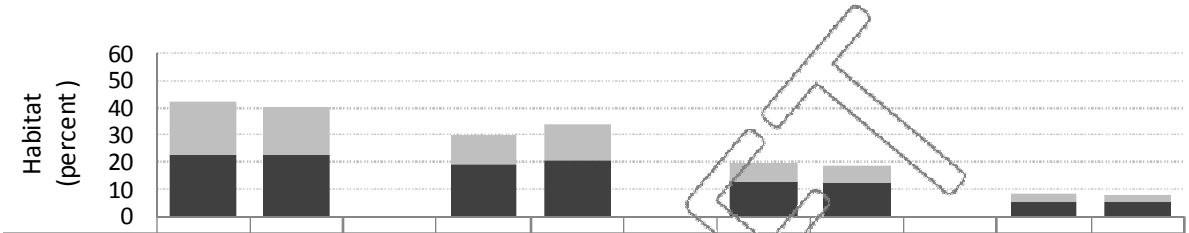
Oregon Coast Range



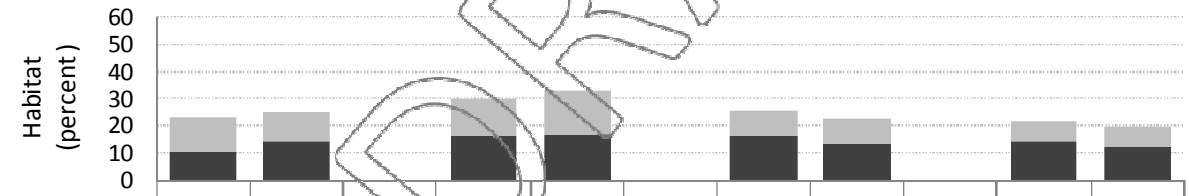
	Habitat class 1		Habitat class 2		Habitat class 3		Habitat class 4	
Nonreserved	9.9	8.1	9.6	11.5	4.4	4.2	3.9	4.0
Reserved	22.0	18.4	14.7	18.4	11.9	11.8	23.6	23.7

Oregon Eastern Cascades



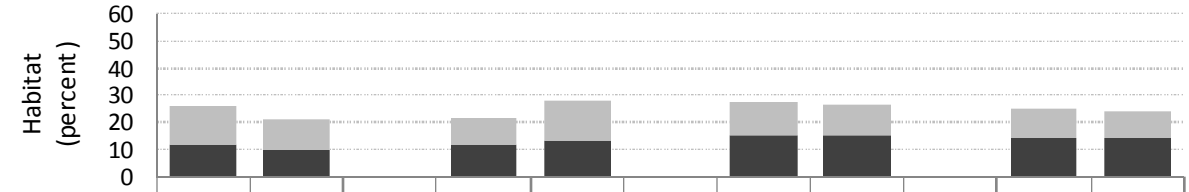
	Habitat class 1		Habitat class 2		Habitat class 3		Habitat class 4	
Nonreserved	19.5	17.5	10.4	13.2	6.9	6.2	2.8	2.7
Reserved	22.4	22.3	19.5	20.8	13.0	12.2	5.4	5.1

Oregon Klamath



	Habitat class 1		Habitat class 2		Habitat class 3		Habitat class 4	
Nonreserved	12.2	10.8	14.2	16.4	9.3	8.6	7.3	7.4
Reserved	10.5	14.1	16.1	16.5	16.2	13.7	14.2	12.5

Oregon Western Cascades



	Habitat class 1		Habitat class 2		Habitat class 3		Habitat class 4	
Nonreserved	14.5	10.9	10.1	14.1	11.5	11.3	10.6	10.4
Reserved	11.5	10.0	11.7	13.8	15.7	15.5	14.4	14.0

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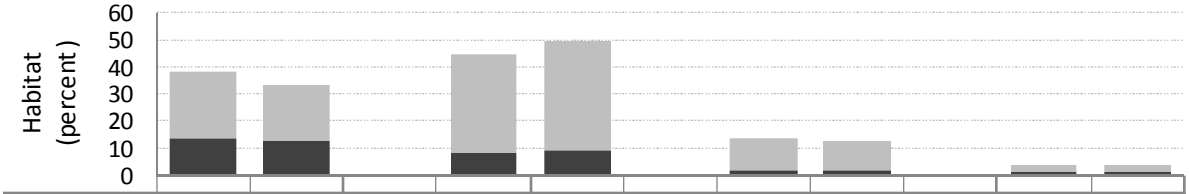
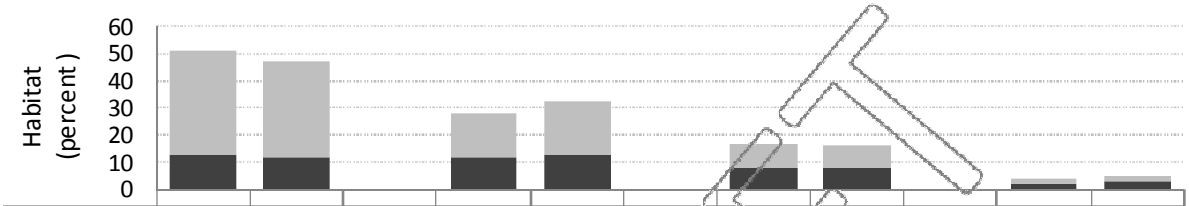
Oregon Willamette Valley



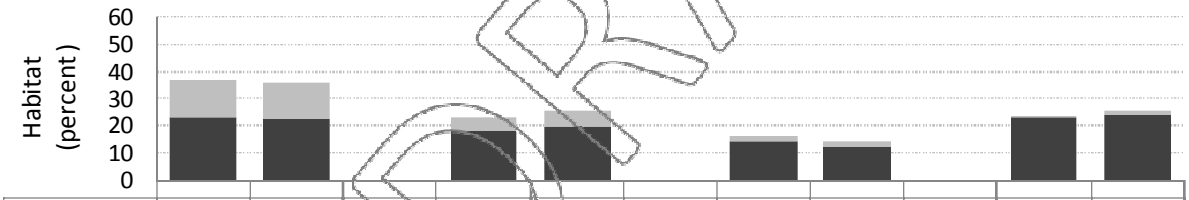
	Habitat class 1		Habitat class 2		Habitat class 3		Habitat class 4	
Nonreserved	24.4	19.8	35.8	40.6	11.8	11.1	2.2	2.6
Reserved	13.7	13.1	8.6	9.2	2.0	2.0	1.6	1.6

California Cascades



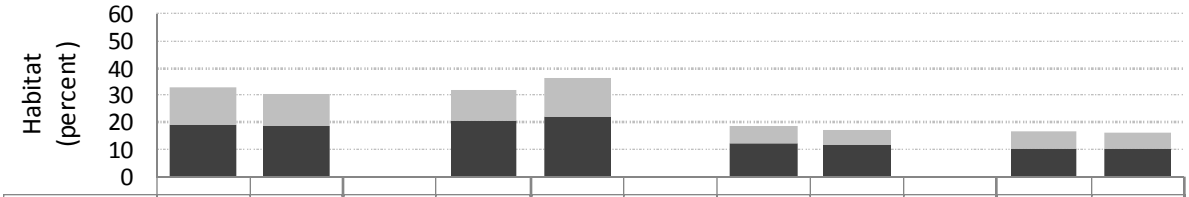
	Habitat class 1		Habitat class 2		Habitat class 3		Habitat class 4	
Nonreserved	37.7	35.5	16.6	19.5	8.9	8.2	2.0	2.0
Reserved	12.9	11.6	11.6	13.1	8.0	7.6	2.2	2.4

California Coast Range



	Habitat class 1		Habitat class 2		Habitat class 3		Habitat class 4	
Nonreserved	13.8	13.4	5.1	5.6	1.7	1.5	1.2	1.2
Reserved	23.3	22.2	17.9	19.7	14.3	12.3	22.8	24.1

California Klamath



	Habitat class 1		Habitat class 2		Habitat class 3		Habitat class 4	
Nonreserved	13.6	11.7	11.7	13.8	6.3	6.1	5.8	5.8
Reserved	19.3	18.8	20.2	22.3	12.4	11.4	10.6	10.2

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Table G-1–Wildfire suitabilty modeling environmental variables and their model contributions.

Environmental variable	Description	Value range	Units	Contribution to model
				-- percent --
August maximum temperature	PRISM (1971-2000)–mean maximum temperature for month of August	1,456-3,635	°C (x 100)	27.8
Lightning ignition density	Kernel density map of all lightning-caused fire ignitions between 1970-2002, from Brown et al. (2002)[a]	0-992	Ignitions/km² (x100)	24.1
Slope	Percentage slope based on analysis of Digital Elevation Model	0-125	Percent	23.7
Distance from road	Linear distance to nearest road, based on road layer in Gallo et al. (2011)[b]	0-28,300	Meters	14.6
Summer precipitation	PRISM (1971-2000)–mean rainfall between May and September, log transformed	3,243-6,884	ln mm (x1,000)	4.4
Elevation	USGS Digital Elevation Model	0-2477	Meters	4.2
Solar radiation	Potential relative solar radiation (PRR) as derived by Pierce et al. (2005)[c]	5,619-20,546	Index	1.1

[a] **Brown, T.J.; Hall, B.L.; Mohrle, C.R.; Reinbold, H.J. 2002**. Coarse assessment of federal wildland fire occurrence data: report for the National Wildfire Coordinating Group. Reno, NV: CEFA Report 02-04. Program for Climate, Ecosystem and Fire Applications, Desert Research Institute, Division of Atmospheric Sciences. 31 p.

[b] **Gallo, K.; Lanigan, S.H.; Eldred, P.; Gordon, S.N.; Moyer, C. 2005.** Northwest Forest Plan–the first 10 years (1994-2003): preliminary assessment of the condition of watersheds. Gen. Tech. Rep. PNW-GTR-647. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 133 p.

[c] **Pierce, K.B.; Lookingbill, T.R.; Urban, D.L. 2005**. A simple method for estimating potential relative radiation (PRR) for landscape-scale vegetation analysis. Landscape Ecology. 20: 137–147.

	August max temp	Slope	Solar radiation	Lightning density	Distance from road	Elevation	Summer precip
August max temp	1.000	-0.182	0.238	0.018	-0.336	-0.441	-0.428
Slope	-0.182	1.000	-0.426	-0.254	0.190	0.052	0.265
Solar radiation	0.238	-0.426	1.000	0.238	-0.234	-0.271	-0.124
Lightning density	0.018	-0.254	0.238	1.000	-0.232	0.340	-0.100
Distance from road	-0.336	0.190	-0.234	-0.232	1.000	0.263	0.166
Elevation	-0.441	0.052	-0.271	0.340	0.263	1.000	-0.118
Summer precip	-0.428	0.265	-0.124	-0.100	0.166	-0.118	1.000

Figure G-1–Correlation matrix (Pearson correlations) for environmental variables used in the model.

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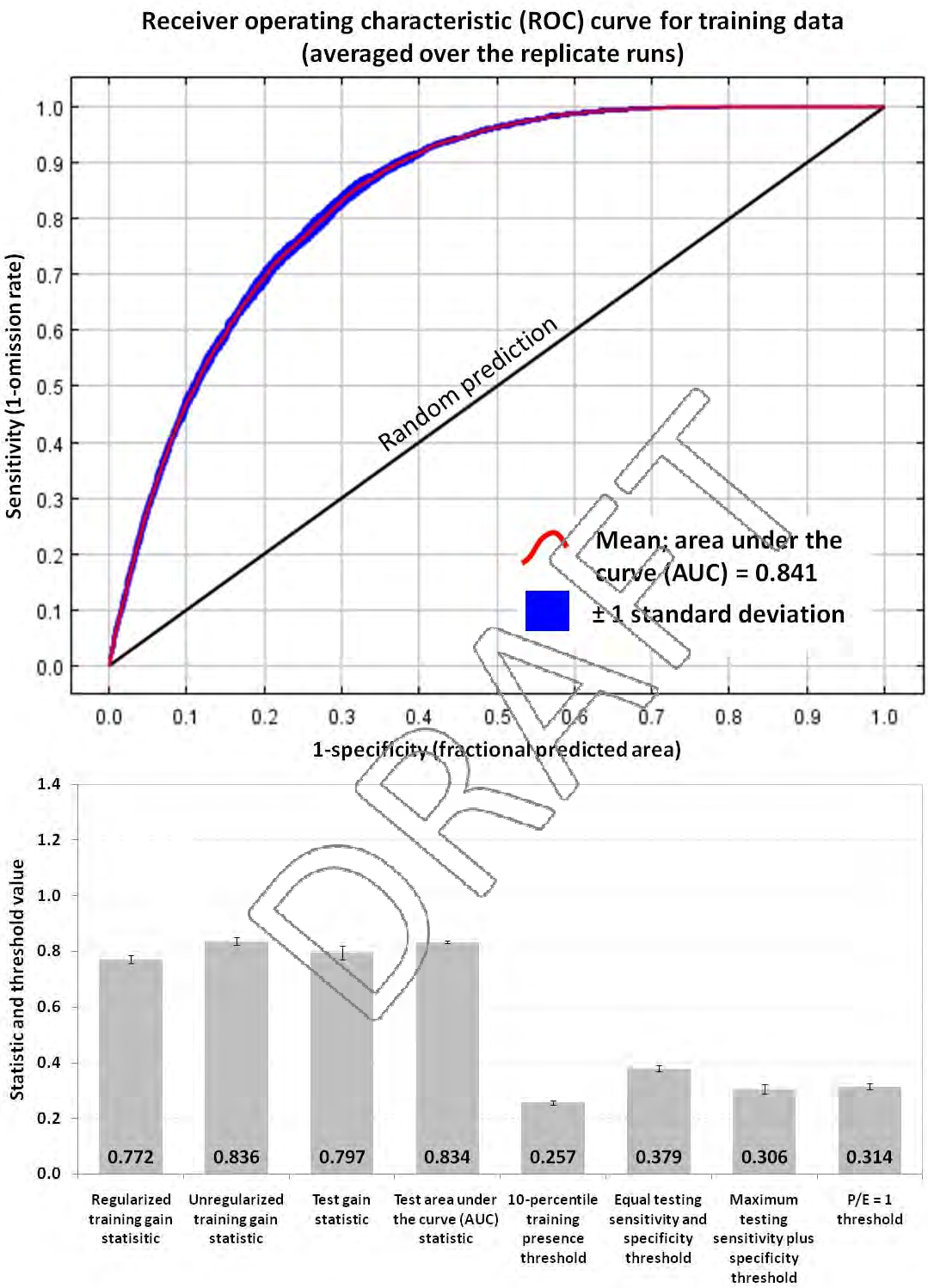

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Figure G-2–Averaged model fit, accuracy, and threshold statistics (with 95-percent confidence intervals) from the 10 bootstrapped model replicates. Note that the P/E=1 threshold is similar to the maximum testing sensitivity plus specificity threshold, which minimizes model omission and commission errors.

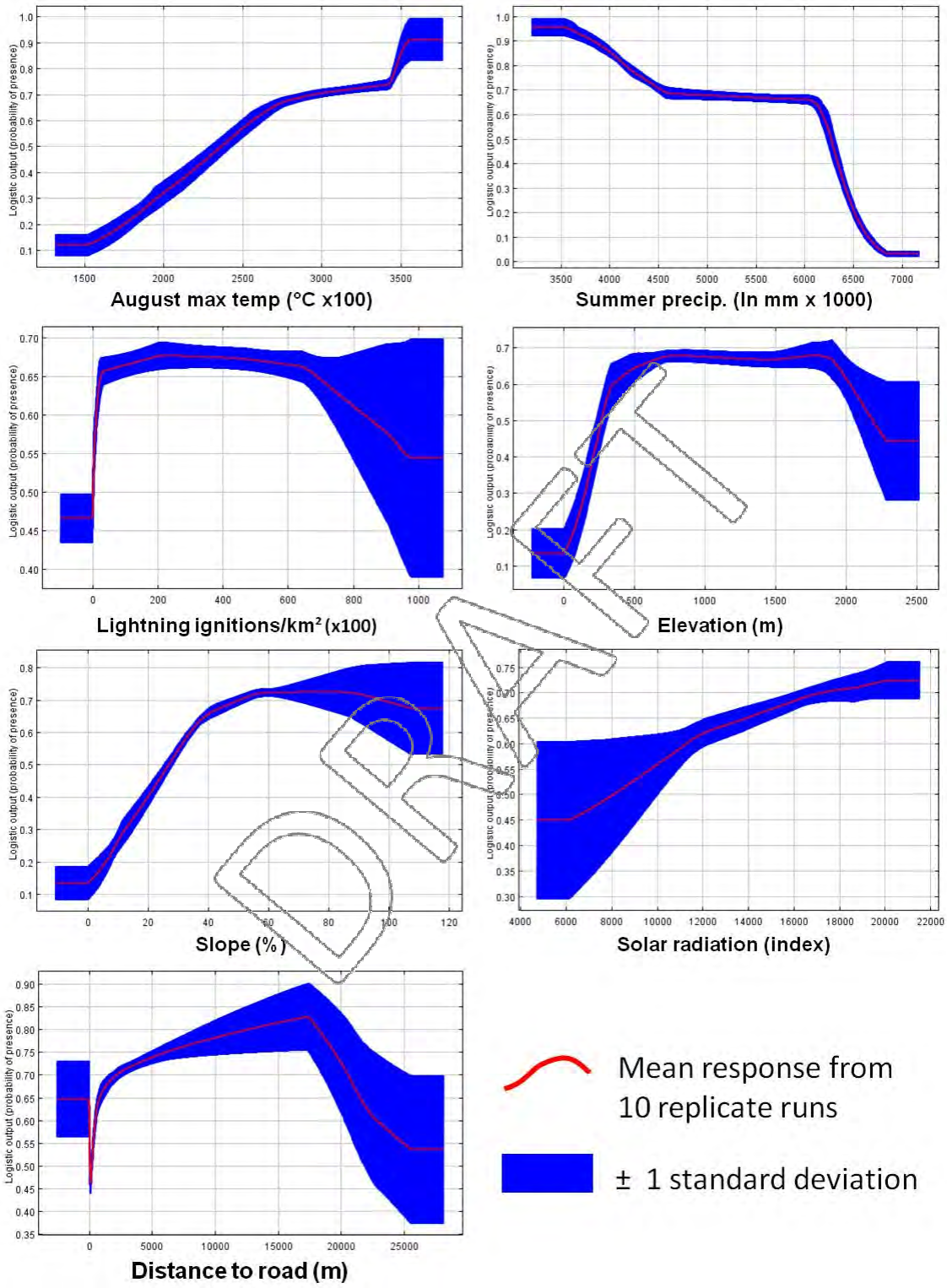

Figure G-3–Model response curves showing logistic probability of large wildfire occurrence (y-axis) for each environmental variable, as it is varied in jackknifed models, keeping all other environmental variables at their average sample values.

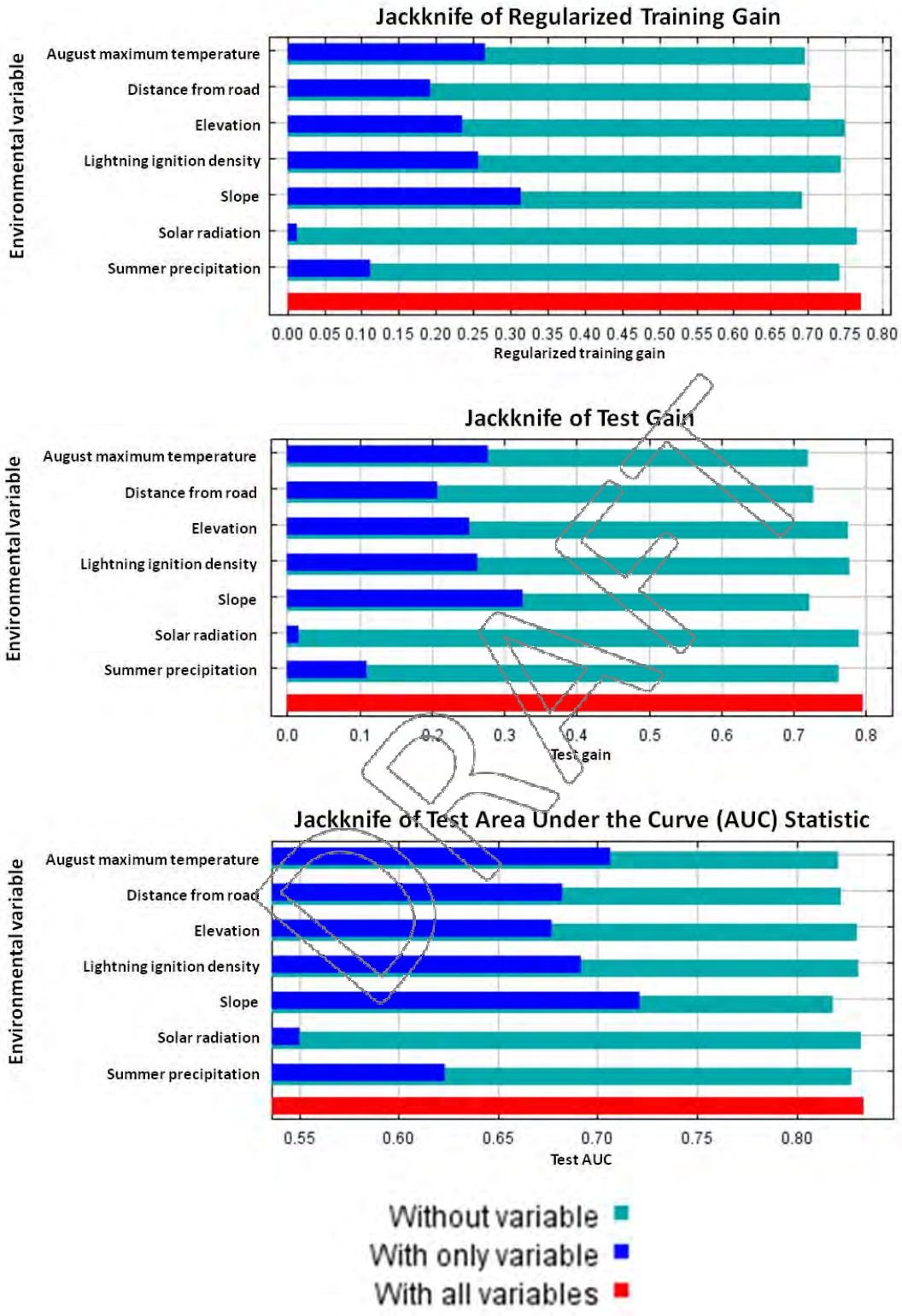

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Figure G-4–Jackknife modeling results for variable importance. Note the similarities between the regularized training gain (top) and test gain (middle) graphs. The high level of similarity between them indicates that the model is not over-fit.

PLOT ANALYSIS

Carol A. Apple and Raymond J. Davis

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An analysis of regional vegetation inventory plots was performed to determine if there have been significant gains in northern spotted owl (*Strix occidentalis caurina*) nesting/roosting habitat since monitoring was implemented. We used plot data from the Current Vegetation Survey (CVS) inventory program on USDA Forest Service (FS) and USDI Bureau of Land Management (BLM) lands in Oregon and Washington. Forest Inventory and Analysis (FIA) program data were used for FS lands in California. Data were not available for USDI National Park Service (NPS) lands or BLM lands in Washington or California.

The CVS inventory provides comprehensive information on vegetative resources on FS lands in Oregon and Washington and BLM lands in the Northwest Forest Plan area in Oregon. The CVS plots consist of four grids of field plots that are separated by 3.4 mi on a north-south, east-west direction. These four inventory grids are offset from one another to produce one single 1.7-mi grid of plots across BLM lands and FS lands, except in wilderness areas where the grid density is 3.4-mi. The FIA plots for FS lands in California are also distributed geographically on a 3.4 mi grid. For specific information on the attributes that are collected on FS lands, refer to the Web sites: http://www.fs.fed.us/r6/survey/ and http://www.fs.fed.us/r5/rsl/projects/inventory/InvInfo.shtml. Refer to pages 31-36 in Moeur et al. (2005) for additional discussion of the current vegetation survey and forest inventory analysis.

A spotted owl nesting/roosting habitat query was developed (table H-1) similar to what was used in the 10-year report (Davis and Lint 2005). There were differences that included:

- Use of a slightly different set of plots
- Summarized data at the plot level vs. subplot level
- Top story quadratic mean diameter (QMD) for only conifer and not all species
- Use of a different strata attribute

These differences were made to adjust to the new gradient nearest neighbor (GNN) variables used for the spatial habitat modeling (see chapter 3, this report). The intent of this analysis was to explore for differences in "query group" acres between the initial measurement and remeasurement period, and not for differences between the 10-year report map results and this report's map results. In addition, the results of this analysis should not be compared to the results of the 10-year report plot analysis.

On Region 6 Forest Service lands, nearly all CVS plots have had two samples, but on Oregon BLM lands, only one-quarter of the original CVS plots had been remeasured at the time of this analysis. Based on the numbers of plots for each year of measurement, the weighted average year for initial plot measurements in Oregon and Washington was 1995, and 2002 for remeasurements. For California the plot measurement period spans 1997 to 2005. The first inventory in California was conducted under the

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older FIA "periodic" sample design. This protocol was replaced by FIA's "annual" sample design, which was used for the plot remeasurments. This change in inventory protocol confounds inferences on habitat changes in California, since "real" change cannot be separated from effects related to changing sampling protocols (see Moeur et al. 2011) for more discussion.

Table H-2—Forest stand condition query for current vegetation survey plot data.

	Low <------- Spotted owl nesting/roosting habitat similarity -------> High					
	Query group					
Query attributes	**A**	**B**	**C**	**D**	**E**	**F**
Query part 1:						
Quadratic mean diameter	<10.5	≥10.5	10.5-20.5	10.5-20.5	≥20.5	≥20.5
Canopy cover (percent)	All	≤40	>40	>40	41-70	>70
Strata	All	All	1	≥2	≥2	≥2
Query part 2:						
Quadratic mean diameter	NA	NA	NA	≥20.5	NA	NA
Canopy cover (percent)				>40		
Strata				1		

As in the 10-year report, the "query groups" in table H-1 represent a progression of stand conditions, based on conifer diameter, total canopy cover, and stand structure complexity (strata) that represent habitat similarity to conditions used by spotted owls for nesting and roosting. A query was applied to both the initial measurement and remeasurement plot data in each physiographic province that occurred within the "habitat capable" areas described in Davis and Lint (2005) to assign a group code to each plot. In addition to the six groups in table H-1, two combined groups of EF and DEF were also assigned.

An analysis was then done using the jackknife method to estimate the variance of mean acres for each query group by measurement period and province. The variance was used in performing a t-test to look at the differences in the means between the two periods. This test assumes independence between the two samples, but in reality many of the plots were remeasured. Taking that into consideration, this test provided conservative results for significance: if it is significant it is very significant.

The results of this analysis did not show any evidence of significant habitat recruitment into classes EF or the broader class DEF. There were some significant decreases in class E, but these were concurrent with significant increases in class F; therefore, these changes "cancelled" each other out, resulting in no significant change in the EF group. Significant decreases in EF and DEF were observed in the California Cascades and Klamath Mountain provinces (table H-4); however, as stated above, the change in protocol used to collect plot information in California confounds this inference. The histograms on the following page display the results of the plot analysis for each physiographic province with significant amounts of federal lands. The results of the t-test are shown in tables H-2 thru H-4.

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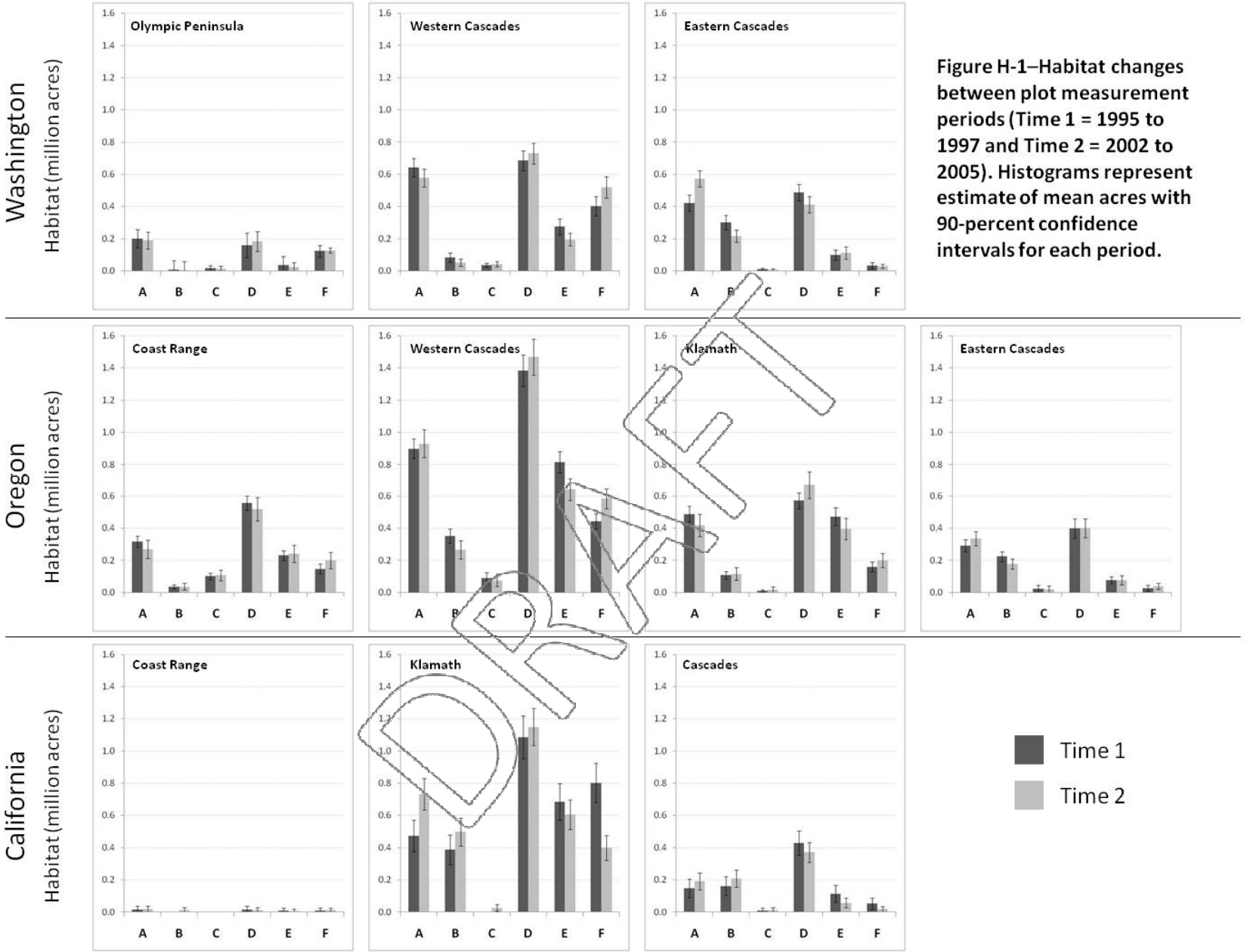

Figure H-1–Habitat changes between plot measurement periods (Time 1 = 1995 to 1997 and Time 2 = 2002 to 2005). Histograms represent estimate of mean acres with 90-percent confidence intervals for each period.

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Table H-3—Test for significant difference (bold-faced) of mean acres between measurement periods by physiographic province by query group at the 0.1 significance level (t=1.6448), Washington

Physiographic province	Query group	t-value	Net change
			------- acres -------
Olympic Peninsula	A	0.386	-9,300
	B	0.379	-1,900
	C	0.197	-1,500
	D	1.016	24,000
	E	1.455	-15,100
	F	0.157	3,900
	DEF	0.442	12,700
	EF	0.438	-11,200
Western Cascades	A	1.346	-65,000
	B	1.427	-31,200
	C	0.559	6,700
	D	0.824	44,800
	E	**2.057**	**-80,000**
	F	**2.134**	**115,600**
	DEF	1.143	80,400
	EF	0.562	35,600
Eastern Cascades	**A**	**3.584**	**151,200**
	B	**2.367**	**-85,000**
	C	0.337	-1,900
	D	**1.738**	**-75,400**
	E	0.477	14,100
	F	0.114	-1,600
	DEF	1.254	-63,000
	EF	0.384	12,400

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Table H-4–Test for significant difference (bold-faced) of mean acres between measurement periods by physiographic province by query group at the 0.1 significance level (t=1.6448), Oregon

Physiographic province	Query group	t-value	Net change
			------- acres -------
Coast Range	A	1.206	-46,500
	B	0.061	900
	C	0.295	6,800
	D	0.770	-37,600
	E	0.318	11,200
	F	1.527	52,400
	DEF	0.479	26,000
	EF	1.374	63,600
Western Cascades	A	0.480	30,500
	B	**1.981**	**-85,000**
	C	0.472	-14,500
	D	0.945	85,400
	E	**2.988**	**-175,300**
	F	**2.993**	**140,500**
	DEF	0.526	50,500
	EF	0.499	-34,800
Klamath	A	1.400	-70,500
	B	0.287	7,600
	C	0.854	8,400
	D	**1.758**	**98,000**
	E	1.478	-77,700
	F	1.281	40,800
	DEF	0.924	61,000
	EF	0.638	-36,900
Eastern Cascades	A	1.290	44,500
	B	**1.743**	**-45,700**
	C	0.272	-5,200
	D	0.055	2,900
	E	0.034	700
	F	0.740	11,300
	DEF	0.272	14,900
	EF	0.464	12,000

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Table H-5—Test for significant difference (bold-faced) of mean acres between measurement periods by physiographic province by query group at the 0.1 significance level (t=1.6448), California

Physiographic province	Query group	t-value	Net change
			------- acres -------
Coast Range	A	0.128	1,900
	B	1.145	12,300
	C	-	-
	D	0.309	-4,200
	E	0.229	-2,300
	F	0.213	2,400
	DEF	0.269	-4,100
	EF	0.008	100
Klamath	**A**	**2.988**	**259,400**
	B	1.404	108,700
	C	**1.722**	**25,200**
	D	0.597	63,700
	E	**0.901**	**-78,800**
	F	**4.835**	**-402,400**
	DEF	**3.887**	**-417,500**
	EF	**4.496**	**-481,200**
Cascades	A	0.929	43,400
	B	0.968	46,000
	C	0.271	3,500
	D	0.994	-57,600
	E	**1.660**	**-57,000**
	F	**1.681**	**-36,400**
	DEF	**2.628**	**-151,000**
	EF	**2.380**	**-93,500**

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References

Davis, R.; Lint, J. 2005. Habitat status and trend. In: Lint, J., tech. coord. Northwest Forest Plan–the first 10 years (1994-2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 21–82.

Moeur, M.; Spies, T.A.; Hemstrom, M.; Alegria, J.; Browning, J.; Cissel, J.; Cohen, W.B.; Demeo, T.E.; Healey, S.; Warbington, R. 2005. Northwest Forest Plan–the first 10 years (1994-2003): status and trend of late-successional and old-growth forest. Gen. Tech. Rep. PNW-GTR-646. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 142 p.

Moeur, M.; Ohmann, J.L.; Kennedy, R.E.; Cohen, W.B.; Gregory, M.J.; Yang, Z.; Roberts, H.M.; Spies, T.A.; Fiorella, M. 2011. Northwest forest plan–status and trends of late-successional and old-growth forests from 1994 to 2007. Gen. Tech. Rep. PNW-GTR-XXX. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. XX p.

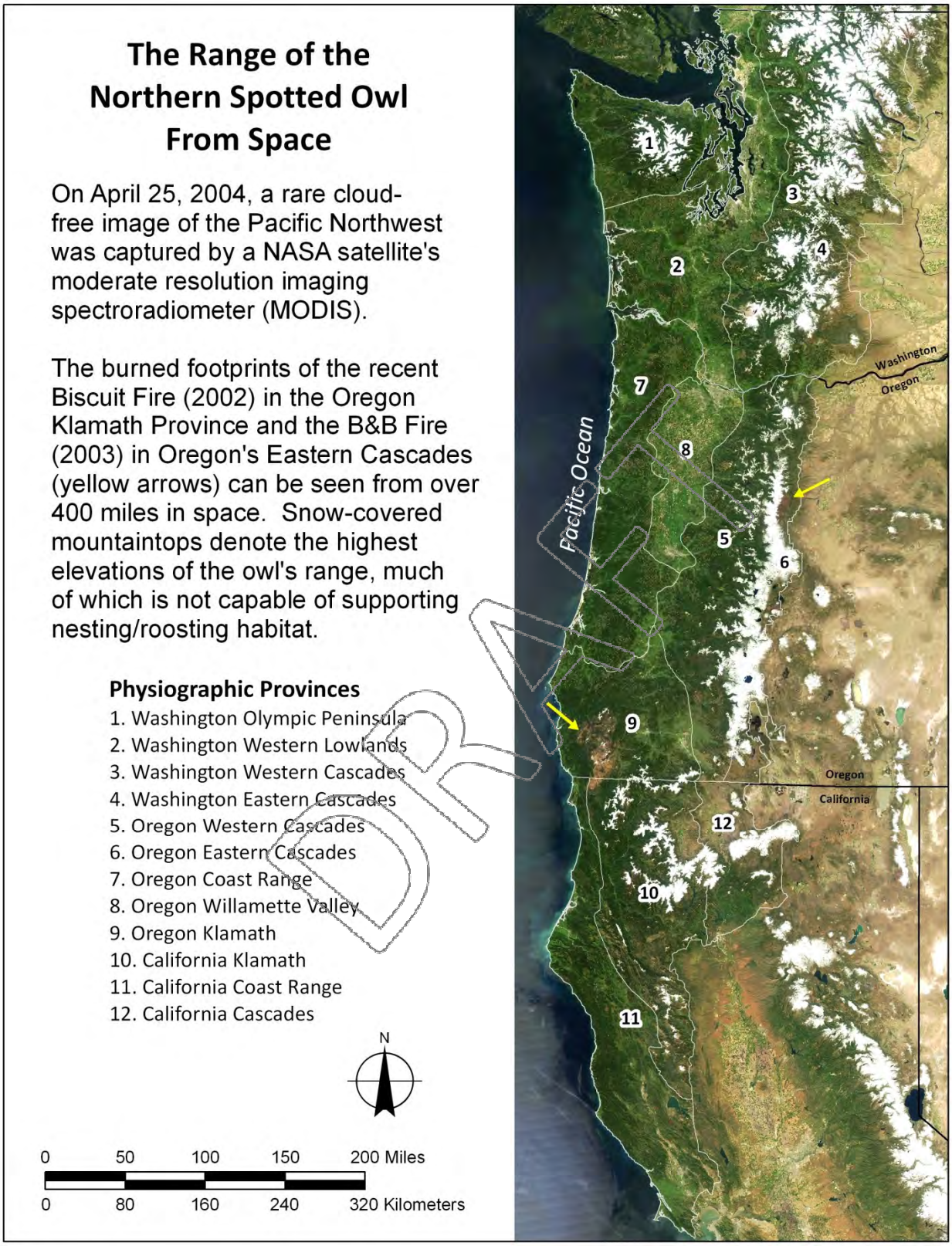

Figure 1-1–The range of the northern spotted owl.

NOTE: THE FINDINGS AND CONCLUSIONS IN THIS REPORT ARE IN PRESS AND SUBJECT TO CHANGE PRIOR TO FORMAL DISSEMINATION BY THE AGENCIES AND SHOULD NOT BE CONSTRUED TO REPRESENT AGENCY DETERMINATION OR POLICY.

Table 2-1–Descriptions of nine demographic study areas associated with land managed under the Northwest Forest Plan. Source: adapted from Forsman et al. (2011).

Study area	Physiographic province	Years	Land-owner class	Ecological region	Study size	Number of banded owls				Total encounters[c]
						S1[b]	S2[b]	Adults[b]	Total	
Washington:					--- mi² ---					
Cle Elum[a]	Eastern Cascades	1989-2008	Mixed	Washington mixed-conifer	689	31	32	148	211	1,170
Rainier	Western Cascades	1992-2008	Mixed	Washington Douglas-fir	837	8	12	133	153	583
Olympic[a]	Olympic Peninsula	1990-2008	Federal	Washington Douglas-fir	861	19	32	337	388	1,510
Oregon:										
Coast Ranges[a]	Coast Ranges	1990-2008	Mixed	Oregon coastal Douglas-fir	1,514	66	97	486	649	3,306
H.J. Andrews[a]	Western Cascades	1988-2008	Federal	Oregon Cascades Douglas-fir	619	28	91	457	576	3,082
Tyee[a]	Coast Range	1990-2008	Mixed	Oregon coastal Douglas-fir	396	137	110	243	490	2,315
Klamath[a]	Klamath	1990-2008	Mixed	Oregon/California mixed-conifer	549	169	134	347	650	2,800
South Cascades[a]	Western and Eastern Cascades	1991-2008	Federal	Oregon Cascades Douglas-fir	1,304	43	80	479	602	2,364
California:										
NW California[a]	Klamath	1985-2008	Federal	Oregon/California mixed-conifer	691	114	80	280	474	2,550
				Totals:	**7,460**	**615**	**668**	**2,910**	**4,193**	**19,680**

[a] One of eight study areas monitored under the northern spotted owl effectiveness monitoring program for the Northwest Forest Plan.

[b] Age class codes indicate age at which owls were banded and became part of the mark-recapture data set: S1 = 1 year old, S2 = 2 years old, and adults ≥ 3 years old.

[c] All captures, recaptures, and resightings, excluding multiple encounters of individuals in the same year.

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Table 2-2–Average survival rates with standard errors (SE) for female northern spotted owls by age class in the nine demographic study areas associated with land managed under the Northwest Forest Plan. Source: adapted from Forsman et al. (2011).

Study area	Landowner class	Age class					
		1 year old		2 years old		≥3 years old	
		Survival[b]	SE	Survival[b]	SE	Survival[b]	SE
Washington:							
Cle Elum[a]	Mixed	0.794	0.051	0.820	0.023	0.819	0.013
Rainier	Mixed	0.541	0.181	0.674	0.156	0.841	0.019
Olympic[a]	Federal	0.529	0.148	0.786	0.081	0.828	0.016
Oregon:							
Coast Ranges[a]	Mixed	0.742	0.072	0.864	0.031	0.859	0.009
H.J. Andrews[a]	Federal	0.717	0.084	0.830	0.042	0.865	0.010
Tyee[a]	Mixed	0.761	0.043	0.864	0.020	0.856	0.008
Klamath[a]	Mixed	0.788	0.040	0.858	0.020	0.848	0.008
South Cascades[a]	Federal	0.692	0.069	0.733	0.053	0.851	0.010
California:							
NW California[a]	Mixed	0.774	0.031	0.784	0.031	0.844	0.009

[a] One of eight study areas monitored under the northern spotted owl effectiveness monitoring program for the Northwest Forest Plan.
[b] Average survival is the arithmetic mean of model-averaged annual survival estimates for females. Standard errors were calculated using the delta method.

Table 2-3–Mean ( ), age-specific fecundity (number of female young produced per female) with standard errors (SE) for northern spotted owls in the nine demographic study areas associated with land managed under the Northwest Forest Plan. Source: adapted from Forsman et al. (2011).

Study area	Landowner class	Age class					
		1 year old		2 years old		≥3 years old	
			SE		SE		SE
Washington:							
Cle Elum[a]	Mixed	0.115	0.083	0.517	0.109	0.553	0.052
Rainier	Mixed	0.100	0.100	0.111	0.111	0.302	0.065
Olympic[a]	Federal	0.150	0.100	0.361	0.162	0.300	0.060
Oregon:							
Coast Ranges[a]	Mixed	0.000	0.000	0.094	0.039	0.263	0.040
H.J. Andrews[a]	Federal	0.083	0.083	0.110	0.043	0.323	0.041
Tyee[a]	Mixed	0.018	0.013	0.218	0.065	0.305	0.034
Klamath[a]	Mixed	0.056	0.024	0.289	0.045	0.377	0.033
South Cascades[a]	Federal	0.060	0.038	0.210	0.064	0.347	0.052
California:							
NW California[a]	Mixed	0.088	0.054	0.152	0.038	0.324	0.027

[a] One of eight study areas monitored under the northern spotted owl effectiveness monitoring program for the Northwest Forest Plan.

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Table 2-4–Trends in fecundity and survival, and mean rate of population change ( ) with standard errors (SE) and 95-percent confidence limits (95% CI) for northern spotted owls from nine demographic study areas associated with land managed under the Northwest Forest Plan. Source: adapted from Forsman et al. (2011)

Study area	Landowner class	Fecundity	Survival	Estimated annual rate of population change (λ_{RJS})[b]			Population trend[c]
					SE	95% CI	
Washington:							
Cle Elum[a]	Mixed	Declining	Declining	0.937	0.014	0.910–0.964	Declining
Rainier	Mixed	Increasing	Declining	0.929	0.026	0.877–0.977	Declining
Olympic[a]	Federal	Stable	Declining	0.957	0.020	0.918 – 0.997	Declining
Oregon:							
Coast Ranges[a]	Mixed	Increasing	Declining since 1998	0.966	0.011	0.943–0.985	Declining
H.J. Andrews[a]	Federal	Increasing	Declining since 1997	0.977	0.010	0.957–0.996	Declining
Tyee[a]	Mixed	Stable	Declining since 2000	0.996	0.020	0.957–1.035	Stationary
Klamath[a]	Mixed	Declining	Stable	0.990	0.014	0.962–1.017	Stationary
South Cascades[a]	Federal	Declining	Declining since 2000	0.982	0.030	0.923–1.040	Stationary
California:							
NW California[a]	Federal	Declining	Declining	0.983	0.008	0.968–0.998	Declining

[a] One of eight study areas monitored under the northern spotted owl effectiveness monitoring program for the Northwest Forest Plan.
[b] λ_{RJS} = reparameterized Jolly-Seber estimate of population change (Pradel 1996).
[c] Population trends based on estimates of realized population change.

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Figure 2-1–Location of nine demography study areas comprising primarily federal lands administered under the Northwest Forest Plan and included in the 2009 northern spotted owl meta-analysis by Forsman et al. (2011).

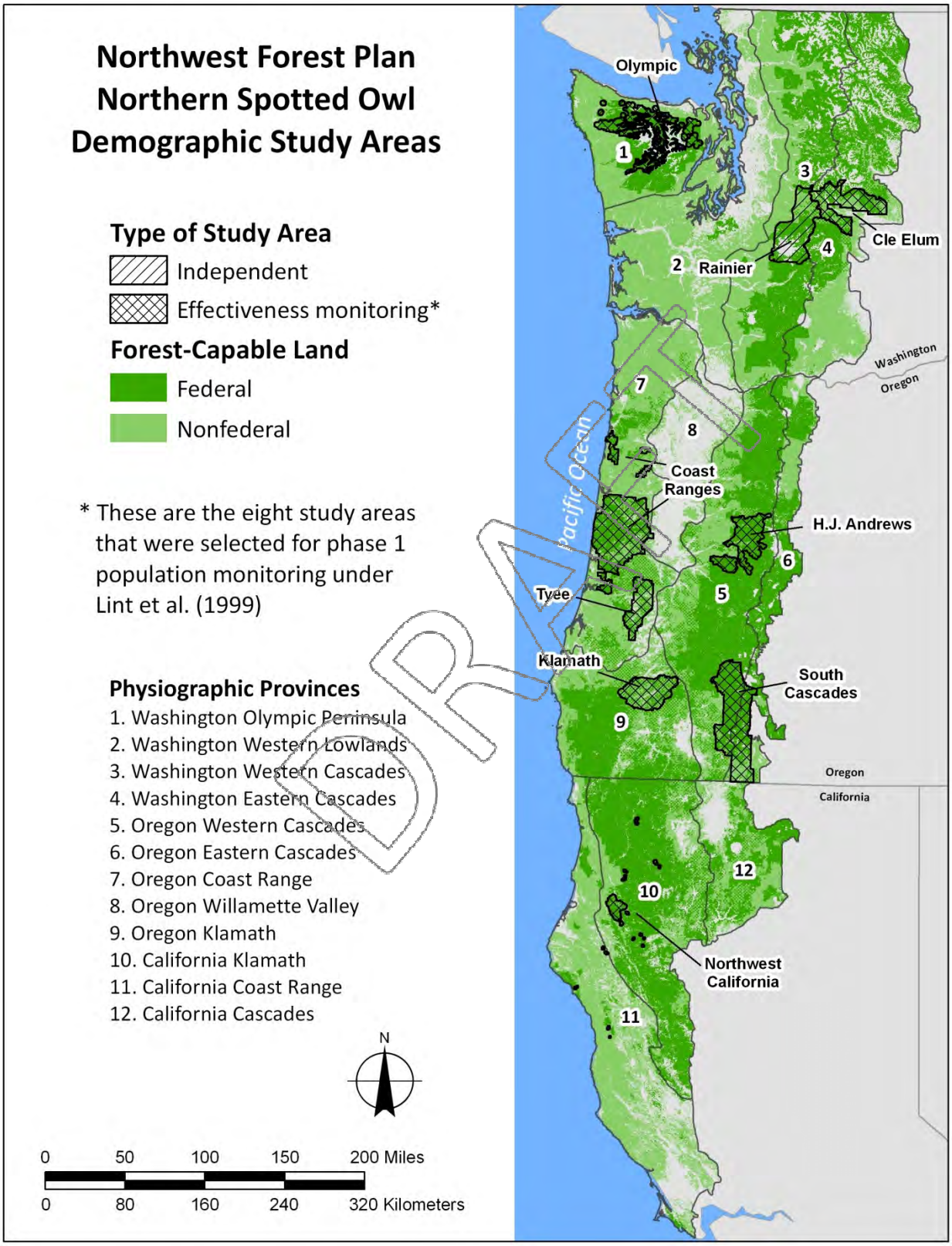

Figure 2-2– Estimates of mean annual rate of population change ( ), with 95-percent confidence intervals for northern spotted owls in nine study areas associated with lands managed under the Plan in Washington, Oregon, and California. Source: Forsman et al. (2011).

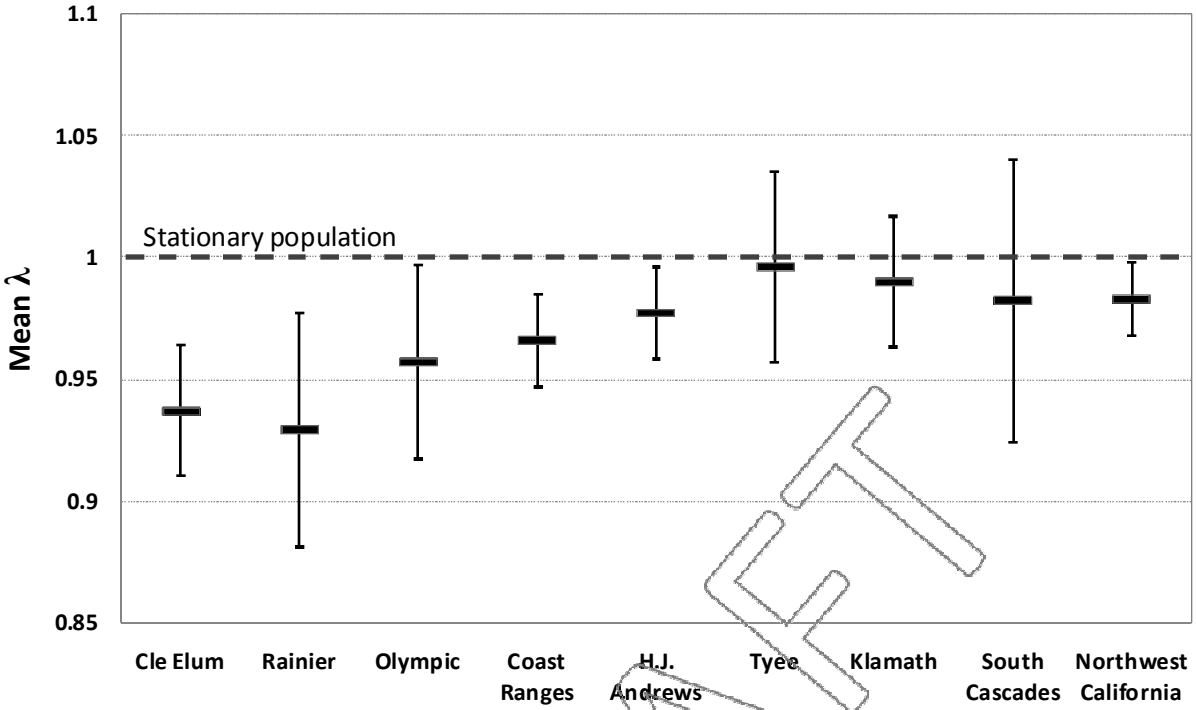

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Figure 2-3–Estimates of realized population change, Δ_t, with 95-percent confidence intervals for northern spotted owls on nine study areas associated with lands managed under the Plan in Washington, Oregon, and California.

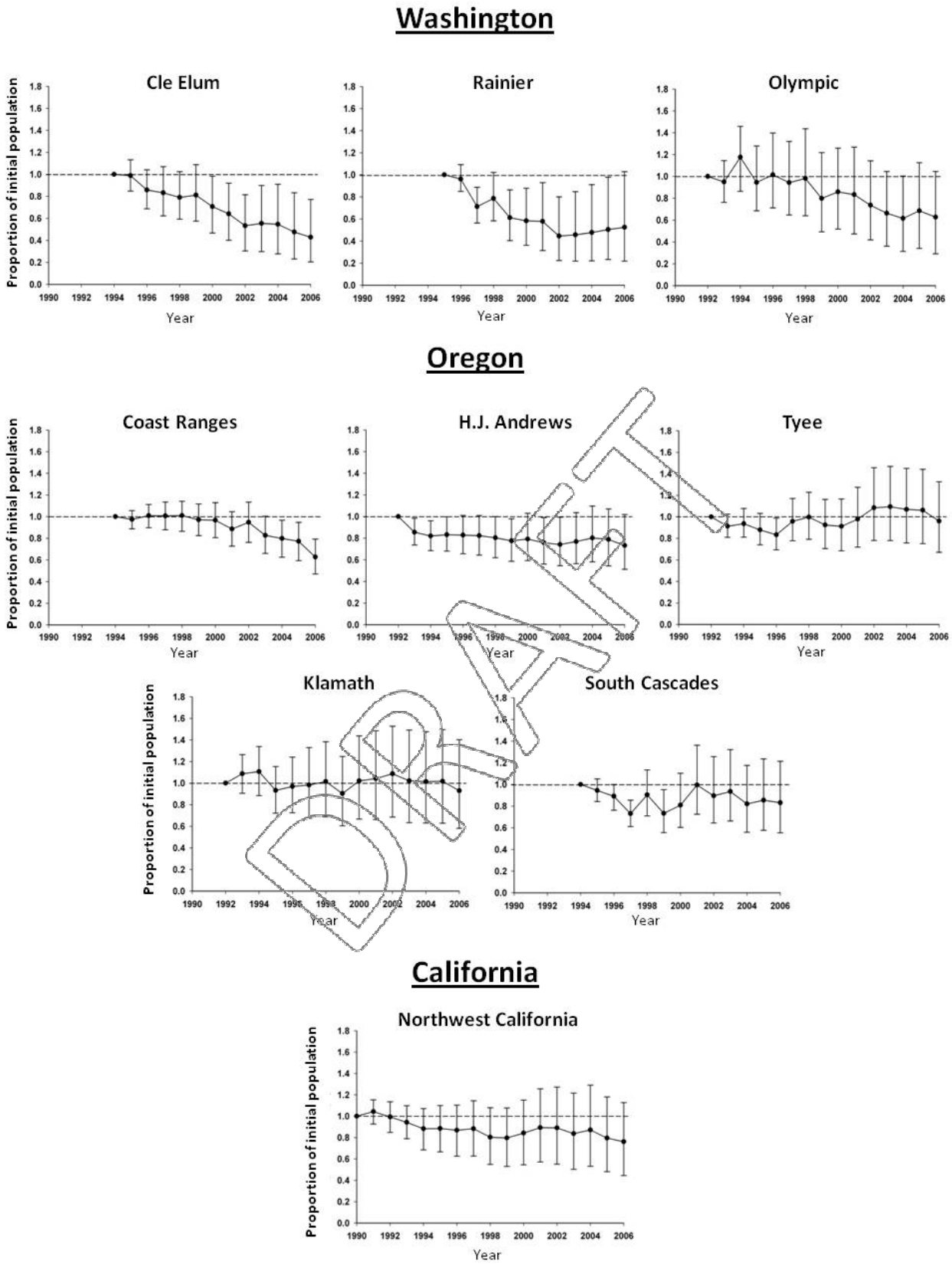

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Table 3-1–Average (± standard deviation) habitat variable values (gradient nearest neighbor) for nesting/roosting habitat classes in each modeling region. This table is intended to provide a general sense of stand structure variable gradients from unsuitable to highly suitable.

Model region	Habitat class	Habitat suitability	Conifer cover	Average conifer d.b.h.[a]	Large conifers (≥30-in d.b.h.)	Diameter diversity	Average Stand height	Average stand age
			--- percent ---	--- inches ---	-- trees/acre --	--- index ---	--- feet ---	--- years ---
Washington Coast and Cascades	Unsuitable	0–6	42 ±29	11 ±10	1 ±3	2 ±2	42 ±30	40 ±57
	Marginal	7–25	79 ±12	17 ±7	3 ±6	5 ±2	76 ±26	73 ±76
	Suitable	26–50	85 ±8	24 ±9	9 ±8	6 ±1	94 ±32	137 ±89
	Highly suitable	51–86	89 ±5	30 ±9	15 ±8	7 ±1	114 ±28	205 ±78
Washington Eastern Cascades	Unsuitable	0–11	48 ±31	13 ±7	1 ±3	3 ±2	45 ±25	87 ±65
	Marginal	12–35	60 ±15	16 ±6	2 ±3	4 ±1	57 ±20	88 ±47
	Suitable	36–50	75 ±10	17 ±6	3 ±5	5 ±1	70 ±20	106 ±54
	Highly suitable	51–93	81 ±9	20 ±7	6 ±7	6 ±1	85 ±23	128 ±58
Oregon Coast Range	Unsuitable	0–9	37 ±31	8 ±9	0 ±1	2 ±2	36 ±26	23 ±20
	Marginal	10–28	61 ±19	19 ±9	1 ±2	4 ±1	74 ±22	46 ±21
	Suitable	29–50	65 ±15	26 ±8	7 ±6	6 ±1	106 ±25	74 ±26
	Highly suitable	51–91	70 ±10	36 ±8	19 ±8	7 ±1	143 ±26	137 ±45
Oregon California Cascades	Unsuitable	0–9	38 ±26	11 ±9	1 ±2	2 ±2	37 ±26	50 ±49
	Marginal	10–30	70 ±15	17 ±6	2 ±5	5 ±1	68 ±24	82 ±60
	Suitable	31–50	76 ±11	22 ±7	7 ±8	6 ±1	91 ±31	123 ±65
	Highly suitable	51–88	82 ±8	29 ±6	16 ±8	7 ±1	115 ±31	185 ±83
Oregon California Klamaths	Unsuitable	0–15	24 ±22	13 ±10	1 ±3	2 ±2	33 ±21	52 ±45
	Marginal	16–37	51 ±20	19 ±10	3 ±5	4 ±2	50 ±24	76 ±47
	Suitable	38–50	60 ±18	25 ±11	7 ±7	6 ±2	66 ±25	111 ±102
	Highly suitable	51–86	65 ±17	29 ±9	11 ±7	7 ±1	95 ±27	151 ±80
California Coast	Unsuitable	0–12	16 ±21	11 ±12	1 ±2	3 ±2	38 ±16	35 ±32
	Marginal	13–35	44 ±20	18 ±9	1 ±2	5 ±2	48 ±20	47 ±22
	Suitable	36–50	64 ±20	24 ±16	5 ±7	5 ±2	63 ±31	57 ±74
	Highly suitable	51–86	78 ±15	24 ±14	7 ±8	6 ±1	84 ±30	78 ±88

[a] d.b.h. = diameter at breast height

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Table 3-2–Estimated fire effects on northern spotted owl nesting/roosting habitat from the 20 largest wildfires between 1996 and 2006.

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

Table 3-3–Habitat fragmentation status and trends based on the percentage of nesting/roosting habitat consisting of core and core-edge habitat. Physiographic provinces are listed in order of least- to most-fragmented federal reserved land allocations based on the status in 1994/96. Negative trend values indicate increased fragmentation.

Physiographic province	Reserved			Nonreserved		
	1994/96	2006/07	Trend	1994/96	2006/07	Trend
	---------- percent ----------			---------- percent ----------		
Washington Olympic Peninsula	72.76	72.75	-0.01	33.22	32.86	-0.36
California Coast Range	68.77	68.81	0.04	46.64	47.19	0.55
Oregon Western Cascades	68.77	67.72	-1.05	59.51	58.39	-1.12
Oregon Coast Range	62.83	62.53	-0.30	39.41	37.77	-1.64
Oregon Klamath	61.69	57.35	-4.34	38.51	36.80	-1.71
Washington Western Cascades	59.23	59.06	-0.17	49.77	49.44	-0.33
Washington Eastern Cascades	55.69	54.39	-1.30	50.89	50.20	-0.69
Oregon Eastern Cascades	55.00	55.04	0.04	48.94	47.28	-1.66
California Cascades	51.70	50.67	-1.03	48.30	45.16	-3.14
California Klamath	49.01	46.31	-2.70	42.22	41.14	-1.08
Washington Western Lowlands	31.34	30.28	-1.06	0.00	0.00	0.00
Oregon Willamette Valley	25.74	25.93	0.19	27.83	26.13	-1.70

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Figure 3-1–Baseline habitat maps for federal lands have evolved over the years. Even so, at the range scale, the general spatial patterns of habitat between them are similar. The differences become more apparent at the finer spatial scales. FEMAT = Forest Ecosystem Management Assessment Team.

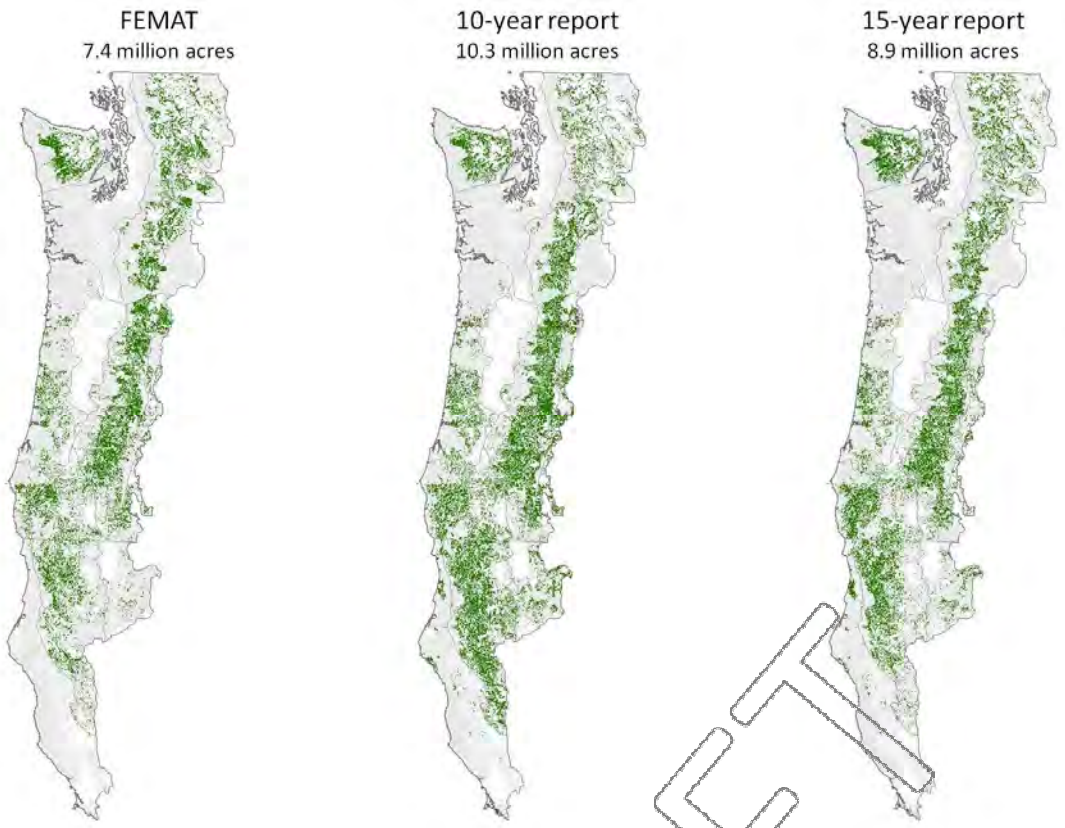

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Figure 3.2: Changes made to the land use allocations since the 10-yr Report (Lint et al. 2005).

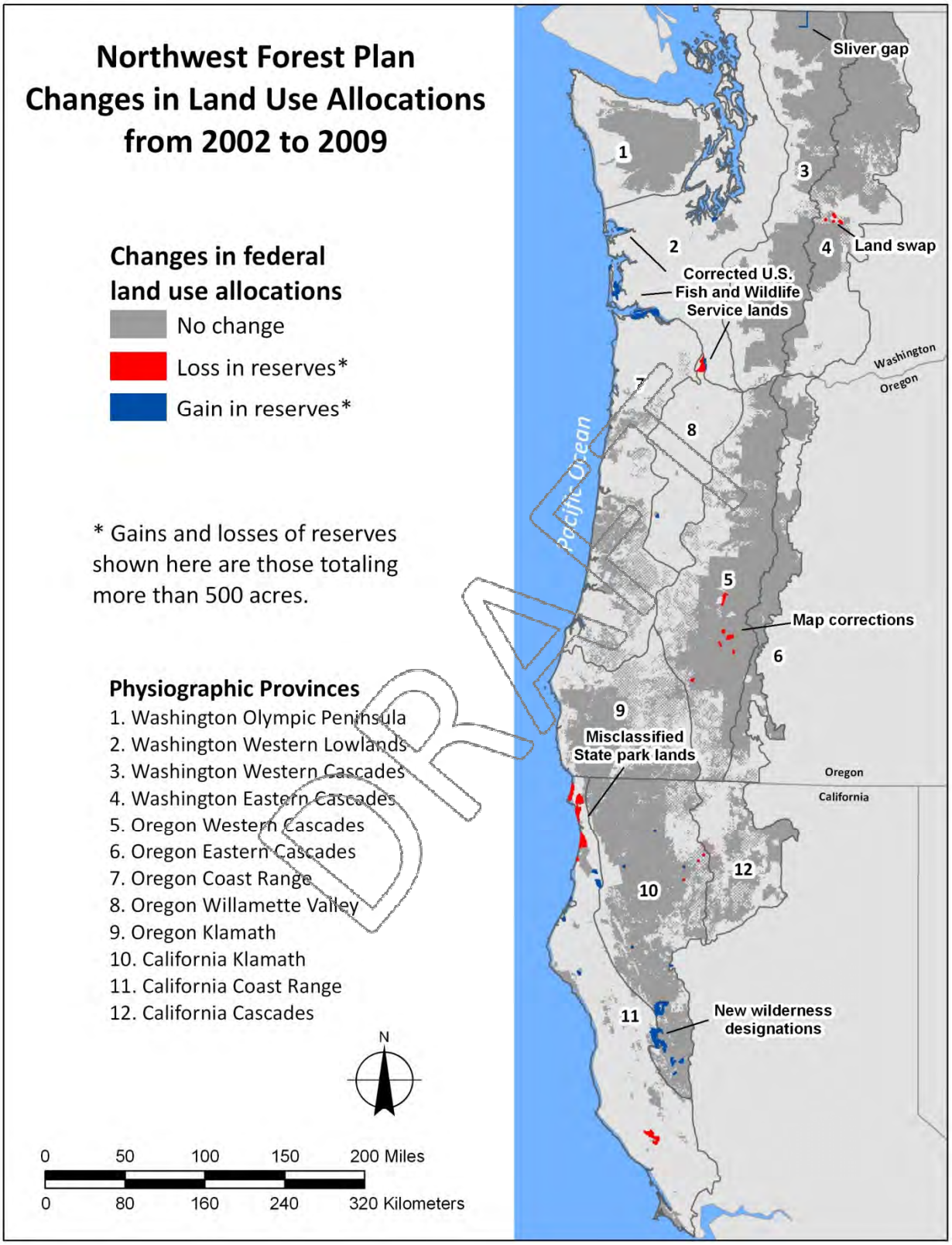

Figure 3-3–Federally administered lands within the range of the northern spotted owl.

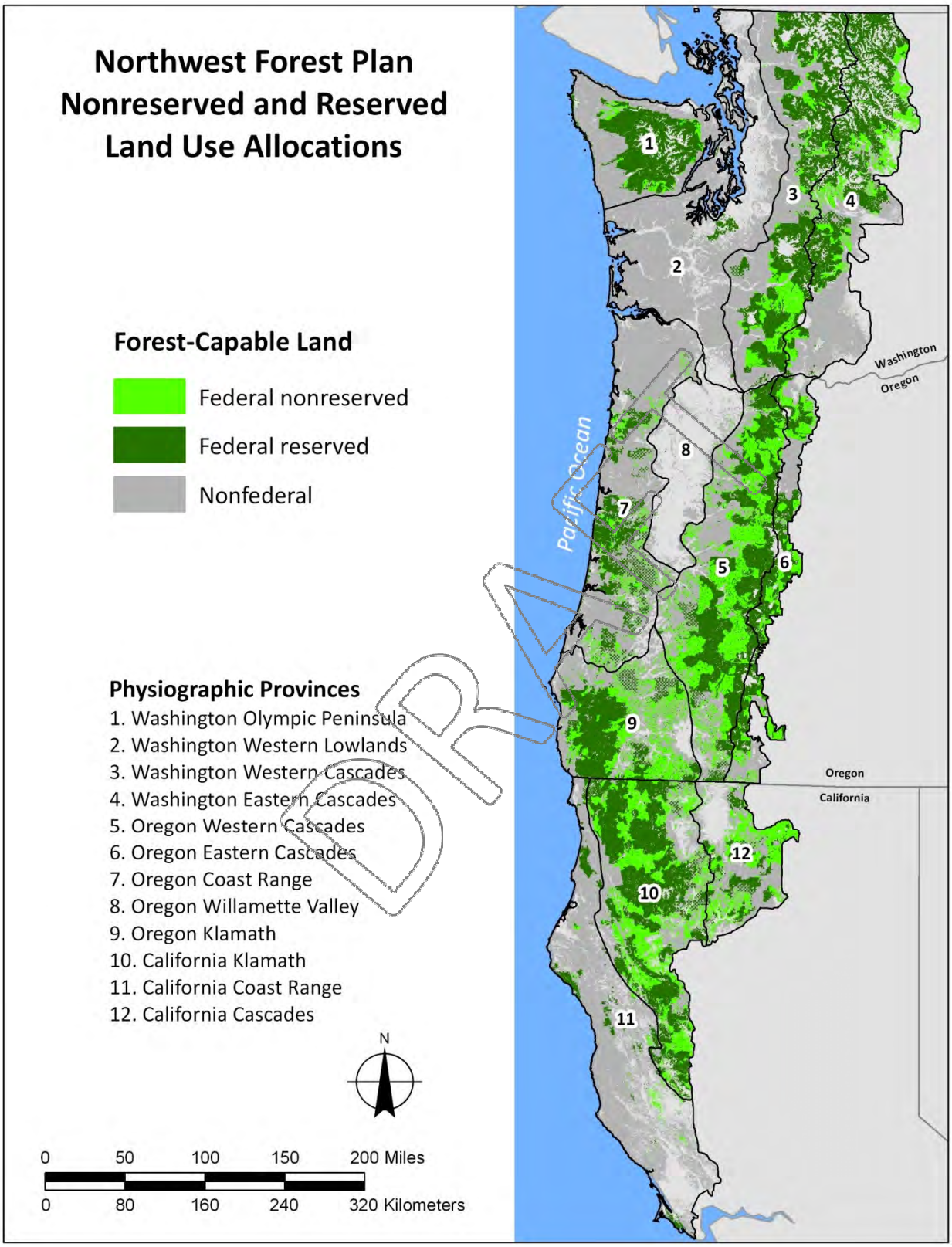

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Figure 3-4–LandTrendr change-detection data (Kennedy et al. 2010).

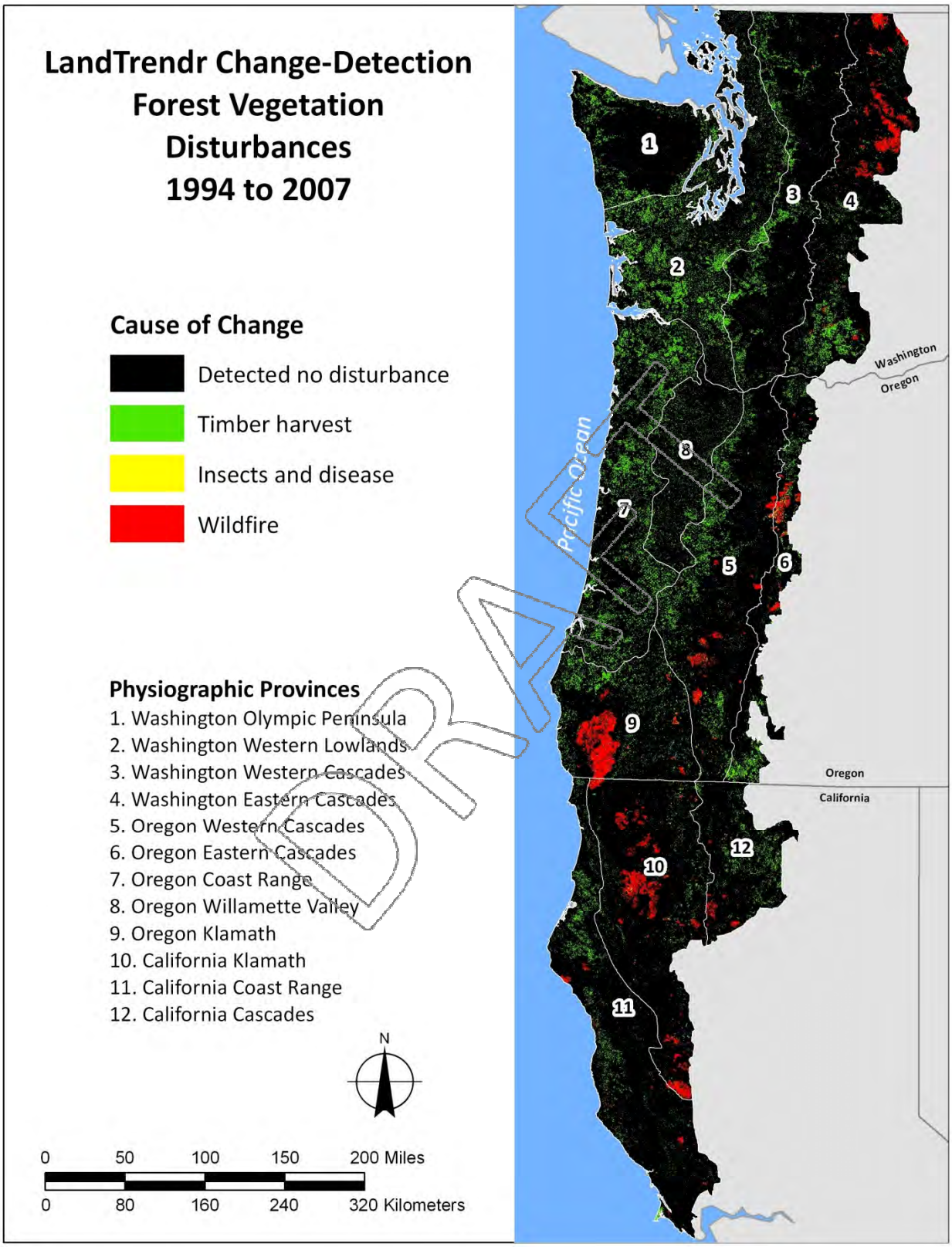

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Figure 3-5–Modeling regions used for modeling northern spotted owl habitat.

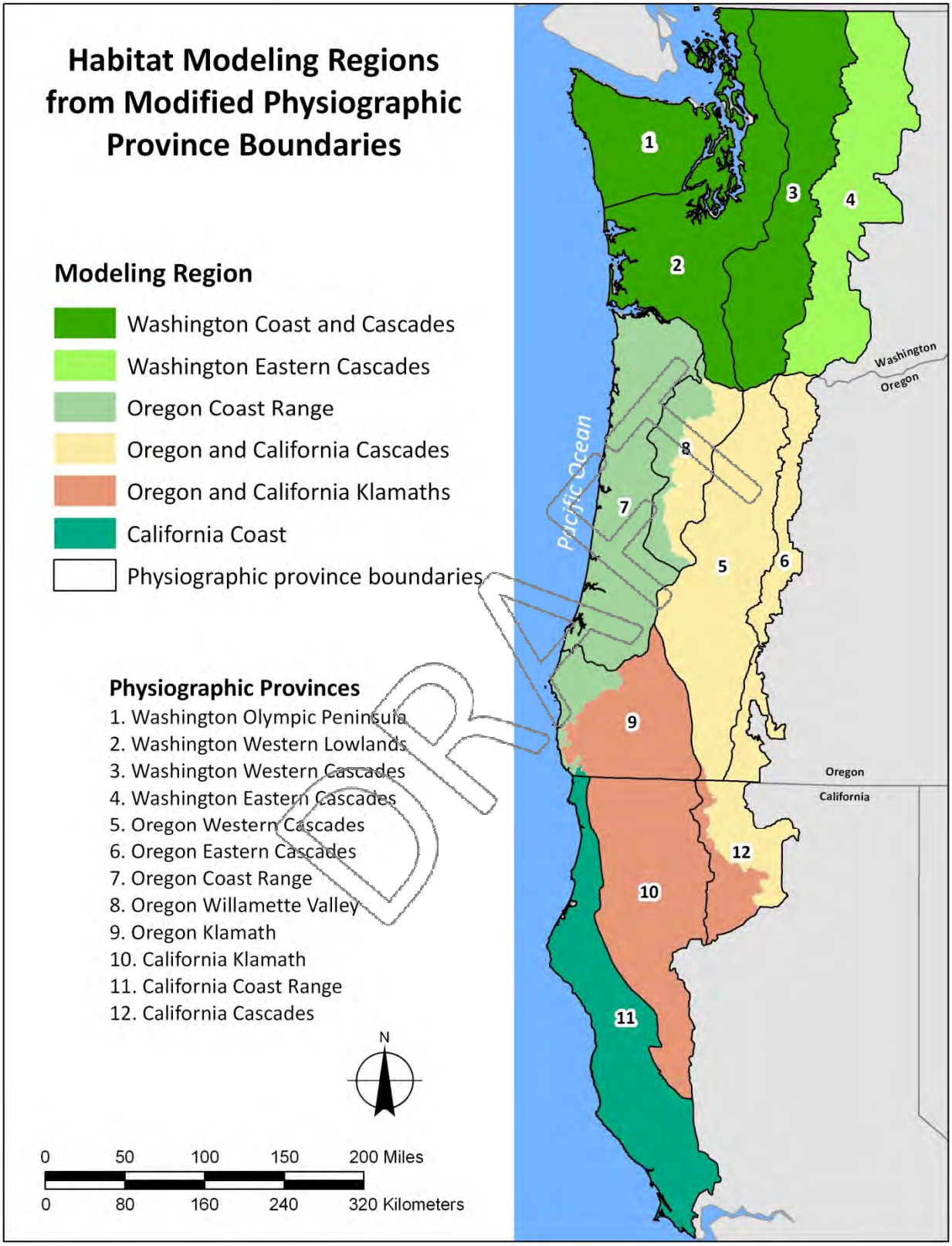

Figure 3-6–The predicted versus expected ratio curve (modified from fig. 6 in Hirzel et al. 2006).

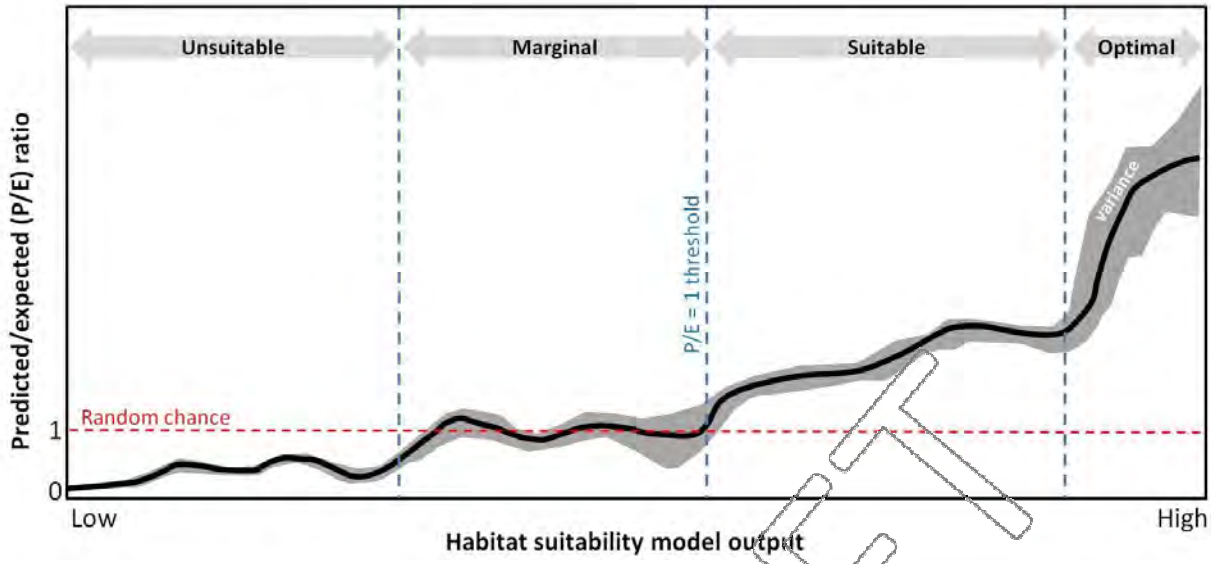

Figure 3.7: Juvenile and nonjuvenile dispersal straight-line paths from Lint et al. (2005) in relation to the amount of dispersal habitat within a 15.5-mi radius that was based on information from Forsman et al. (2002) where only 8.7 percent of dispersing individuals moved more than 31 linear miles.

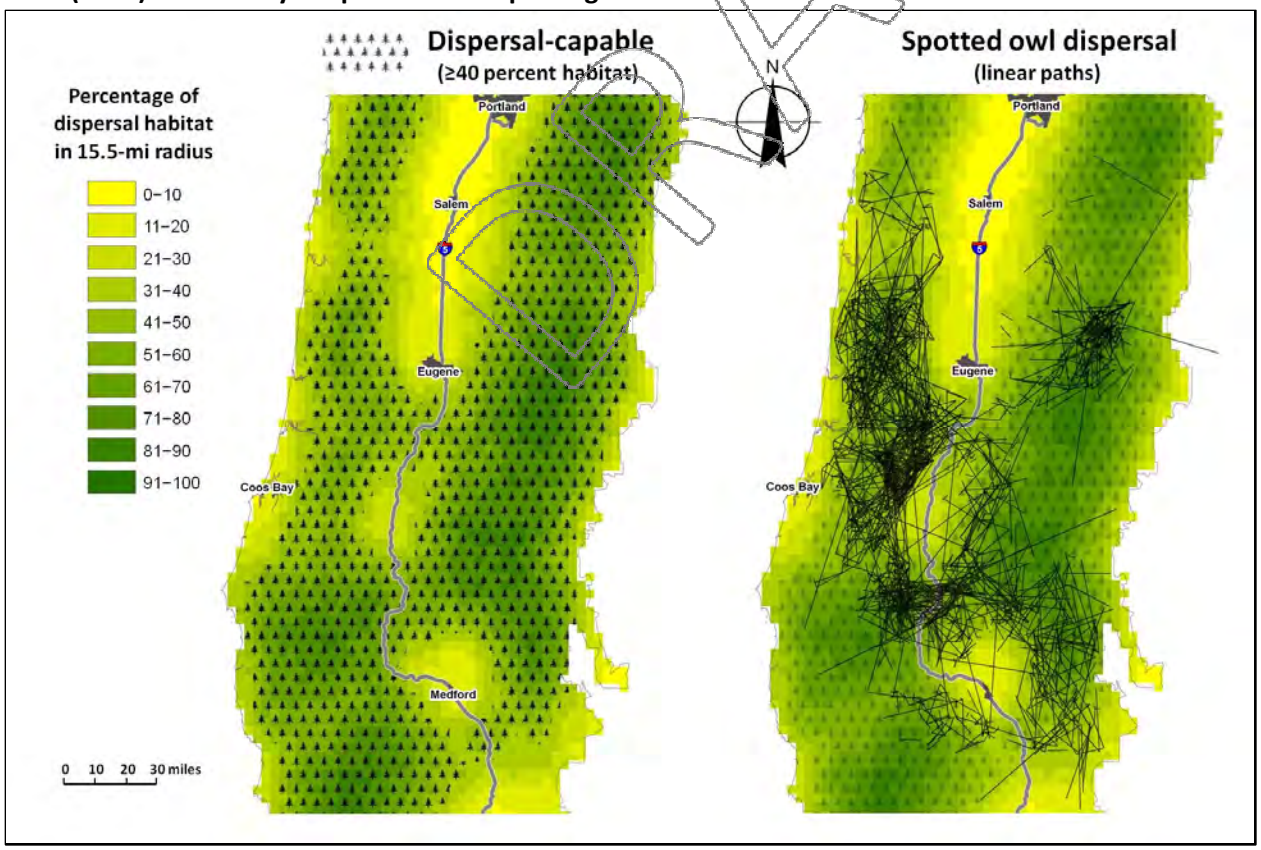

Figure 3-8–Example of the morphological spatial pattern analysis (MSPA) on binary maps of nesting-roosting habitat.

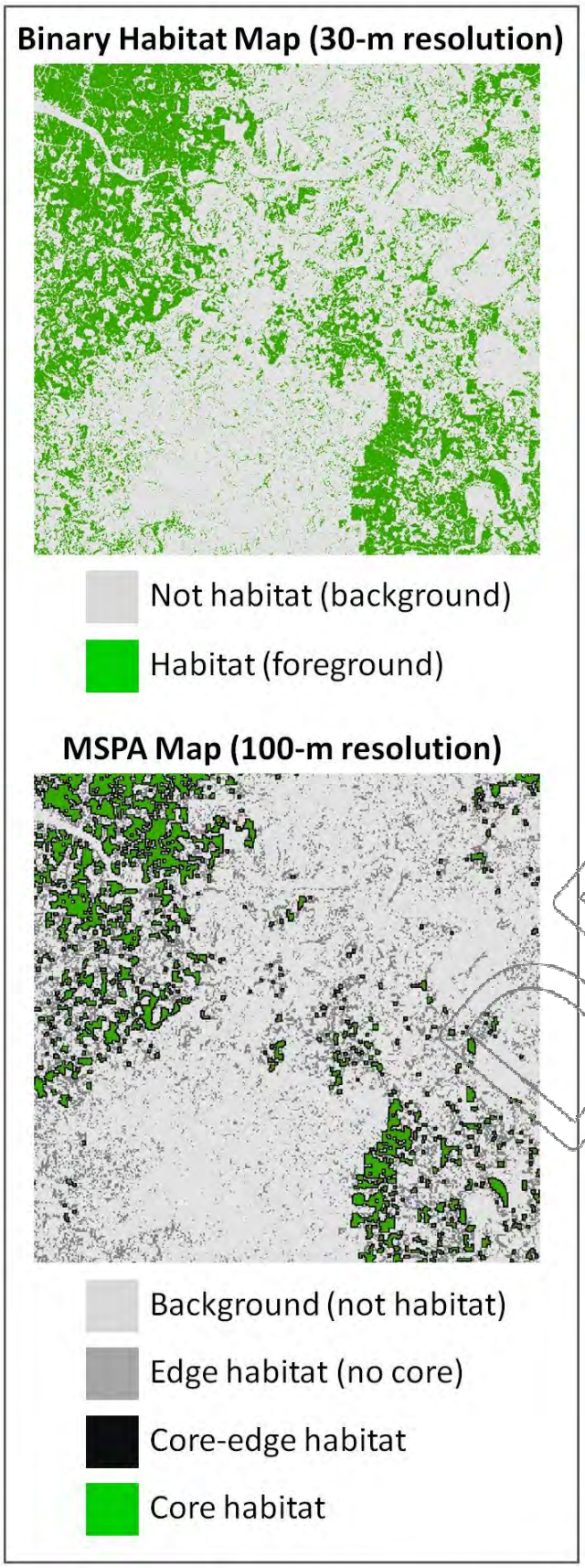

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Figure 3-9–Northern spotted owl habitat suitability map showing the spatial distribution of nesting/roosting habitat as of 2006 (in Oregon and Washington) and 2007 (in California).

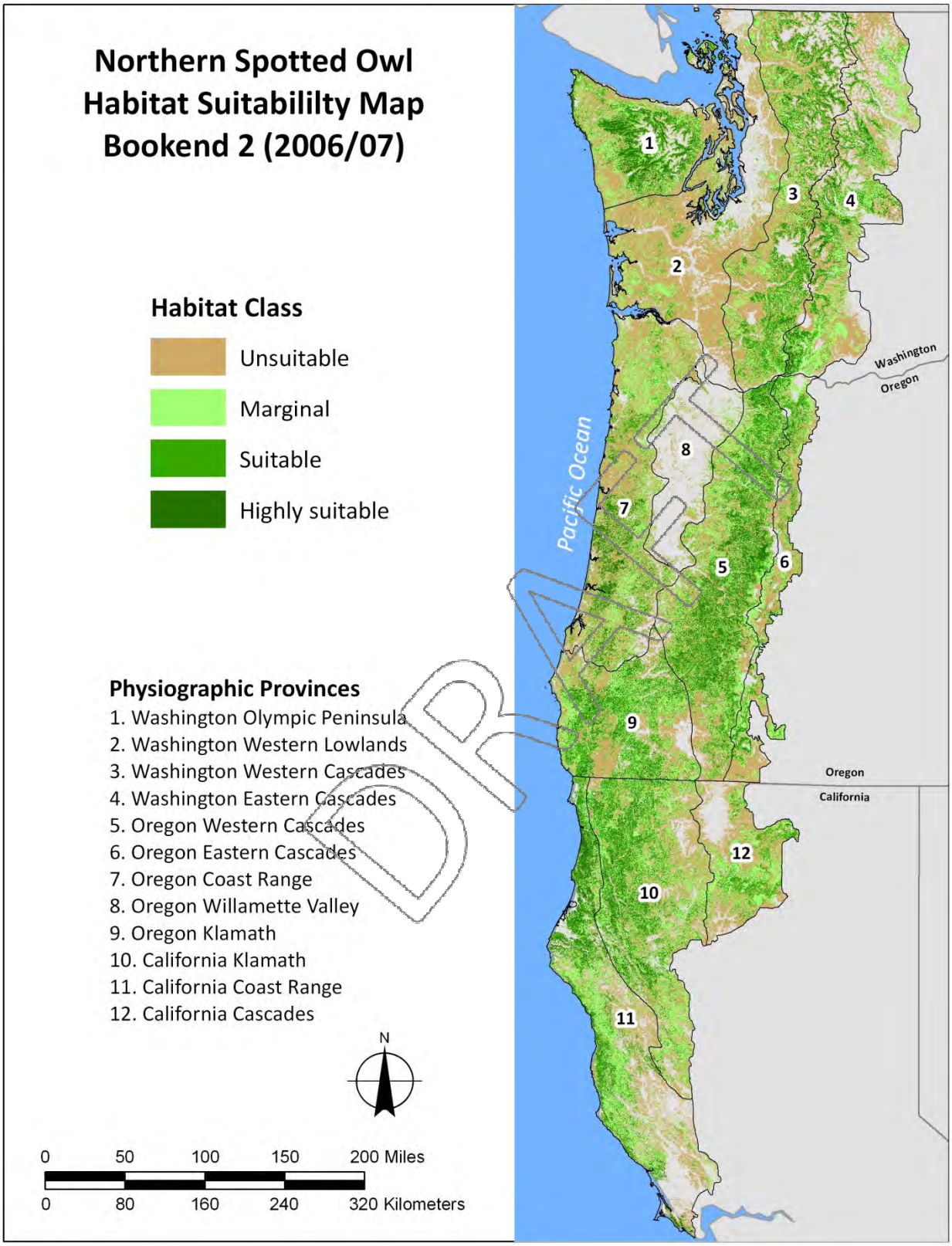

Figure 3-10–Observed differences in average modeled habitat suitability for spotted owl pair locations within demographic study areas between 1994/96 and 2006/07.

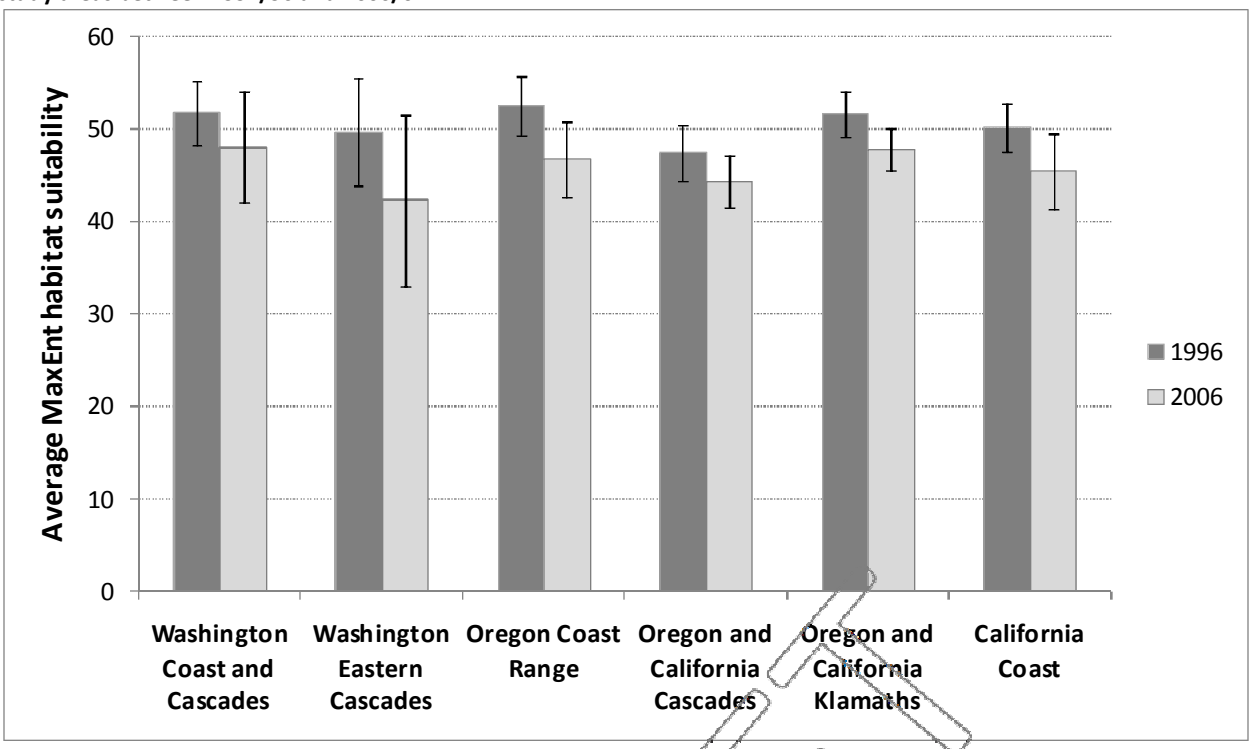

Figure 3-11–Causes of nesting/roosting habitat loss on federally administered lands.

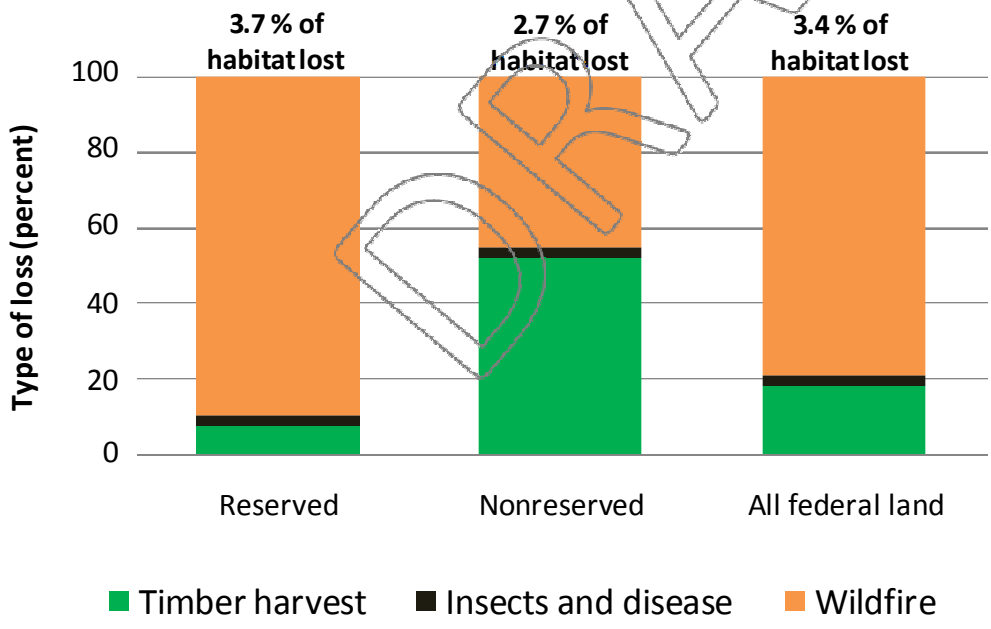

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Figure 3.12–Nesting/roosting habitat trends (based on the LandTrendr analysis) from 1994/96 to 2006/07 by physiographic province for reserved and nonreserved federal lands.

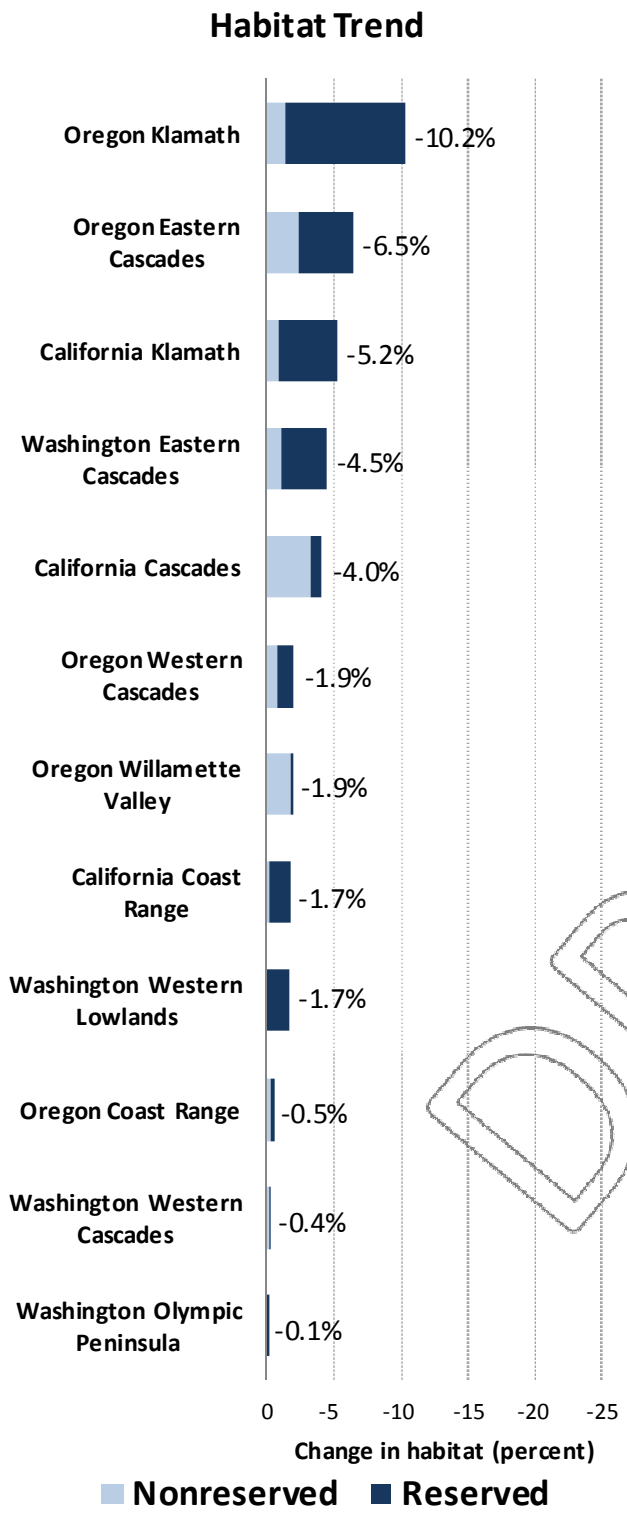

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Figure 3-13–Provincial differences in nesting/roosting habitat losses from the fires in Table 3-2.

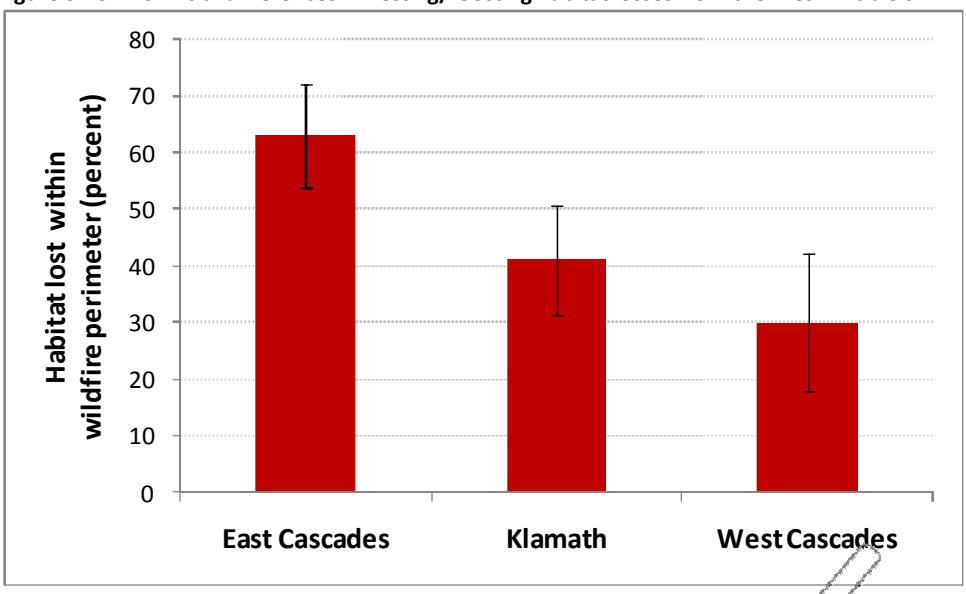

Figure 3-14–Provincial differences in nesting/roosting habitat degradation from the fires in Table 3-2.

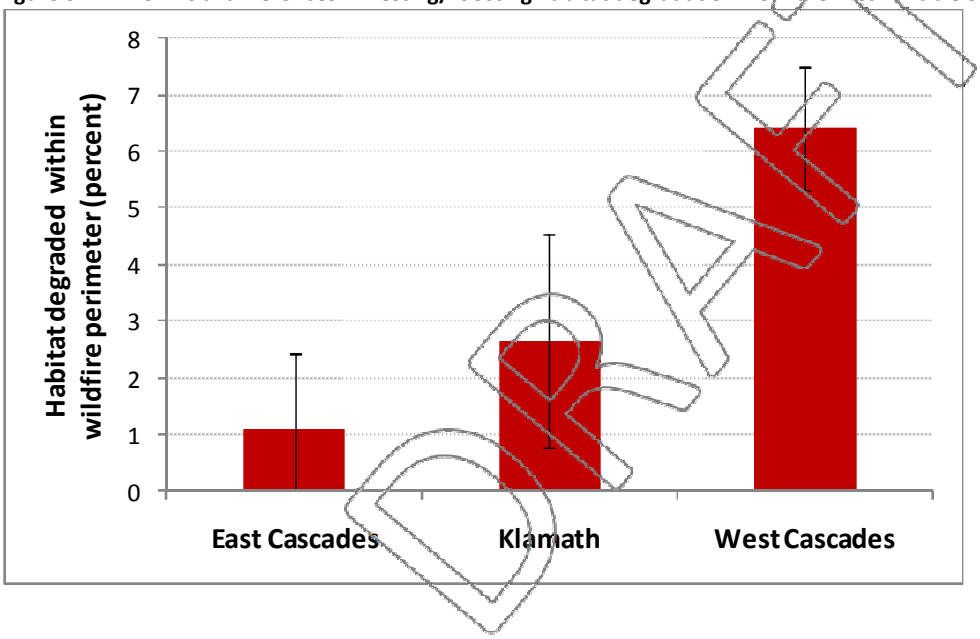

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Figure 3-15–Causes of dispersal habitat loss on federally administered lands.

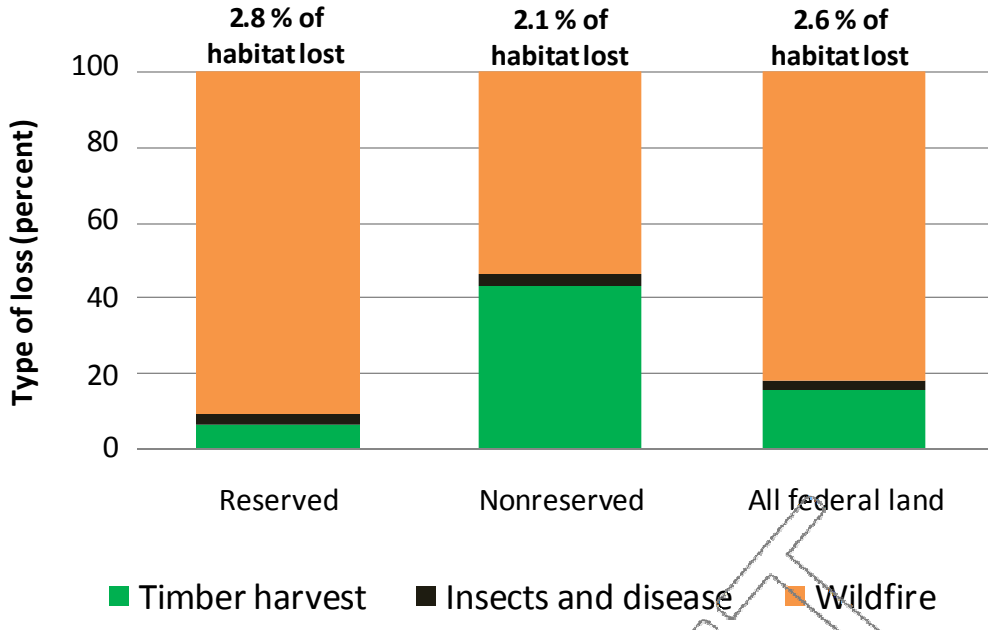

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Figure 3-16–Recruitment of dispersal habitat in the Oxbow Fire (1966) in the Oregon Coast Range.

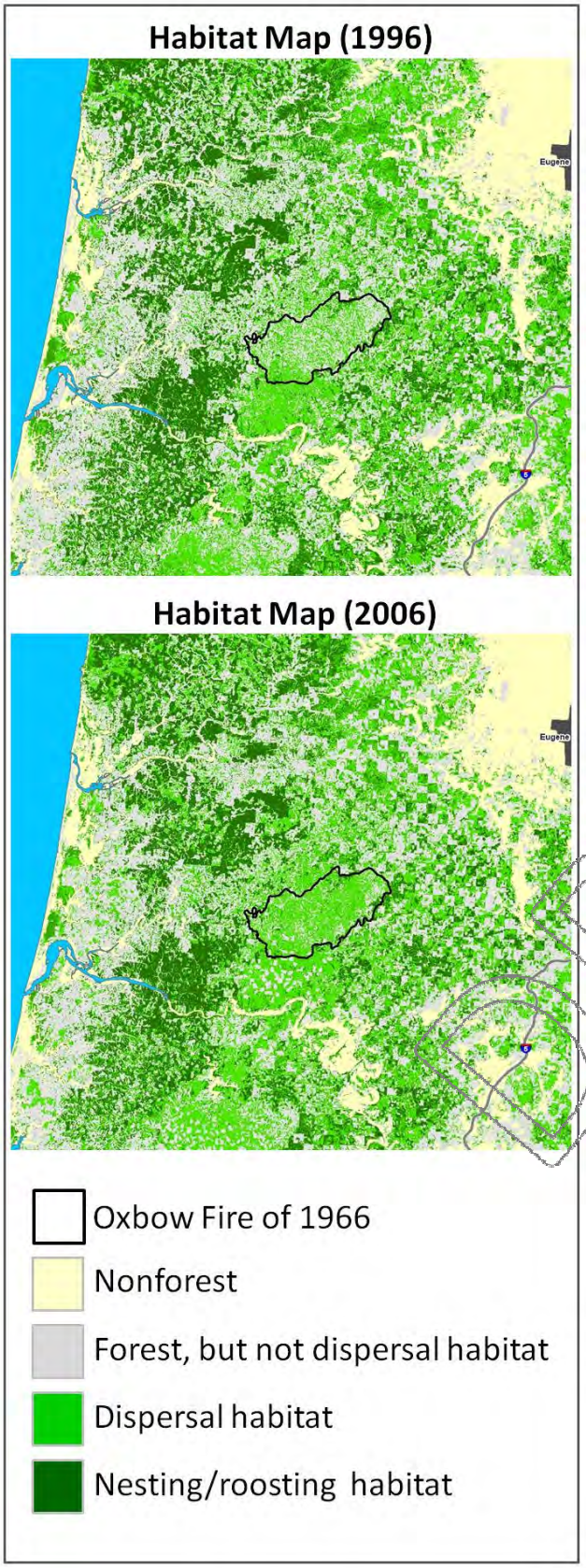

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Figure 3-17–Changes in dispersal-capable landscapes across the owl's range.

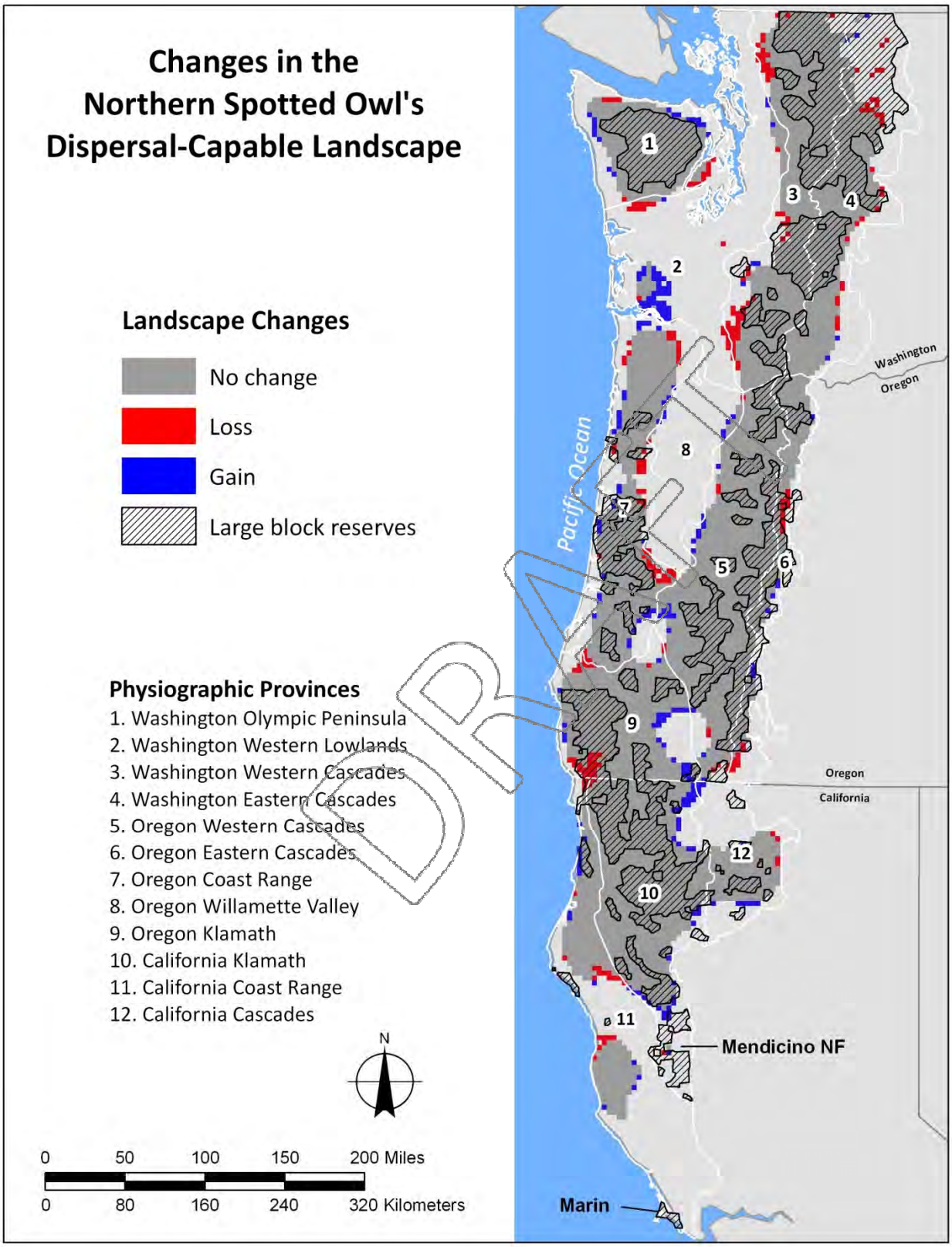

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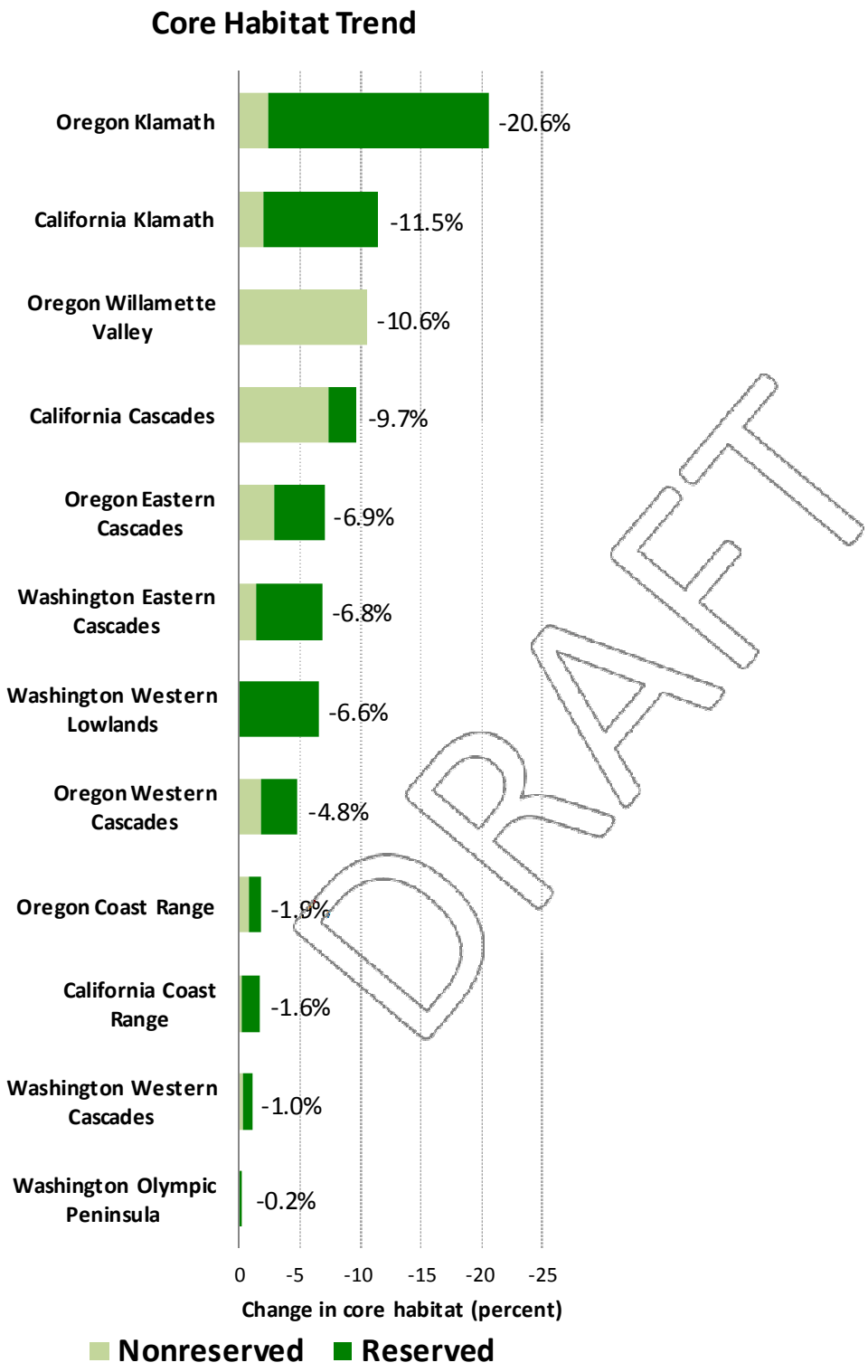
Figure 3-18–Nesting/roosting "core" habitat trends from 1994/96 to 2006/07 by physiographic province for reserved and nonreserved federal lands.



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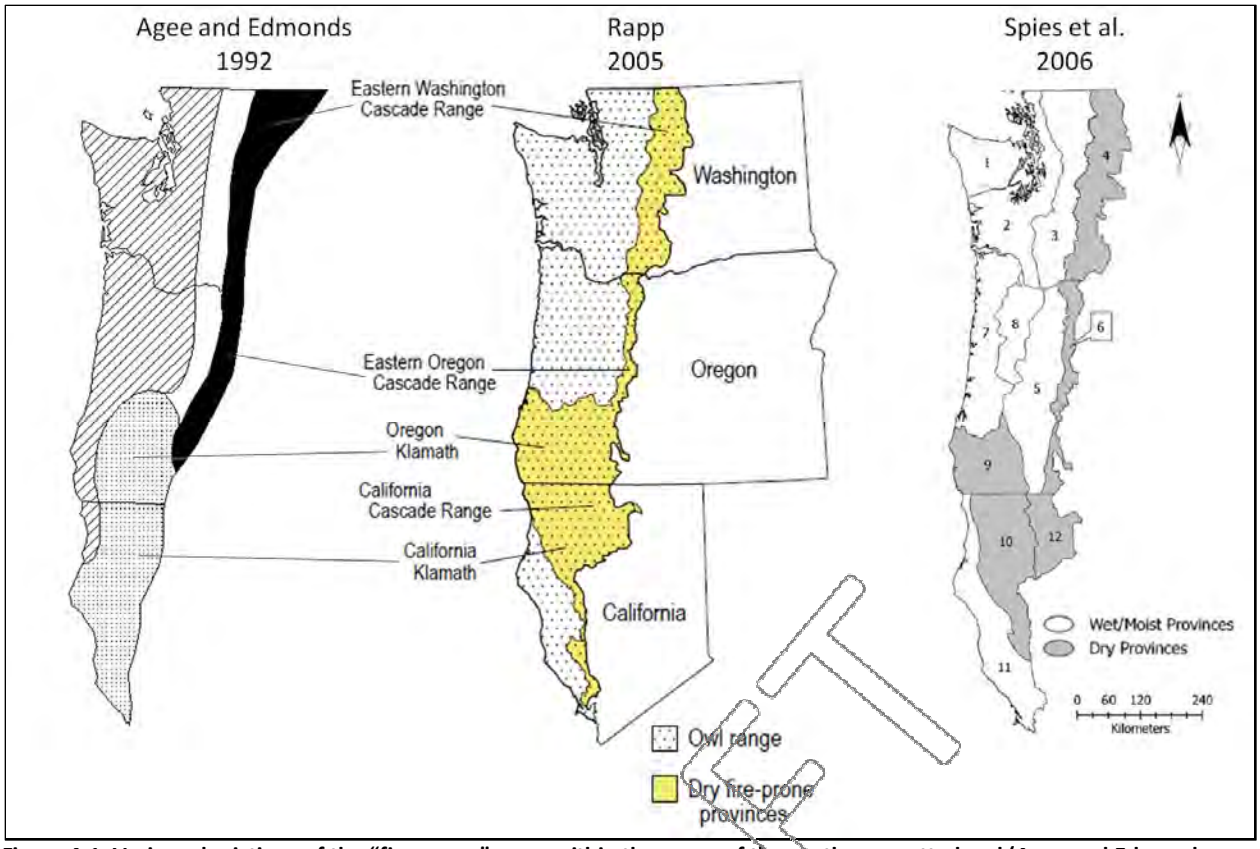

Figure 4-1–Various depictions of the "fire-prone" areas within the range of the northern spotted owl (Agee and Edmonds 1992, Rapp 2005, Spies et al. 2006).

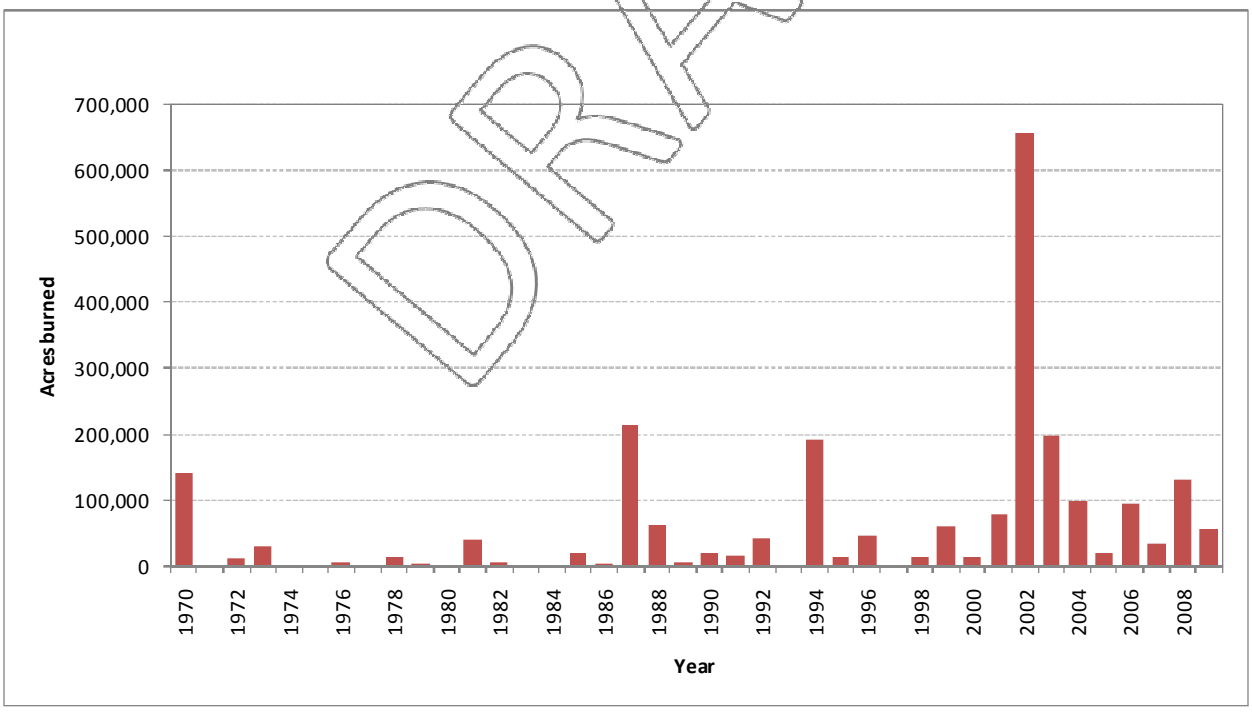

Figure 4-2–Frequency histogram of acres burned by wildfires within the range of the northern spotted owl between 1970 and 2009 (data sources from large wildfire data from this analysis).

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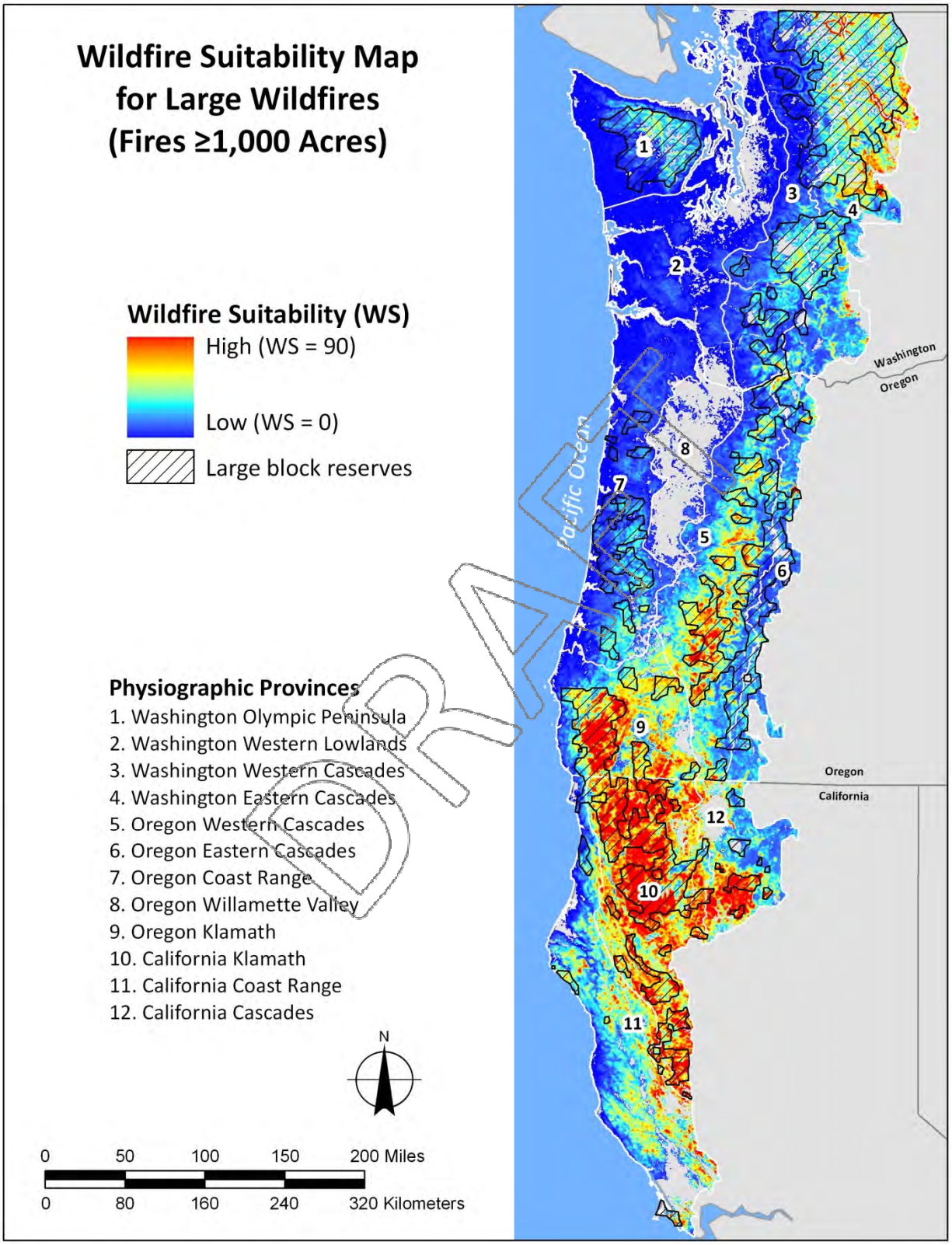

Figure 4-3–Although large (≥1,000 ac) wildfires are known throughout the entire range of the owl, this wildfire suitability map represents the likelihood for occurrence of these fires based on three decades of large wildfire occurrence and the underlying combination of "fire environment" variables from where they occurred (see fig. 4-4).

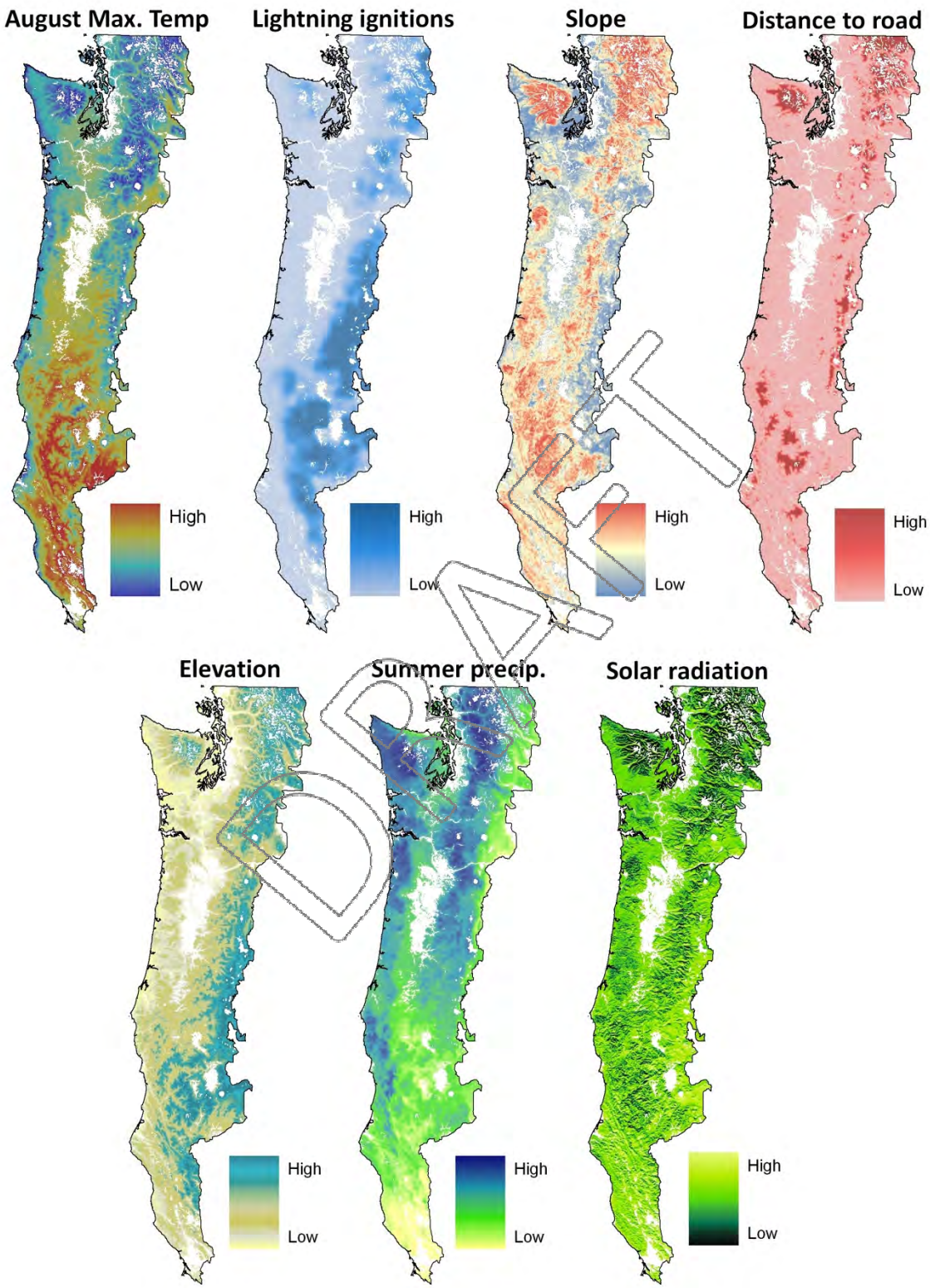

Figure 4-4–Environmental variables used in the model to define the "niche" of large wildfires in the owl's range.

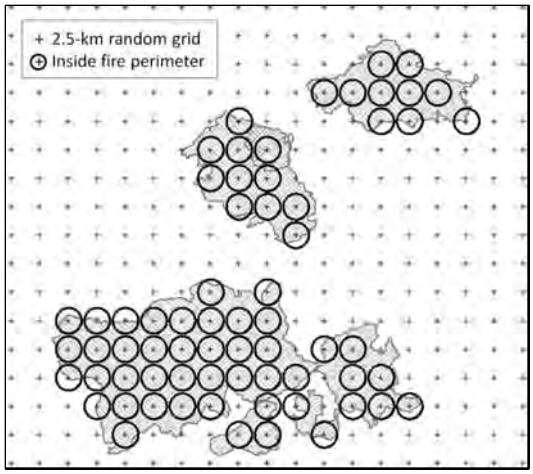

Figure 4-5–Model training and testing data came from grid points that occurred within large-fire perimeters. Points were spaced by 2.5 km to reduce spatial autocorrelation of environmental data, which were averaged within 1,000-ac circles as shown in this figure.

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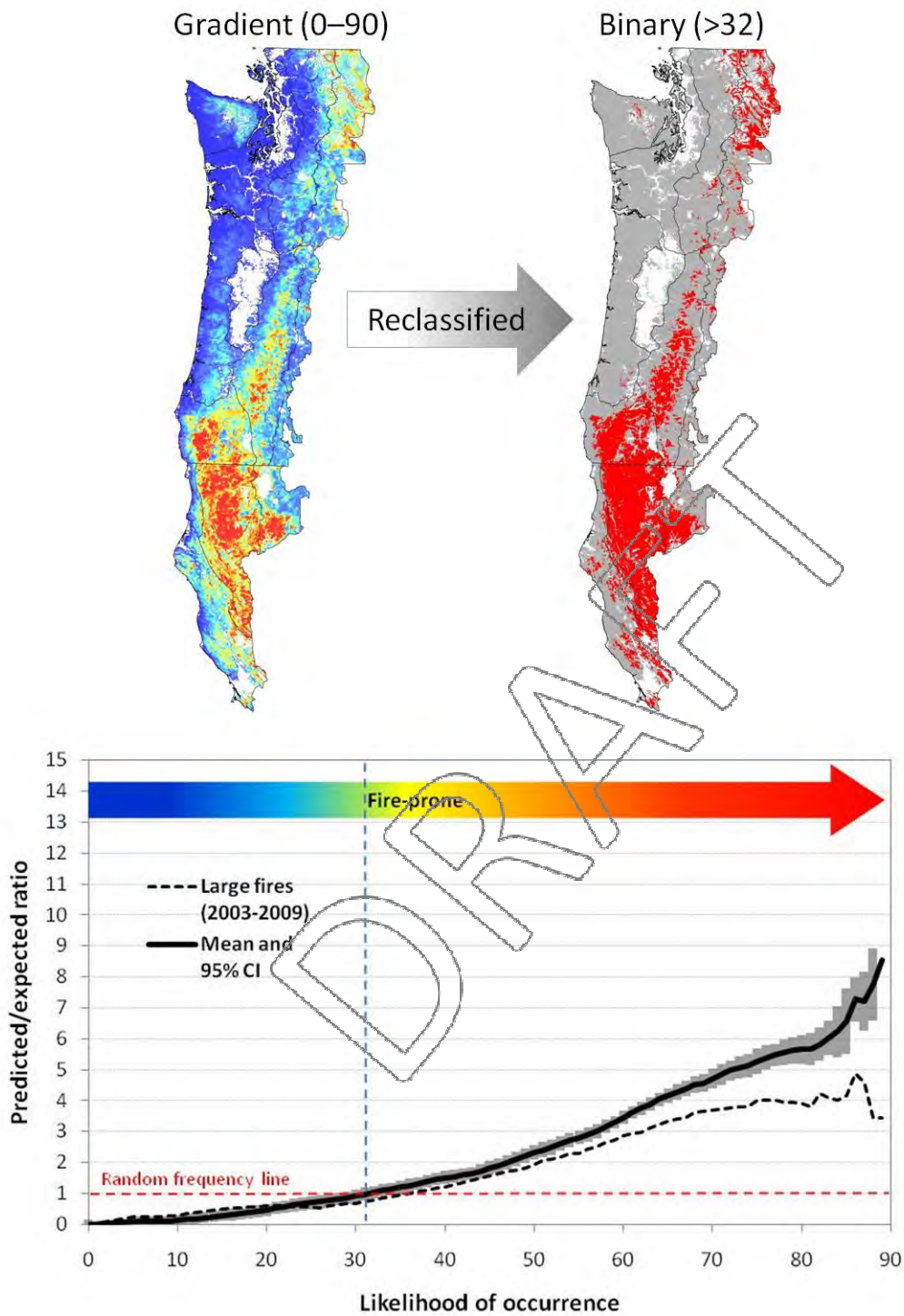

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Figure 4-6–Results of model bootstrapped replicates (based on fire data from 1970-2002) and independent testing (dashed-line based on fire data from 2003-2009) are shown in this predicted vs. expected curve (Hirzel et al. 2006). The curves indicate that the model performed well in both tests. The point at which the mean curve crosses the random frequency line (P/E=1) is used as the threshold modeled likelihood value (>32) for delineating the "fire-prone" areas of the binary map from the full gradient map. The gray-shaded area along the mean curve represents the 95-percent confidence intervals (95% CI) from the bootstrapped replicates.

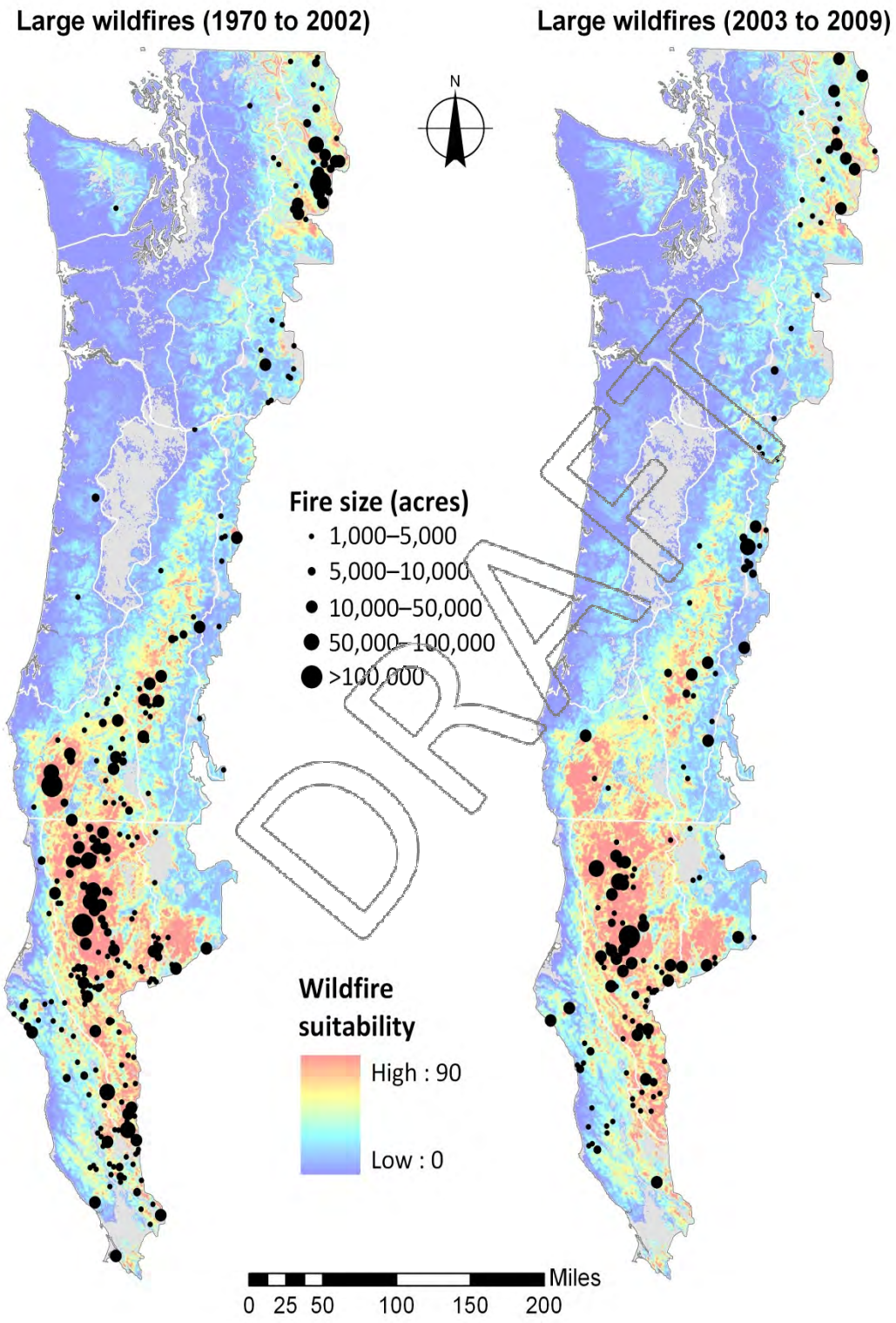

Figure 4-7–The full gradient version of the wildfire suitability model showing locations of large wildfires used to train the model (left) and locations of large wildfires that occurred after 2002 (right) that served as our independent testing data.

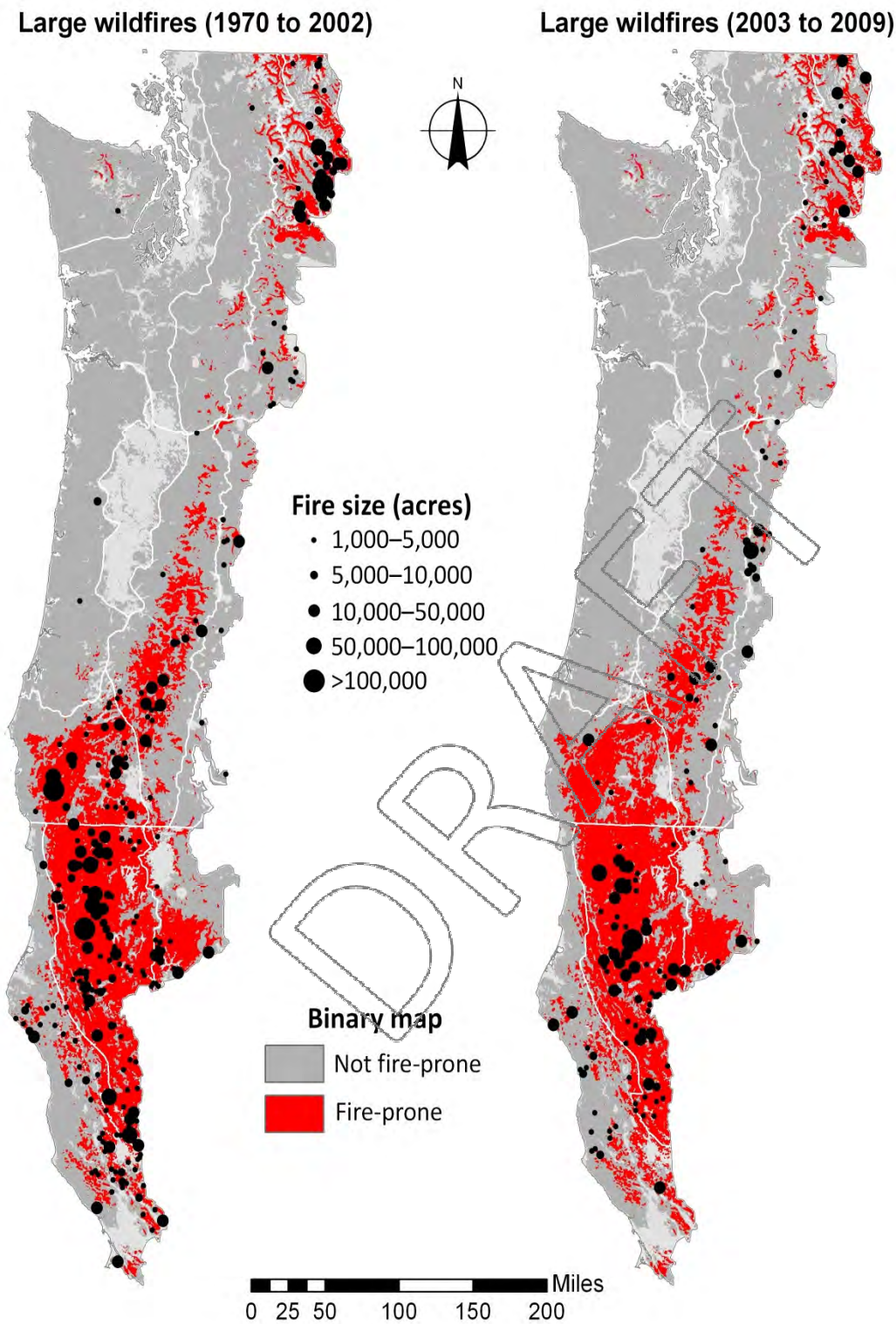

Figure 4-8–The binary version of the wildfire suitability model showing locations of large wildfires used to train the model (left) and locations of large wildfires that occurred after 2002 (right) that served as our independent testing data.

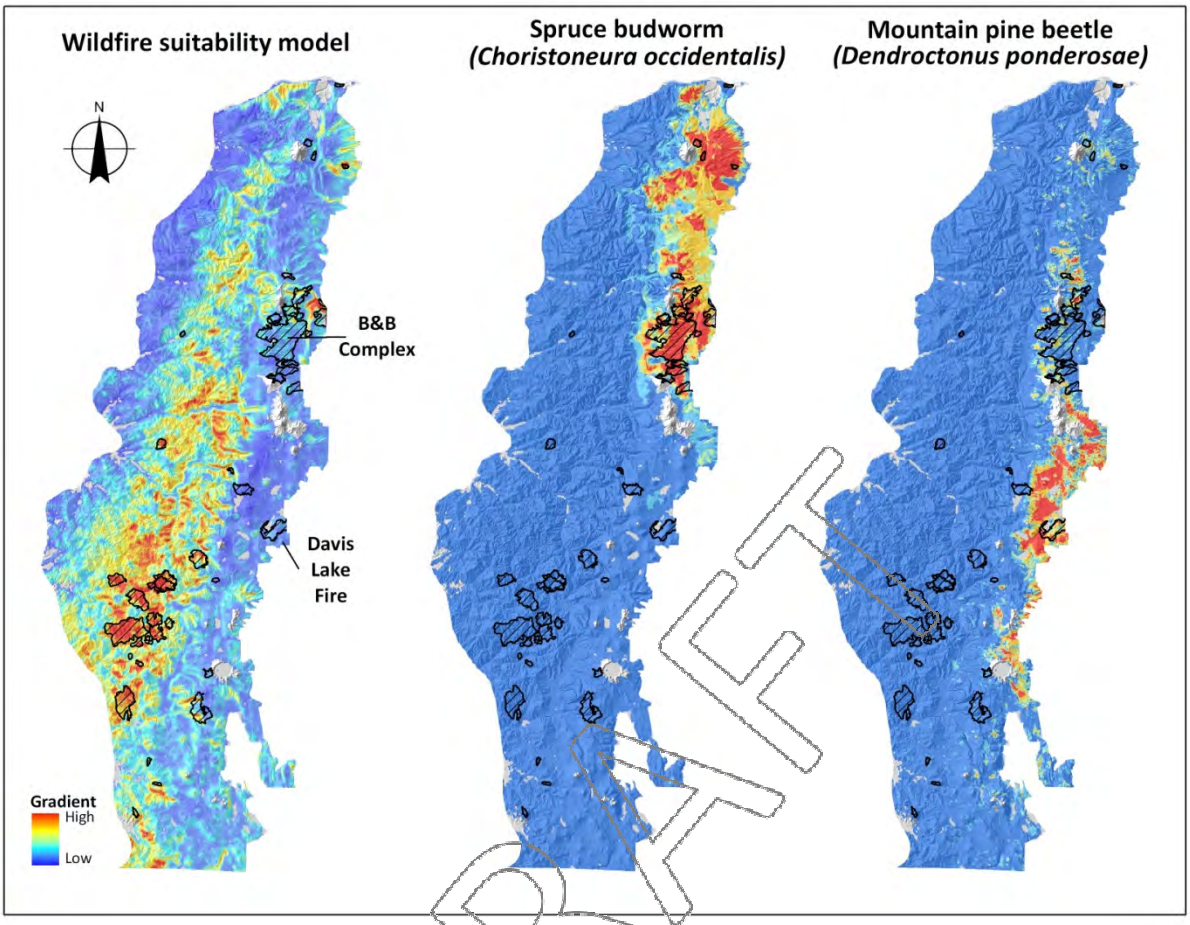

Figure 4.9–Episodic outbreaks of insects in the Oregon Cascades provinces beginning in the 1980s, shown above, may help explain why portions of the eastern Cascades of Oregon have experienced recent large wildfires in areas where the wildfire suitability map indicates lower wildfire suitability (blue indicates lower amounts in the maps above, such as wildfire suitability or years of insect detection, whereas red indicates higher amounts). Large wildfires from 1970-2009 are shown as black cross-hatched polygons.

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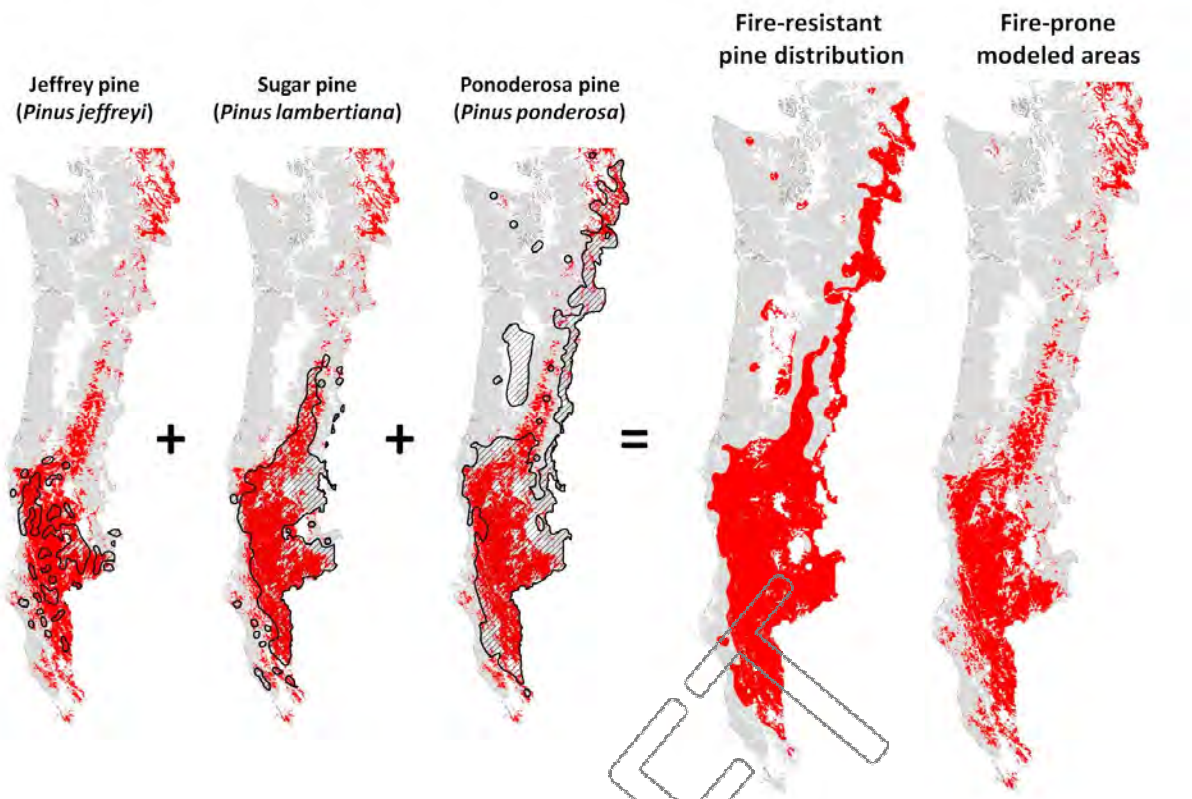

Figure 4-10–Fire-resistant pine distribution maps that were delineated in 1971 (Little 1971, USDI 1999) overlaid on the wildfire suitability binary map.

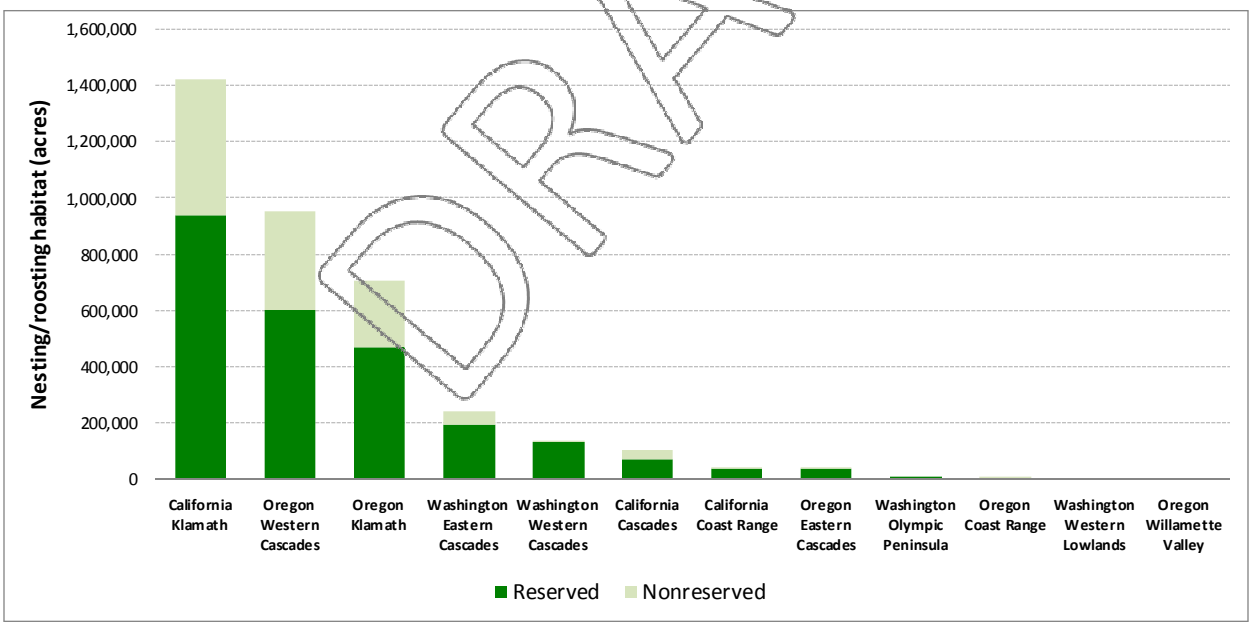

Figure 4-11–Fire-prone spotted owl nesting/roosting habitat, both reserved and nonreserved, by physiographic province. The majority of the fire-prone habitat occurs within the Klamath provinces, and the southern portions of the Oregon Western Cascades. Over half is in reserved land use allocations.

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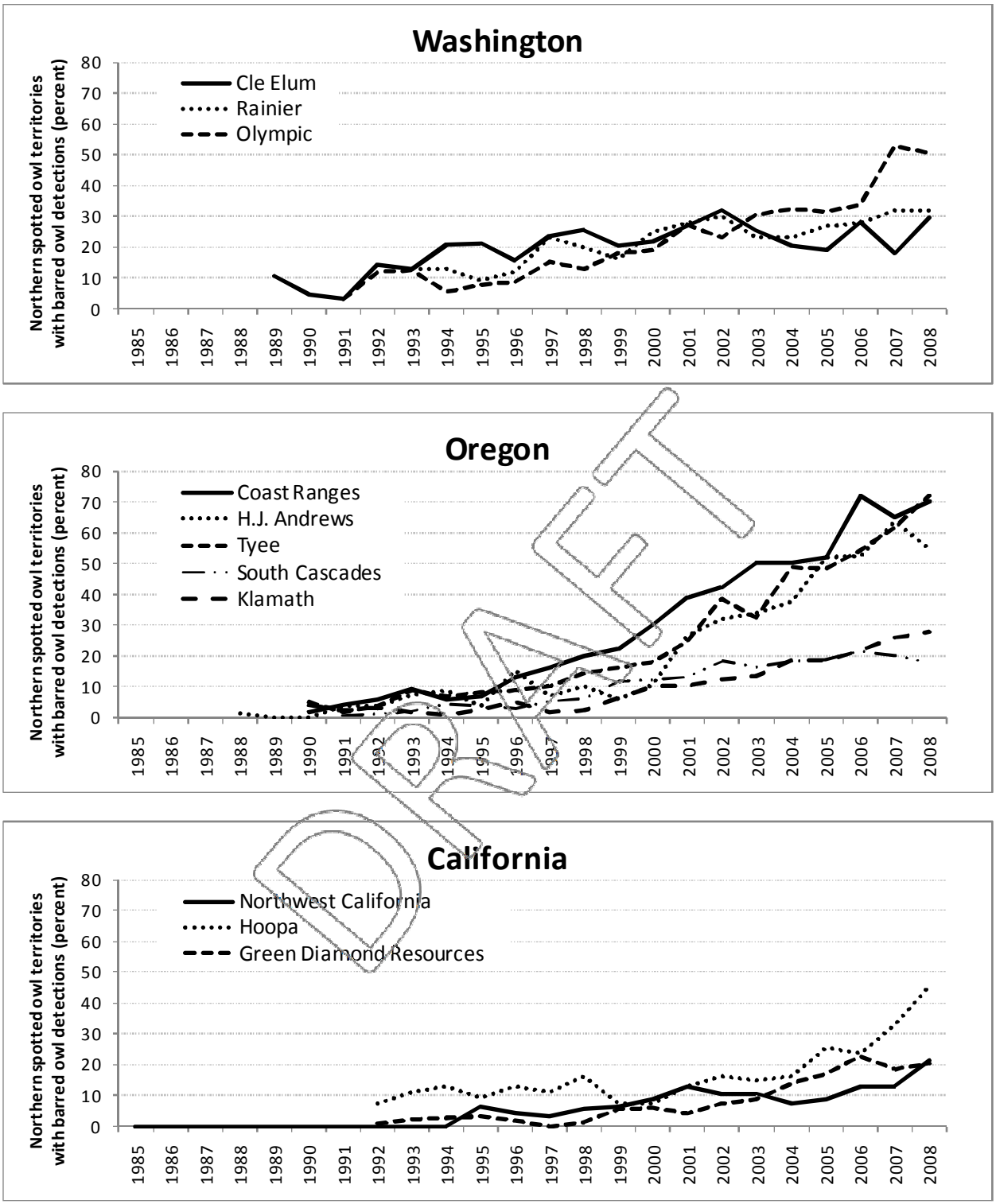
Figure 5-1–Annual proportion of northern spotted owl territories with barred owl detections on study areas in Washington, Oregon, and California. Source: adapted Forsman et al. (2011).



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