MODELING SUPPLEMENT to the Final Rule to Revise Critical Habitat for the Northern Spotted Owl, submitted to the Federal Register November 21, 2012

Modeling and Analysis Procedures used to Identify and Evaluate Potential Critical Habitat Networks for the Northern Spotted Owl

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BACKGROUND

This document serves as a technical supplement to the 2012 Final Rule to Revise Critical Habitat for the Northern Spotted Owl, and is referenced in that rule as our "Modeling Supplement" (Dunk et al. 2012b). This supplement provides technical information and a chronological history of the modeling process utilized by the U.S. Fish and Wildlife Service (Service) to identify and evaluate potential critical habitat networks for the northern spotted owl (*Strix occidentalis caurina*). Additionally, Appendix A of this document provides responses to some of the more technical comments we received on the proposed revised critical habitat designation (77 FR 14062; March 8, 2012) regarding the modeling used to develop both the proposed and final revised critical habitat rules. The modeling framework we used was initially developed as part of the Revised Recovery Plan for the Northern Spotted Owl (USFWS 2011), and is described in detail in Appendix C of that plan. Appendix C of the Revised Recovery Plan provides the fundamental aspects of the process that underlies the discussion that follows. For those who are not familiar with Appendix C, we recommend reading Appendix C first to fully understand this document. We have provided Appendix C of the Revised Recovery Plan as an attachment to this document.

INTRODUCTION

This paper does not utilize the traditional scientific manuscript structure (Introduction, Methods, Results, and Discussion). Due to the complexity of the modeling process, we believe this chronological style leads to a document that is easier to follow and understand. We consistently base our evaluations on the best scientific information available, while acknowledging that this information is clearly incomplete. However, it is important to recognize that the best scientific information and data *available* differ from the best *possible* scientific information. We do our best to recognize and articulate uncertainties, and the relative strength of evidence for information versus our use of professional judgment or other sources of information for making recommendations.

There are likely to be multiple defensible approaches to the challenge of identifying a species' critical habitat. We conjecture that most rigorous alternative approaches should result in similar areas being identified as essential for the species of interest. The approach we have adopted makes use of the best available quantitative modeling tools, and is designed to be thorough, transparent, and repeatable.

Guiding Principles

Our critical habitat evaluation process began with the statutory definition of critical habitat, which is aimed at identifying lands occupied at the time of listing containing the physical and biological features essential to the conservation of the species as well as unoccupied areas essential to its conservation. Based on this we developed a set of *Guiding Principles* that generally identified what would be essential to conserving the species. These principles formed the basis for establishing quantitative and qualitative criteria used by the Service while evaluating and comparing potential critical habitat networks. As the purpose of critical habitat is to contribute to the conservation of the listed species, we used the recovery goals and criteria of the Revised Recovery Plan for the Northern Spotted Owl (USFWS 2011) as the foundation for our guiding principles and rule set for identifying critical habitat.

Guiding Principles for Northern Spotted Owl Critical Habitat

1) Ensure sufficient habitat to support population viability across the range of the species.

    - Habitat will be sufficient to support an increasing or stable population trend (e.g., a rate of population change (lambda ≥ 1.0) Habitat will be sufficient to insure a low risk of extinction.

2) Support demographically stable populations in each recovery unit.

    - Habitat will be sufficient to support an increasing or stable population trend (e.g. lambda ≥ 1.0) in each recovery unit.
    - Habitat will be sufficient to insure a low risk of extinction in each recovery unit.
    - Conserve or enhance connectivity within and among recovery units.
    - Conserve genetic diversity.
    - Ensure sufficient spatial redundancy in critical habitat within each recovery unit.

- Accommodate habitat disturbance due to fire, insects, disease, and catastrophic events.

3) Ensure distribution of spotted owl populations across representative habitats.

    - Maintain distribution across the full ecological gradient of the historical range.

4) Incorporate/consider/accommodate uncertainty – barred owls, climate change, fire/disturbance risk, demographic stochasticity.

5) These critical habitat objectives of supporting population viability and demographically stable populations are intended to be met in concert with the implementation of recovery actions to address other non-habitat based threats to the owl.

OVERVIEW OF THE MODELING PROCESS

In general, our approach to evaluating potential critical habitat networks for the northern spotted owl involved a series of iterative steps.

We used the modeling framework presented in *Development of a Modeling Framework to Support Recovery Implementation and Habitat Conservation Planning* (Appendix C of the Revised Recovery Plan for the Northern Spotted Owl, hereafter "Appendix C"; USFWS 2011) to help develop, refine and evaluate alternative possible critical habitat networks. The modeling process consisted of three principal steps:

> **Step 1:** At the outset, we identified the attributes of forest composition and structure and characteristics of the physical environment associated with nesting, roosting, and foraging habitat—physical and biological features used by the species-- based on extensive literature review, analysis of numerous data sets, and input from individual spotted owl experts. We then used these physical and biological features of nesting, roosting, and foraging habitats to create a range-wide map of relative habitat suitability (RHS) using MaxEnt (Phillips *et al.* 2006, entire; Phillips and Dudik 2008, entire). The RHS model was based on the patterns of habitat selection exhibited by nearly 4,000 known owl pairs (USFWS 2011, pp. C-20 to C-28).
>
> **Step 2:** We developed potential northern spotted owl critical habitat networks based on the relative habitat suitability map created in Step 1 using the Zonation conservation planning model (Moilanen and Kujala 2008, entire). The Zonation model used a hierarchical prioritization of the landscape based on relative habitat suitability and other user-specified criteria (e.g., land ownership) to

develop the most efficient solutions for incorporating high value habitat. Zonation analyses were conducted separately for each of 11 "modeling regions" (Appendix C, p. C-7) to ensure that habitat would be well-distributed across the range of the owl. Zonation also allowed for consideration of land ownership in development of potential network designs. Potential critical habitat areas identified by Zonation were viewed as "starting places." As the iterative process of refining potential critical habitat areas went on, information on land ownership, boundaries, and our guiding principles led to changes in Zonation-defined boundaries.

Step 3: In this last step, we determined the amount and spatial distribution of the physical and biological features, as well as unoccupied areas, that are essential to the conservation of the species. To do this we used a spatially-explicit individual-based northern spotted owl population model (HexSim) (Schumaker 2008, entire) to predict relative responses of northern spotted owl populations to different potential critical habitat network designs, different assumptions of barred owl (*Strix varia*) impacts, and competing scenarios describing trends in relative habitat suitability. Results from the HexSim model were used to compare population performance under varying habitat network designs, habitat change scenarios, and assumptions governing barred owl impacts. We evaluated these responses against the recovery objectives and criteria for the northern spotted owl using a rule set based on those criteria, as described in our Guiding Principles (above). Simulations from these models are not meant to be estimates of what will occur in the future, but rather provide information on trends predicted to occur under different network designs; this allowed us to compare the relative performance of various habitat change scenarios.

Relative Habitat Suitability Model

We used spatially explicit relative habitat suitability (RHS) models as one step in helping to identify potential critical habitat networks, and to gauge the responses of owl populations to differing scenarios of changing RHS. To improve the realism of our models, we divided the range of the northern spotted owl into 11 regions (hereafter "modeling regions") based on differences in forest environments, spotted owl habitat use and prey distribution, and variation in ecological conditions (Appendix C, pp. C-7 to C-13), and conducted modeling within each region separately. These 11 modeling regions (map, Appendix C, p. C-13) correspond to the 11 critical habitat units in the proposed and final critical habitat rules, and are identified as follows:

Modeling Region/Critical Habitat Unit	Abbreviation
North Coast Olympics	NCO
West Cascades North	WCN
West Cascades Central	WCC
West Cascades South	WCS
East Cascades North	ECN
East Cascades South	ECS
Oregon Coast	ORC
Klamath West	KLW
Klamath East	KLE
Redwood Coast	RDC
Inner California Coast Ranges	ICC

After each region's best model was attained, we used a geographic information system (GIS) to produce a region-wide map of RHS for the owl's entire range within the United States (Figure 1). Our RHS model performed very well (USFWS 2011) at distinguishing northern spotted owl territories from the conditions available in the landscape. The model's predictions were similar to those reported by Davis et al. (2011).

Some reviewers of the proposed critical habitat rule (77 FR 14062; March 8, 2012) questioned the appropriateness of using MaxEnt for modeling relative habitat suitability, expressing concern that other methods might be better or produce different results. Some reviewers believed our MaxEnt models were overfit. Others had misunderstandings of our use of MaxEnt and the resulting RHS values.

Regarding the contention that MaxEnt doesn't perform well or that other analytical techniques would be superior, we based our decision to use MaxEnt on its proven (and very good to excellent) performance on a wide range of species, sample sizes, and areas; especially relative to the performance of many other modeling techniques (see Elith et al. 2006, Wisz et al. 2008). Furthermore, our critical evaluation of our MaxEnt models' performance using cross-validation and independent data showed that the models we developed performed very well for the purposes that we used them for (identifying relative habitat suitability). The fact that all of our MaxEnt models performed well under cross-validation and (when available) with independent data undercuts the contention that they are overfit.

Aarts et al. (2012) noted that (1) many popular methods for analyzing habitat selection are "motivated by the same underlying exponential IPP model, and thus that the IPP model provides a useful unifying framework for modeling species distribution and habitat preference data." (IPP = inhomogenous Poisson point process); and (2) there is a common misconception about resource selection function models, that their predictions are proportional to occupancy. Instead, Aarts et al. (2012) argue, that such models are proportional to the density of observations. Our evaluation of our MaxEnt models' calibration is effectively an evaluation of the expected density of spotted owls among various RHS classes. That is, our strength of selection evaluation was done by dividing the proportion of the spotted owl locations found in a particular RHS bin (or class) by the areal extent of that RHS bin in the modeling region (i.e., the density of northern spotted owl (NSO) locations). If spotted owls used RHS bins proportionate to their extent (i.e., the percentage of the landscape they occur on), the strength of selection would be flat (a horizontal line) and suggest no selection for one bin or another. Instead, we found strong selection against low RHS bins and strong selection for high RHS bins (or low densities of owls in low RHS bins and high densities in high RHS bins) (see pages C-38 and C-39, and Figure C-5 of Appendix C).

Lastly, we reiterate that we used MaxEnt to predict areas of varying (relative) habitat suitability. We do not believe that the variables within each model are the only features that spotted owls respond to or need – the variables we used contributed to the predicted RHS. All models are simplifications of reality, and ours are no different. Our MaxEnt models help predict areas with higher or lower suitability for northern spotted owls. While the actual suitability of an area is a function of many more variables that are not represented in the model, we believe our models provide reliable predictions of relative habitat suitability.

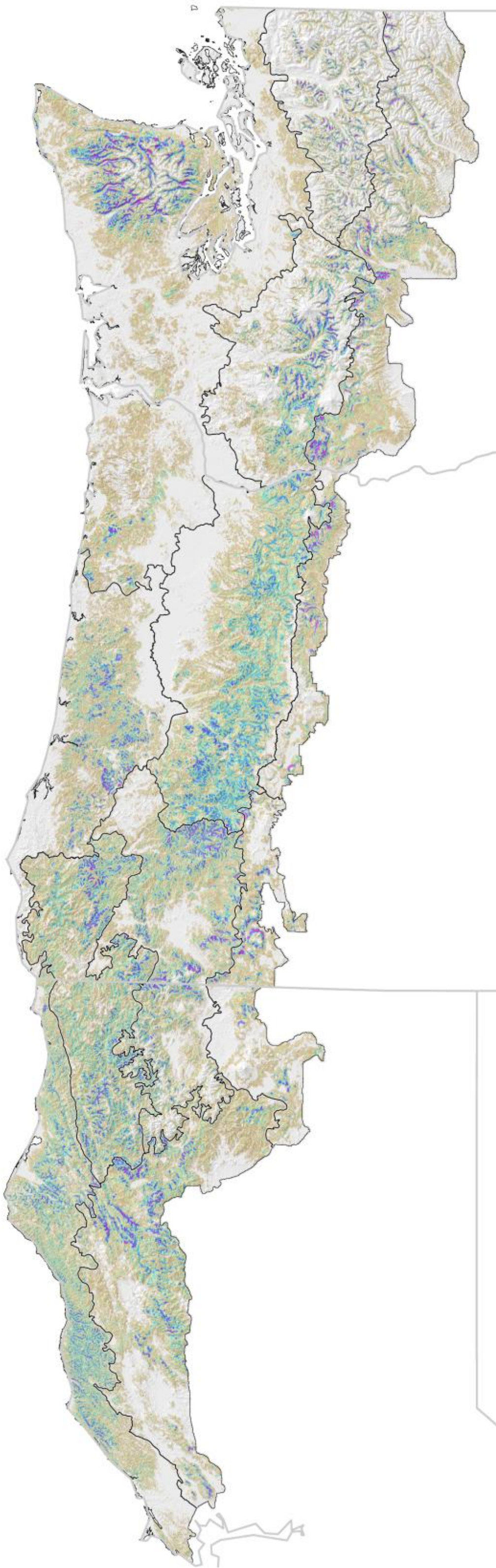
Habitat Network Scenarios: Approaches to Refining a Critical Habitat Network

The starting point for the potential habitat network scenarios described was the habitat conservation network scenarios described in Appendix C of the Revised Recovery Plan. The six Zonation scenarios described there (Z30pub, Z50pub, Z70pub, Z30all, Z50all, and Z70all) used were developed to provide a wide range of potential configurations, sizes, and land ownerships. Zonation enables the user to specify the proportion of habitat value (based on RHS) to include in a given scenario. These six Zonation scenarios were composed of 30, 50, or 70 percent of habitat value. The "pub" scenarios used a precedence masking technique where non-public lands were removed first and public lands were removed last. This had the effect of focusing potential critical habitat networks on public lands, but if the total amount of habitat value specified (e.g., 50% or 70%) could not be acquired from cells in public lands, other lands were included in the solution. All land ownerships were treated equally (that is, no one ownership was prioritized relative to others) in the "all" scenarios, and these scenarios represent the potential of the entire area to provide for spotted owls. So for example, "Z50pub" refers to a Zonation scenario based on 50 percent of habitat value, while prioritizing public lands for inclusion; "Z50all" would also be based on 50 percent of habitat value, but would not prioritize lands on the basis of ownership. We also evaluated the Northwest

Forest Plan (NWFP) Late-Successional Reserve (LSR) network because it is an existing reserve system, and it served as a benchmark to which we compared the performance of other potential networks.

These initial seven networks varied widely in their sizes and configurations (see results in Appendix C, USFWS 2011). Each of the seven networks was then used to evaluate the relative performance of simulated northern spotted owl populations given assumptions about future habitat conditions and barred owl populations.

Figure 1. Relative habitat suitability (RHS) of the northern spotted owl based on modeling conducted in each of 11 modeling regions, then combined to create a rangewide map. Purples and blues are higher RHS values than browns and white.



Population Modeling: Evaluating Spotted Owl Population Responses to Potential Critical Habitat Networks and Conditions

We used HexSim to develop a spatially explicit individual-based model of northern spotted owl populations. We then used this simulator to quantify spotted owl population responses to our alternative habitat networks and scenarios regarding future habitat conditions and barred owl distribution. A detailed description of the HexSim northern spotted owl model can be found in Appendix C of the Revised Recovery Plan (USFWS 2011). For this assessment, however, we used a variant of our HexSim model that also included environmental stochasticity.

Adding environmental stochasticity to the HexSim model greatly increased the variability observed in the results between replicates. Without stochasticity included (as in Phase 1 modeling; see below), five to ten replicates often sufficed for getting a reasonable, or at least general, estimate of population performance. However, with stochasticity, many more replicates were necessary in order to get reliable results. In Phase 2 and 3 modeling we ran 100 replicates of each simulation (for a given potential critical habitat network and set of scenarios about future habitat conditions and barred owl populations).

Every HexSim simulation that included environmental stochasticity was run for 350 time steps (time steps are analogous to years, but should not be equated with "years from the present"). Our simulations started out with 10,000 female owls -- an intentionally large number -- in "today's landscape." During the initial time steps, the 10,000 female owls needed to reach a realistic equilibrium with available habitat and the model showed dynamic changes during these time steps. These initial transient behaviors typically subsided over the first 25-50 time steps.

Our HexSim NSO model was a female-only model. Such a model does not consider potentially important ecological impacts that are likely to occur in small populations. For instance, finding a mate is less likely in extremely low density populations. Our HexSim model treated reproduction as a probabilistic event, regardless of NSO density. Similarly, random variation in demographic features such as sex ratios of offspring are likely to have more pronounced effects with small populations (e.g., a small population of five breeding pairs of NSOs in an area is much more likely to have all male or all female offspring than in a population of 50 or 500 NSOs). Again, our NSO HexSim model did not account for such factors because it is difficult to model these factors accurately. Thus, in cases such as these, we may overestimate population sizes and underestimate extinction rates. Nonetheless, because we were conducting comparative analyses using an identical platform, differences among various potential critical habitat networks are estimated to be a function of the different networks rather than some over- or under-estimate of the model (i.e., model imperfections are identical among comparisons, thus relative differences amongst the comparisons are a function of differences in the network rather than the model itself).

Today's trends in spotted owl population size and distribution (see Forsman et al. 2011) are attributable in part to recent land management activities, such as the rate of timber harvesting, and the changing history of other disturbance regimes to which these birds have been exposed (e.g., wildfires, barred owl population trends). Because our HexSim simulations are forward-looking only, they are unable to capture all of the impacts of such past activities. For this, and other reasons, we used the relative steady-state simulated population size and distribution information produced by HexSim as a basis for comparing the potential critical habitat networks. Such relative comparisons have the advantage that they are largely immune to model imperfections that cause under- or over-predictions in population size, since these types of errors can be assumed to appear consistently across all potential critical habitat networks as well as barred owl and RHS scenarios. In our stochastic HexSim simulations, a steady-state, where simulated population size reflected the critical habitat network conditions, was generally achieved after time step 150.

Use of Relative Habitat Suitability Model in Population Modeling

As described in Appendix C (pp. C-56, 69-70) we used the RHS map as a proxy for resource quality. In the HexSim Spotted Owl model, RHS influences population dynamics through territory acquisition (i.e., a hexagon had to have at least a minimal RHS value to become a part of an owl's territory) and subsequent resource acquisition classes (which were a function of both home range size and RHS within hexagons that occurred within an owl's home range; see pp. C-62 to C-63 of Appendix C) that, in addition to stage class and barred owl presence or absence, determined an owl's survival rate.

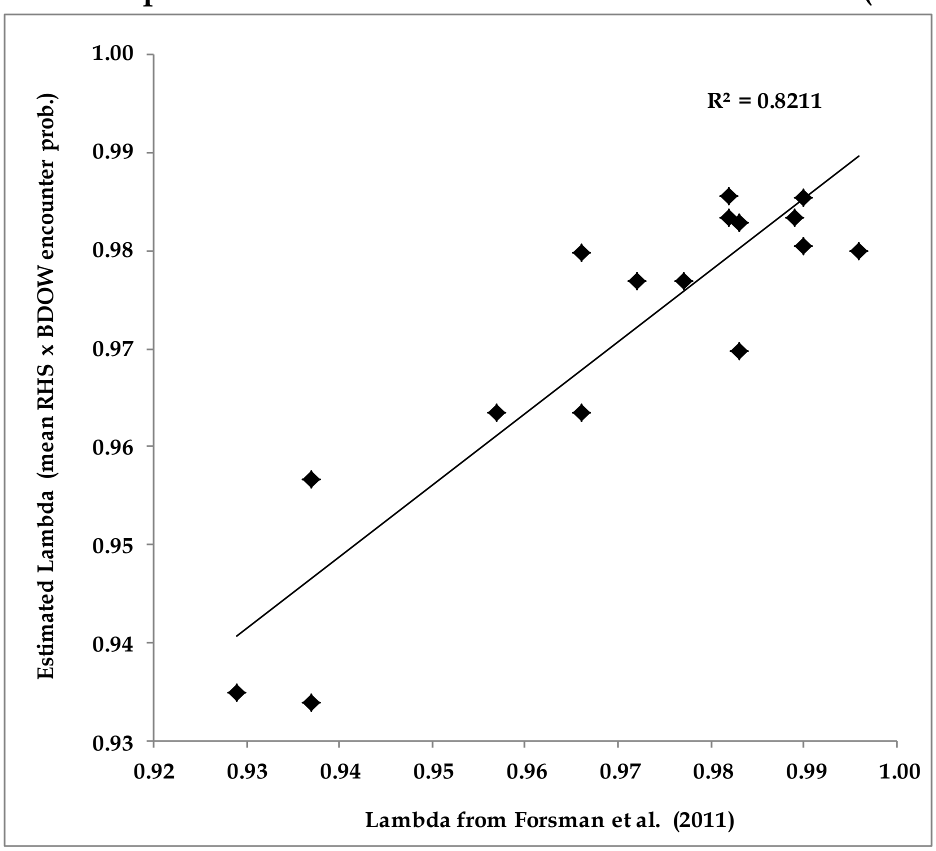
Ecological theory suggests that organisms select habitats that maximize their fitness; that good habitats allow for higher survival and reproduction, and poor habitats contribute to lower survival and reproduction. For NSOs, some studies have found relationships between habitat and survival and/or reproduction (e.g., Franklin et al. 2000, Dugger et al. 2005, Forsman et al. 2011). Nonetheless, some public comments to the proposed critical habitat rule suggested that the lack of a strong relationship between habitat and population performance should be interpreted to mean that habitat was or is relatively less important than other factors to NSO population performance.

In the proposed critical habitat rule we noted that habitat is necessary, but alone not sufficient, to recover the NSO. The reason for this is that factors other than habitat can have significant impacts on populations. For the NSO, one of those factors is the impact of barred owls (Dugger et al. 2011, Wiens 2012).

In order to evaluate the combined effects of barred owls and habitat on NSO population trends we created a simple regression model and assessed its accuracy (i.e., its ability to predict population growth rates). First, we overlaid all 11 Demographic Study Area (DSA; see Forsman et al. 2011) boundaries on our modeling region boundaries. When DSA boundaries spanned more than one modeling region we divided it by modeling region. This resulted in 18 different subdivisions. We calculated the mean RHS for each of the 18 DSA/modeling region subdivisions, as well as attributing our modeling-region specific barred owl encounter probabilities (i.e., the probability that a territorial spotted owl will have a barred owl on its territory) among modeling regions to them (Appendix C, p. C-66). The dependent variable in our regression model was the Lambda value estimated for each of the 11 DSAs by Forsman et al. (2011). We used generalized additive models, with the independent variables being mean RHS and DSA/modeling region specific barred owl encounter probabilities. We used the interaction of mean RHS and barred owl encounter rate to estimate Lambda.

When we regressed our estimated Lambda values against the Lambda values from Forsman et al. (2011), the coefficient of determination was 0.8211 (Fig 2). In essence, this simple evaluation suggests that the combination of RHS and barred owls is strongly correlated with NSO population growth rate. Our finding corresponds closely with those of Dugger et al. (2011) who found that occupancy dynamics of NSOs were related to both habitat and barred owls.

Figure 2. Comparison of Lambda estimates from Forsman et al. (2011) with modeled Lambda (interaction of RHS and barred owl encounter probability) in Demographic Study Areas.



Population Connectivity and Source-Sink Dynamics

Recovery goals for the spotted owl focus on both range-wide criteria as well as smaller scale recovery zones. More localized populations (i.e., those that occur within modeling regions (or physiographic provinces, in the Revised Recovery Plan) are influenced both by factors that occur within those areas (e.g., RHS and barred owls) as well as factors occurring in other areas. For example, spotted owls are able to disperse over fairly large areas (tens of kilometers), and thus dispersal functionally connects areas that may be physically distant. Empirical information supports this (see Figure 3), and this same information was programmed into the spotted owl HexSim model (see Figure 3b).

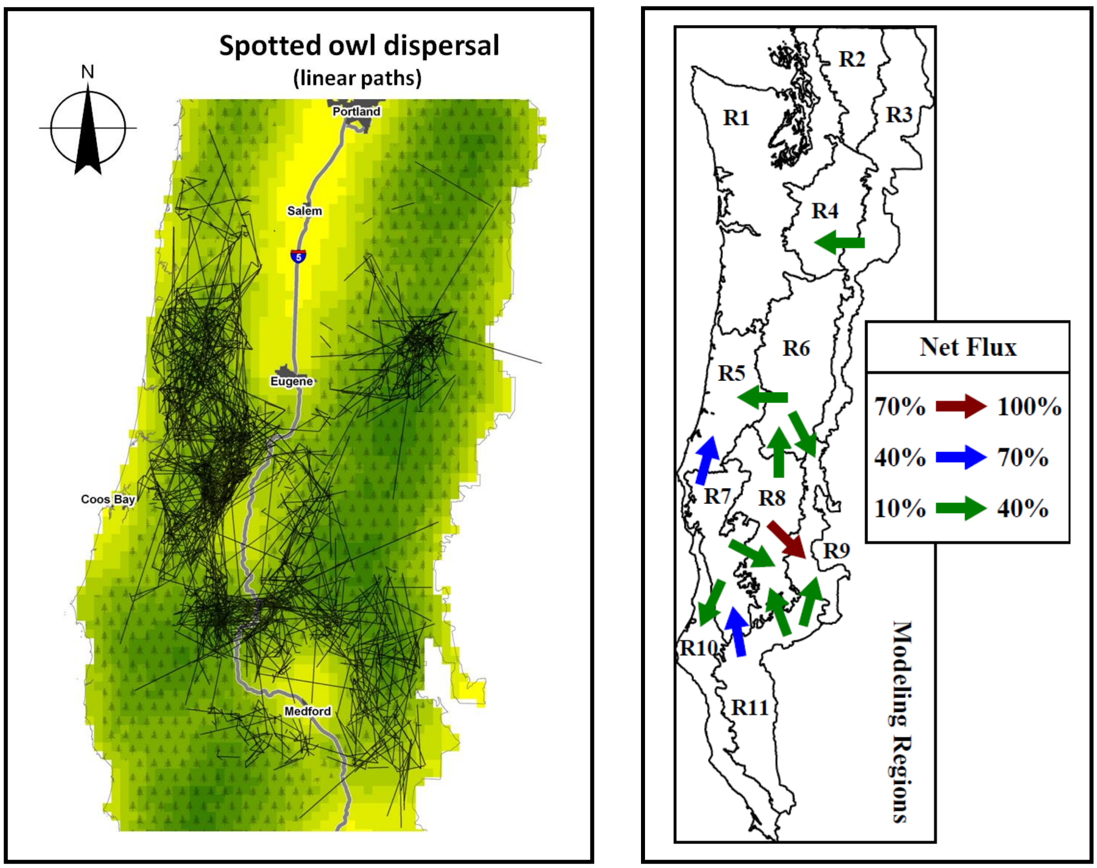


Figure 3. a (left pane) - Graphic from Davis et al. (2011) depicting movement patterns of northern spotted owls in Oregon. b (right pane) – Graphic from Schumaker et al. (in prep.) displaying "net flux" of simulated northern spotted owls between and among 11 modeling regions. Net flux refers to the net exporting of owls from one modeling region to another. Arrows refer to flux between regions (R5 is the Oregon Coast Range modeling region) which is an importer of owls from R7 (the Klamath West) and R6 (the West Cascades South).

It is important to note that population responses within each modeling region are a function of processes not only within that region, but may be affected by responses outside that region as well. Some areas (modeling regions) produce an excess of offspring and are net exporters of individuals, whereas other areas fail to produce enough offspring to maintain their own populations, and are net importers of individuals. Ecologically, these differences are considered to be "sources" (exporters) or "sinks" (importers). A change in habitat area in source regions or important connectivity areas will have a disproportionate effect on populations in adjacent sink areas. An equivalent amount of habitat change in sink areas would be expected to have a very different, presumably smaller, effect on owl populations. For example, in Fig. 1b above, the Oregon Coast Range is estimated to be a sink population that is largely reliant on importing owls from the Klamath West and West Cascades South modeling regions.

The reason for including this brief section is to provide a broader context for interpretation of the results that follow, and which may at times appear to be counter-intuitive. For example, it is possible – and logical – to have a result in which the reduction of area in a potential critical habitat network within a modeling region could result in a population increase in that region; this is because that increase would be attributable primarily to importing (dispersing) owls from adjacent modeling regions where potential critical habitat area may have increased. In short, simulated owl population responses within modeling regions are a function of both within and between/among modeling region processes.

HexSim Sensitivity Analyses

The purpose of conducting sensitivity analyses is to evaluate the degree to which a model's results are influenced by small changes to individual parameter values. Parameter values are usually inexact estimates, and sensitivity analysis quantifies the importance of this uncertainty. Due to the intensive and extensive research conducted on NSO demographics (e.g., Forsman et al. 2011) there exist relatively accurate and precise estimates of age-specific survival and reproduction. However, some parameter values used in our NSO HexSim simulations were based on our own deductions (from studies of limited spatial or temporal extent) and "tuning" earlier iterations of the model after evaluating results (e.g., the number of hexagons a simulated NSO could explore and the repulsion that low value hexagons had on dispersing owls). Theoretical and empirical models of NSO population dynamics suggest that population size should be most sensitive to changes in adult survival rates. Therefore, we expected that our sensitivity analyses would show similarly strong effects of changing survival rates. We also expected the resource targets (owl resource acquisition goals) would strongly influence population dynamics since owls in low resource acquisition classes experienced lower survival (Appendix C, p. C-70).

We conducted a formal sensitivity analysis of the NSO HexSim model by modifying several individual parameters, while holding all other parameters at their "base" value, and evaluating the impact on estimated NSO population performance. The base value for a parameter was the value used in the critical habitat planning simulations, which are described in detail earlier in this paper and Appendix C of the Revised Recovery Plan. We used Phase 3's Composite 7 without stochasticity) as the base network[1]. Our sensitivity analysis consisted of 21 different individual parameter modifications. Each time a parameter was modified, we performed 100 replicate simulations and computed the mean population size M_i at time step 350 and also the ratio M_i/B, where B represents the mean population size obtained from 100 replicates of the base simulation. A ratio (M_i/B) close to 1.0 would indicate that parameter modification i had no appreciable impact on the simulation results. A ratio appreciably different than 1.0 would mean that a modification did have a strong influence on the model's outcome. We were interested in the magnitude of parameter sensitivities, and therefore did not test for statistical significance in these analyses.

Our sensitivity analysis approach (Table 1) involved modification of nine separate parameter values. Seven of the nine were subjected to two modifications (one decrease and one increase), one was assigned four distinct values (two lower and two higher), and one was modified three times. Thus, our sensitivity analysis consisted of 21 additional HexSim simulations, each consisting of 100 replicates. The nine parameters we modified were: 1) the minimum value for a hexagon to be included in a NSO's territory; 2) the minimum resource necessary to form a territory; 3) the modeling region-specific resource targets; 4) the threshold values defining the low, moderate, and high resource acquisition categories; 5) the maximum explored area; 6) survival rates; 7) reproductive rates; 8) the resource quality goal used within dispersal; 9) the extent to which poor quality hexagons are avoided by dispersing owls.

[1] As described below (see *Phase 1 modeling conclusions*), a "composite" scenario is developed in Phase 2, composed of various modeling region-specific habitat scenarios depending on how simulated owl populations in each modeling region performed in Phase 1. Phase 2 composite scenarios are a mixture of various Zonation or NWFP scenarios by modeling region. In other words, in a composite, one modeling region might be Z50pub, while another would be Z70all, and so on.

Table 1. Parameters modified for sensitivity analysis of NSO HexSim Model. The first column is a parameter ID, and the last four columns (A-D) represent the specific values assigned to a parameter. Each parameter-value pair corresponds to a specific 100-replicate simulation. For example, scenario 6A was used to quantify the impact on population size resulting from a 2.5% reduction in survival rates (across all stage class x barred owl categories).

				A	B	C	D
	HexSim Modeling Section	**Parameter**	**Value used in base NSO HexSim Model**	**low1**	**low2**	**high1**	**high2**
1	Population > Range Data	Hexagons Range-Eligible if Value at Least	35	30		40	
2	Population > Range Data	Minimum Range Resource	105	95		115	
3	Population > Range Data	Resource Targets within modeling regions		-10%	-25%	10%	25%
4	Population > Traits > Resource Class	Resource trait threshold		25, 50		25, 75	50, 75
5	Event Sequence > Movement > Floater Prospecting > Exploration	maximum number of hexagons explored	500	400		600	
6	Event Sequence >survival > Stage Class	Rates: specified by stage class under normal nesting	varied by stage class, resource acquisition class, and barred owl presence	-2.50%		2.50%	
7	Event Sequence >reproduction > Stage Class	Rates: specified by stage class under normal nesting	varied by stage class	-10.00%		10.00%	
8	Event Sequence > Movement > Stage 0 Dispersal > Dispersal	Mean Resource Quality	35	30		40	
9	Event Sequence > Movement > Stage 0 Dispersal > Dispersal	Repulsion maximum	-3.3	-1.5		-5	

Results of Sensitivity Analyses

At the range-wide scale, appreciable effects of varying parameter values were observed when we varied either survival directly or parameter values that influenced survival (e.g., see 3A-D; 4A-C; 6A-B in Table 1), and reproduction (7A-B) (see Table 1). Varying survival rates (by only 2.5%) had the most dramatic impacts on population sizes (6A and 6B). As noted above, this was expected prior to conducting the sensitivity analyses. Nonetheless, a reduction in survival of 2.5% had a much larger negative effect on population size (a 250 fold decrease) than did a 2.5% increase (a 2.24 fold increase) in survival (Table 1). Ten percent increases and decreases in reproduction also resulted in relatively large effects on population sizes; again with reductions of 10% showing larger negative effects (8.6 fold decrease) than 10% increases showed (a 1.73 fold increase). In large part, the sensitivity analysis evaluations at the modeling region scale showed very similar patterns to those at the geographic range scale (Table 2).

Although some of the parameter value changes we evaluated in the sensitivity analyses resulted in large population-level effects, none of the results were contrary to our expectations. We expected that modifying survival (and factors that influence survival such as resource acquisition class) would have relatively large impacts. It might appear that the variation we evaluated in reproduction also had large effects, however, it should be noted that we increased and decreased reproductive rates by 10%, whereas we only changed survival rates by 2.5%, so the relative impact of each parameter should be interpreted with this in mind. Given the uncertainty in some of the model's parameter settings (e.g., number of hexagons explored, repulsion to low value hexagons), the sensitivity analysis suggests that our choices of these parameter values did not have a strong effect on the modeling results.

For parameter values such as 4A, C, and D (resource trait thresholds, how we divided owls into high, moderate, and low resource classes), our model calibration (see Figure C-14 of the Revised NSO Recovery Plan) provided support for the values we chose. Northern spotted owl birth and survival rates are well known from multiple demographic studies (e.g., Forsman et al. 2011). Our sensitivity analysis generally showed that the NSO HexSim model was most sensitive to parameters that have precise empirically-derived estimates, and relatively insensitive to those parameters that are less well known.

Table 2. Ratios of population sizes between parameter-value modified conditions and the base NSO HexSim model at time-step 350 for the entire geographic range and within each of the eleven modeling regions. Ratios near 1.0 suggest little or no difference. Specific values modified (e.g., 1A, 4C) can be identified in Table 1). Mean MR = mean of the ratios for all modeling regions, with the associated standard errors.

Area	Metric	1A	1C	2A	2C	3A	3B	3C	3D	4A	4C	4D	5A	5C	6A	6C	7A	7C	8A	8C	9A	9C
Range	N_{350}	1.005	0.976	1.004	1.001	1.216	1.620	0.836	0.640	1.612	0.804	0.772	1.014	0.999	0.004	2.242	0.116	1.727	1.049	0.957	0.992	0.992
ECN	N_{350}	0.893	0.946	0.947	1.033	1.187	1.759	0.802	0.544	1.722	0.764	0.682	0.946	0.919	0.003	4.374	0.053	2.904	1.074	0.832	0.924	0.979
ECS	N_{350}	0.992	0.961	1.010	1.011	1.216	1.532	0.854	0.679	1.560	0.846	0.744	1.016	1.015	0.009	1.838	0.198	1.503	1.014	0.977	0.956	1.011
ICC	N_{350}	1.003	0.973	0.996	0.984	1.189	1.569	0.843	0.650	1.563	0.806	0.801	1.016	1.001	0.002	1.738	0.163	1.364	1.046	0.969	0.981	0.991
KLE	N_{350}	1.005	0.990	1.002	1.000	1.201	1.552	0.843	0.663	1.536	0.811	0.785	1.038	0.973	0.002	1.823	0.107	1.459	1.039	0.964	0.979	0.996
KLW	N_{350}	1.005	0.975	1.004	0.993	1.193	1.560	0.837	0.652	1.555	0.807	0.791	1.008	0.990	0.002	1.699	0.108	1.385	1.088	0.956	0.997	0.983
NCO	N_{350}	1.025	0.891	0.978	1.023	1.207	1.886	0.749	0.609	1.872	0.741	0.646	0.896	1.198	0.001	4.753	0.036	3.305	1.085	0.909	0.925	1.044
ORC	N_{350}	1.014	0.892	1.040	1.025	1.163	1.483	0.851	0.654	1.570	0.856	0.805	0.995	1.046	0.001	3.063	0.034	2.376	0.841	0.967	1.001	0.967
RDC	N_{350}	1.006	0.979	0.999	0.996	1.274	1.772	0.811	0.589	1.750	0.762	0.746	1.011	0.990	0.003	2.009	0.182	1.491	0.975	0.909	0.979	1.012
WCC	N_{350}	0.930	0.936	0.991	0.987	1.329	1.916	0.914	0.447	2.181	0.692	0.627	1.033	0.857	0.000	5.415	0.053	3.512	1.086	0.979	0.865	0.944
WCN	N_{350}	0.801	0.692	0.749	0.946	0.995	2.473	0.585	0.263	2.092	0.503	0.584	1.038	0.776	0.002	9.259	0.013	4.308	0.664	0.801	0.677	1.015
WCS	N_{350}	1.030	1.024	1.019	1.027	1.282	1.738	0.843	0.643	1.679	0.816	0.741	1.026	1.026	0.000	3.526	0.043	2.695	1.182	1.000	1.063	0.985
	Mean MR	0.973	0.933	0.976	1.002	1.203	1.749	0.812	0.581	1.735	0.764	0.723	1.002	0.981	0.002	3.591	0.090	2.391	1.009	0.933	0.941	0.994
	SE	0.021	0.027	0.024	0.008	0.026	0.085	0.026	0.038	0.068	0.03	0.023	0.013	0.033	0.0007	0.697	0.02	0.311	0.043	0.019	0.03	0.008

PHASE 1 MODELING

As the initial step in an iterative process of comparing and refining potential habitat networks, for Phase 1 modeling we used a "coarse-filter" approach. In Phase 1, we compared spotted owl population responses among seven habitat network scenarios (presented on page 4), three general habitat change scenarios, and four barred owl population scenarios, for a total of 84 scenarios analyzed. These scenarios, described below, enabled us to establish broad sideboards of population risk and to evaluate network performance within the individual modeling regions. Results of Phase 1 modeling were then used to develop two new alternative habitat network scenarios, representing relatively lower and higher levels of risk.

Network, Habitat and Barred Owl Scenarios

For Phase 1 modeling, we used the six Zonation and the NWFP reserve scenarios as articulated in Appendix C (USFWS 2011) and above.

Habitat Change Scenarios

We used three habitat change scenarios for Phase 1 modeling:

- HAB1 consisted of maintaining the RHS value within potential habitat network areas at their currently-estimated values, and reducing all non-network lands with RHS values >35 to a value of 34. This is the Round 2 scenario described in Appendix C (USFWS 2011, p. C-82). This scenario was intended to simulate an "isolated" habitat network by only allowing territory establishment within the potential critical habitat network. In HexSim, territory establishment was only allowed to happen when hexagon RHS values were ≥ 35 for three adjacent hexagons (USFWS 2011, p. C-62). Areas outside of the network could still contribute resources to owls, but nest sites were restricted to the habitat network in this scenario.

- In HAB2 we maintained the RHS value within potential habitat network areas at their currently-estimated values, and reduced all non-network areas with RHS values >35 to a value of 34, but maintained RHS >50 on *non-network areas on public lands* at their currently-estimated values. This is identical to the Round 3 Scenario described in Appendix C (USFWS 2011, p. C-82). This scenario is intended to emulate the management approach of maintaining occupied spotted owl habitat outside of the potential critical habitat network (full implementation of Recovery Action 10 (USFWS 2011) on public ownerships).

- The HAB3 scenario was identical to HAB2, except that RHS > 50 was maintained on all non-network lands. This scenario simulated full implementation of Recovery Action 10 (USFWS 2011) on both public and non-public ownerships).

For the purposes of developing habitat scenarios in Phase 1, Congressionally Reserved lands (e.g., Wilderness Areas and National Parks) were treated as if they were within the network, regardless of whether Zonation had selected these areas. This was done because such areas were set aside by acts of Congress, and we assumed that habitat quality would continue to be retained as in the potential critical habitat network.

Barred Owl Scenarios
Barred owl impacts were included in HexSim using variations of their currently-estimated encounter probability (i.e., the probability that a territorial spotted owl will have a barred owl on its territory) among modeling regions. See USFWS (2011, Appendix C) for a discussion of how barred owl encounter probabilities and impacts were developed and implemented. The barred owl scenarios used for Phase 1 included:

- STVA1) assumed no barred owls existed (i.e., that the barred owl encounter probability was set to zero for all individual spotted owls in all places);
- STVA2) barred owl encounter probabilities were held constant at their currently-estimated rates within each of the 11 modeling regions;
- STVA3) barred owl encounter probabilities were held constant at 0.25 everywhere in the spotted owl's range; and
- STVA4) barred owl encounter probabilities were held constant at 0.5 everywhere in the spotted owl's range.

In sum, Phase 1 modeling included 12 combinations of RHS scenarios and barred owl scenarios evaluated in HexSim for each of seven habitat network scenarios. For Phase 1 modeling, barred owl impacts (encounter probabilities) were inserted at time-step 40, and RHS changes were inserted at time-step 50.

HexSim Population Performance Metrics

For Phase 1 modeling, we had not yet included environmental stochasticity into HexSim. Because Phase 1 model runs had less variation among replicates than models with environmental stochasticity included, we ran five replicates of each scenario, and ran each replicate for 250 time-steps. Population performance metrics were evaluated range-wide and for each modeling region.

The following range-wide population performance metrics were used to compare and rank the various Phase 1 reserve networks by habitat and barred owl scenarios: 1) mean percentage population change among the five replicates between time-steps 50 and 250; 2) percentage of time-steps during which lambda (λ; mean of five replicates ± 95% CI) was ≥1.0 between time-steps 50 and 250; and 3) the first year that λ (mean ± 95% CI) was ≥1.0. Because we were interested in longer-term trends, we calculated λ as N_t/N_{t-10} rather than by successive time-steps.

For each of the 11 modeling regions we evaluated the following population performance metrics of Phase 1 models (see Table 7):

1) percentage of time-steps during which population growth rate (λ) (mean of five replicates ± 95% CI) was ≥1.0 between time-steps 50 and 250;
2) the first year that λ (mean ± 95% CI) was ≥1.0;
3) the percentage of replicates during which the population fell below 250 individuals;
4) the percentage of replicates during which the population fell below 100 individuals; and
5) the percentage of replicates during which the population went to extinction. The “thresholds” of 250 and 100 individuals were considered to be quasi-extinction thresholds, or population sizes that we believed to be at relatively high risk of extinction.

As noted above, during Phase 1 modeling we had not yet included environmental stochasticity into HexSim. This, in addition to other assumptions we made (USFWS 2011, Appendix C), suggested to us that the model was more likely to provide optimistic results, or that it would be predisposed to underestimate extinction risk. Because of this we chose the two quasi-extinction thresholds of 250 and 100 individuals, population sizes below which owl population persistence would be less likely than if populations were larger. It is important to recognize that during Phase 1 modeling only five replicates were run. Thus, two scenarios that were identical in all ways other than one falling below 100 individuals one more time than another would differ in that metric by 20%.

We recognized that five replicates were likely too few to support strong conclusions. However, Phase 1 modeling was understood from the start as providing coarse-level information that would be used to refine and create subsequent reserve scenarios which would be subjected to more thorough evaluations. Therefore, the evaluation of Phase 1 modeling included comparing the quantitative measures articulated above, as well as using professional judgment. For example, we carefully considered the fact that only five replicates were run for each of the 84 combinations of habitat network design, RHS change, and barred owl rates in Phase 1. Small differences were generally ignored. Furthermore, we did not weigh each performance metric equally. For example, one of the 84 combinations might have had a population that was the first with λ ≥1.0, but subsequently declined rapidly or became very unstable over the longer-term. Longer-term stability was considered more important in such circumstances. There were also circumstances where some of the quantitative information did not make intuitive sense, such that we felt that more replicates would likely produce different results. Effectively, we used the quantitative information and professional judgment to transition from Phase 1's 84 combinations of habitat network design, RHS change, and barred owl effects to Phase 2 modeling.

Phase 1 Results

In general, among similar barred owl and RHS scenarios, the NWFP performed worse than any of the Zonation habitat network scenarios, whereas the Z70all and Z70pub scenarios performed best. Barred owl impacts were substantial, especially STVA4 when all areas had an encounter probability of 0.5 (an encounter probability that is currently observed or exceeded in some parts of the northern spotted owl's range). For example, when non-network lands had RHS<35 and barred owl encounter rates were 0.5, the range-wide spotted owl population was estimated to decline by 87% (Z70all) to 94% (NWFP) between time-steps 50 and 250. This is in contrast to estimated population declines of between 16% (Z70all) and 54% (NWFP) for the same habitat scenario when barred owl encounter probabilities were 0.25 in all modeling regions.

For individual modeling regions, Phase 1 modeling suggested that spotted owls in the Interior California Coast (ICC), Klamath East (KLE), Klamath West (KLW), and West Cascades South (WCS), and Redwood Coast (RDC) modeling regions were the most stable and least prone to fall below either quasi-extinction threshold or go to extinction. In contrast, the West Cascades Central (WCC), West Cascades North (WCN), and East Cascades South modeling regions most frequently fell below quasi-extinction thresholds (especially 250), even under scenarios with no barred owls and in which RHS was maintained in networks and only truncated to below 35 (for those areas that were estimated to be >35) outside of network lands. There were general differences in owl performance metrics among the various habitat network scenarios, again with the Z70 scenarios generally performing well and NWFP and Z30 scenarios performing more poorly.

In general, ranking of the seven habitat network scenarios by various RHS and barred owl assumptions revealed that the largest networks (Z70all and Z70 public) ranked highest, and the NWFP ranked lowest (Table 3). However, the NWFP was larger in area than Z30all and ranked much lower, overall, than Z30all did. This result highlights the potential value of NWFP 'matrix' lands to spotted owls, as well as the existence of lower-quality habitat within NWFP reserves.

Table 3. Rankings of the seven reserve scenarios used in Phase 1 relative to habitat change and barred owl scenarios. Rankings are presented for both range-wide and modeling region evaluations. Rankings of 1 are the best and rankings of 7 are the worst.

RHS by STVA scenario	Ranking Focus	NWFP	Z30all	Z50all	Z70all	Z30pub	Z50pub	Z70pub
HAB1-STVA1	Range-wide	7	5	3	1	5	3	1
	Modeling Region	7	5	2	2	6	4	1
HAB1-STVA2	Range-wide	6	5	3	2	7	4	1
	Modeling Region	7	5	2	2	6	4	1
HAB2-STVA1	Range-wide	7	4	3	1	4	4	1
	Modeling Region	7	3	3	1	6	5	2
HAB2-STVA2	Range-wide	6	4	1	3	6	5	1
	Modeling Region	7	4	1	2	4	3	6
HAB3-STVA1	Range-wide	5	5	1	1	5	1	1
	Modeling Region	5	2	7	4	5	1	3
HAB3-STVA2	Range-wide	4	4	4	2	4	2	1
	Modeling Region	2	4	3	4	6	7	1
HAB1-STVA3	Range-wide	7	5	4	1	5	1	1
	Modeling Region	7	5	2	3	6	3	1
HAB1-STVA4	Range-wide	4	4	1	1	4	4	1
	Modeling Region	7	5	3	2	6	4	1
HAB2-STVA3	Range-wide	6	4	2	1	7	4	2
	Modeling Region	7	3	2	1	6	4	5
HAB2-STVA4	Range-wide	3	1	3	1	3	3	3
	Modeling Region	4	2	3	1	4	7	4
HAB3-STVA3	Range-wide	2	7	5	3	5	3	1
	Modeling Region	7	1	4	3	2	4	4
HAB3-STVA4	Range-wide	1	1	1	1	1	1	1
	Modeling Region	6	2	3	5	3	1	6
	MEAN Rank	5.5	3.8	2.8	2.0	4.8	3.4	2.1

Phase 1 modeling conclusions

In Phase 1, we were not trying to create the "best" configuration, but rather to evaluate population performance across a broad range of scenarios.

Rather than choose the overall (rangewide) best performing Phase 1 habitat network scenarios to continue with to Phase 2, we evaluated the performance of various habitat scenarios among the individual modeling regions. This evaluation led us to create two scenarios to carry forward to Phase 2 called "composite" scenarios. These composite scenarios were composed of various Phase 1 modeling region-specific habitat scenarios depending largely on how simulated owl populations in each modeling region performed in Phase 1. That is, Phase 2 composite scenarios were a mixture of various Zonation or NWFP scenarios by modeling region. For example, the Phase 1 Z30pub scenario may have performed quite well in a particular modeling region, and thus for that modeling region we chose Z30pub, whereas for another modeling region we may have chosen Z50all or Z50pub. The two composite scenarios that became the Phase 2 scenarios were developed with the intent that one was expected to be of lower population risk (Composite 1) and the other was expected to be of higher risk (Composite 2) although still meeting the goals of our Guiding Principles. We also carried the NWFP scenario forward in Phase 2 modeling. Composites 1 and 2, along with our assumed modeling region-specific barred owl encounter rates, are fully articulated in Table 4.

PHASE 2 MODELING

This phase represents a more detailed and rigorous evaluation of a reduced number of habitat network scenarios (NWFP, and Composites 1 and 2), habitat change, and barred owl scenarios. Given the results from Phase 1 modeling, we sought to refine and limit the number of RHS and barred owl scenarios as well as move from "one-size-fits-all" Zonation networks (i.e., all modeling regions had Z50 or Z70) to more idiosyncratic networks that were informed by Phase 1 results.

Phase 2 modeling: Initial Network, Habitat and Barred Owl Scenarios

Habitat Change Scenarios

We used habitat change scenarios to evaluate the influence of future habitat conditions on spotted owl populations in the HexSim model. We recognized that a wide range of methods and assumptions could be employed to simulate or predict future habitat conditions for use in population modeling, including forest growth models and wildfire risk models. However, we also recognized the great complexity involved in using such models across the large geographic range of the spotted owl, and the high degree of uncertainty surrounding future climate, forest growth rates, harvest rates, and other important determinants of habitat trends. In addition, we understood that it would be extremely challenging to translate these other models into our relative habitat suitability (RHS) model that forms the base habitat layers for Zonation and HexSim modeling. Because our goal was to evaluate relative population performance among a range of habitat network designs, we elected instead to develop two contrasting "what if" scenarios that directly project RHS values into future conditions. The two RHS change scenarios used in Phase 2 and 3 modeling were dubbed "optimistic" and "pessimistic," as explained further below.

These "what if" scenarios were not intended to be predictions, forecasts, or recommendations of future habitat conditions. The goal of these futuring scenarios was to evaluate how different the various population outcomes were as a function of different RHS change scenarios, not to obtain an (HexSim) estimate of what spotted owl populations will do under expected conditions. We chose the optimistic and pessimistic scenarios to reflect our belief that because they were plausible; they are not that they were the most extreme cases we could imagine. The Service believed that the future reality on the ground would likely fall somewhere between the optimistic and pessimistic RHS scenarios we developed.

Our objective for the **optimistic scenario** was to evaluate spotted owl population response to future habitat conditions that resembled current conditions and habitat trends. We used estimates of habitat (RHS) change that were measured between 1996 and 2006, and projected these conditions and rates into the future. We calculated the change in mean RHS at the hexagon (86.6 ha) scale between 1996 and 2006 (two time periods during which the base GNN vegetation data existed – see Appendix C of USFWS 2011) in each modeling region for five classes of RHS, and the direction of change. The five RHS categories for which we estimated RHS change were: 0-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8, and >0.8. We also created six categories of RHS percentage change between 1996 and 2006: <1%, 1-2%, 2-3%, 3-4%, 4-5%, and >5%. We estimated the percentage of the modeling region within each RHS category that increased in RHS, by each RHS percentage change class, and that decreased in RHS. Stratification of RHS change by modeling region, direction of change, RHS categories and RHS percent-change classes resulted in 1,320 change-classification strata that were derived from the range-wide map.

For the optimistic habitat change scenario, we applied the "observed" gains and losses in RHS as follows: *within potential critical habitat networks*, future gains and losses in RHS occurred as estimated from 1996-2006, whereas *outside of habitat networks* gains were reduced by 50 percent and losses occurred as observed. In most circumstances the outside-of-network RHS changes resulted in a small net decrease of RHS. For the six percentage change classes, we projected the midpoint of each of the first five classes, but for the >5% class we estimated the mean amount of change that was estimated between 1996 and 2006, for each RHS category for each modeling region, and projected that value. The optimistic scenario were implemented as two 20-year change increments (RHS changes inserted at time steps 70 and 90), compounded (= two steps at 10% each, not one step at 20%). Hexagons to change were randomly selected, with replacement.

Because the primary goal of this evaluation was to compare simulated spotted owl population performance across a range of network designs, the objective of the **pessimistic scenario** was to "isolate" the potential critical habitat networks by increasing contrast between network and non-network areas. The pessimistic scenario used in Phase 2 and Phase 3 modeling was identical to the HAB1 scenario used in Phase

1. In this scenario we held RHS *within* network areas constant at its 2006 estimated level, whereas *outside* of network areas we truncated all RHS values that were >35 to a value of 34 − *just below the value needed for territory establishment*. All other non-network areas (already <35) remained constant. Through time (HexSim time-steps), this scenario resulted in the distribution of occupied spotted owl territories to be almost exclusively limited to identified habitat network areas and Congressionally Reserved (Wilderness, National Parks) lands.

For all Phases, in HexSim modeling we considered Congressionally Reserved areas to be treated identically to those areas identified to be in the potential critical habitat networks. For example, if in one network 3 million acres of Congressionally Reserved lands were not included (identified) as potential critical habitat, when we ran HexSim those 3 million acres were *treated* identical to potential critical habitat even though they were *not identified* as potential critical habitat. The reason for this is that Congressionally Reserved lands have very restricted management options, and we believed that their general management in the future would be consistent with largely maintaining their current RHS.

During our evaluations of population modeling results among modeling regions and habitat change scenarios, we recognized that the pessimistic scenario did not reflect a plausible scenario for the RDC (Redwood Coast), where privately owned lands continue to support large numbers of spotted owls despite a long history of intensive timber management. To address this, we modified the pessimistic scenario as follows. Habitat suitability (RHS) *within network areas* remained constant at its estimated 2006 level, whereas RHS *outside of network areas* was reduced by 5 percent in each of two 20 year time-steps (not compounded).

The optimistic scenario generally resulted in future RHS values remaining near their currently-estimated values. Habitat change was much more pronounced in pessimistic scenarios, resulting in more variability in population results among the various network scenarios. Therefore, we put more emphasis on population results from pessimistic scenarios, and the optimistic minus pessimistic evaluations. As noted above, network scenarios in which simulated owl populations performed well under the pessimistic RHS scenarios represent those that are more resilient to potential future changes in RHS. That is, if a habitat network scenario performed well under pessimistic RHS conditions, it would perform even better under more optimistic conditions.

Establishing an 'assumed' Barred Owl Encounter Rate

For Phase 2 HexSim modeling we used a constant barred owl encounter rate (see Table 4). Phase 1 modeling revealed the strong impact that barred owl encounter probability had on population performance metrics. Modeling regions with high barred owl encounter probabilities, particularly in Washington and coastal Oregon, required nearly all suitable habitat be included in order to sustain spotted owl populations through time. Because critical habitat cannot be expected to ameliorate all non-habitat based stressors to spotted owl populations, it was necessary to establish reasonable assumptions regarding barred owl encounter probabilities that we believed could, along with critical habitat designation, lead to recovery of the northern spotted owl. Controlling for the effect of barred owls in a reasonable way (in HexSim) in the course of evaluating various habitat scenarios was necessary in order to isolate and identify those specific areas that provide the physical or biological features essential for the conservation of the northern spotted owl, by reducing the confounding effects of barred owls from the effects of habitat on spotted owl population viability. The designation of critical habitat requires that we identify those areas that are essential to the conservation and recovery of the species, and is intended to assist in addressing threats faced by the species due to the loss or degradation of its habitat. Critical habitat is not intended to single-handedly achieve the recovery of the species and address all existing threats, whether habitat-based or not.

We used various metrics of population viability to determine the habitat network – the amount and configuration of habitat – that is essential to the conservation of the northern spotted owl. However, the overwhelming negative influence of barred owls on those measures of population viability confound those results, unless we make some reasonable assumptions that the barred owl threat will be addressed to some degree in the course of recovery implementation. We could have assumed no barred owl presence at all, which would result in an entirely independent determination of essential habitat. However, as barred owls are likely already present throughout the entire range of the northern spotted owl, such an assumption, which would hypothetically require complete eradication of the barred owl, was deemed unrealistic. Therefore, we chose what we considered to be a reasonable middle ground between the extremes of no barred owl control (barred owls continue to increase across the range of the northern spotted owl unabated) and complete eradication. We did not make any assumptions as to the possible methods by which barred owls might be managed, only that encounter probabilities might change to some reasonable degree in certain regions.

We made modeling region-specific decisions about reasonable barred owl encounter rates based on the HexSim results from Phase 1 and barred owl encounter probabilities estimated from long-term demographic study areas (Forsman et al. 2011) within each modeling region. We established a maximum encounter probability of 0.375 for the modeling process because population performance ranged from marginal to poor at higher barred owl encounter probabilities. For some modeling regions with currently-estimated barred owl encounter probabilities greater than 0.375, this resulted in a substantial reduction in the barred owl encounter rates through time. For modeling regions with currently-estimated barred owl encounter probabilities less than 0.375, we generally assumed that barred owl encounter probabilities would remain similar to current estimates or would increase slightly over time and could potentially be maintained at those levels through management actions. Table 4 shows the comparison of currently-estimated and assumed barred owl encounter rates we used in Phase 2 modeling. In HexSim simulations, currently-estimated modeling region-specific barred owl encounter rates were inserted at time-step 40; the final rates were inserted at time-step 60.

Table 4. Composites 1 and 2 that resulted from Phase 1 modeling. These composites include both the modeling region-specific habitat network scenario from Phase 1 as well as the assumed barred owl encounter rate for Phase 2 modeling. Composite 1 was considered to be lower risk and Composite 2 was considered higher risk.

		Habitat Network Scenario		
Modeling region	**Barred owl encounter rate for HexSim models after Phase 1 (currently estimated encounter rate)**	**Composite 1 (lower risk)**	**Composite 2 (higher risk)**	**NWFP**
OCR	0.375 (0.710)	Z50Pub	NWFP+Elliott State Forest	NWFP
KLW	0.25 (0.315)	Z50Pub	Z30Pub	NWFP
RDC	0.25 (0.205)	Z30Pub+HCPs	All public lands	NWFP
KLE	0.25 (0.245)	Z50Pub	Z30Pub	NWFP
ICC	0.25 (0.213)	Z50Pub	Z30Pub	NWFP
WCS	0.375 (0.364)	Z50Pub	Z30Pub	NWFP
WCC	0.375 (0.320)	Z70Pub	Z50Pub	NWFP
WCN	0.375 (0.320)	Z70Pub	Z50Pub	NWFP
NCO	0.375 (0.505)	Z70PUB-- with addition of SOSEAs[/1] plus Satsop stepping stone[/2] (private land). RHS artificially inflated to =0.4 at step 1 within Satsop but not SOSEAs	NWFP with the addition of Satsop, Capitol State Forest, Lower Chehalis, and SOSEAs. RHS artificially inflated to =0.4 at step 1within all additions except SOSEAs.	NWFP
ECN	0.375 (0.296)	Z70all	Z70Pub	NWFP
ECS	0.25 (0.180)	Z70Pub	Z50Pub	NWFP

/1: SOSEA (Spotted Owl Special Emphasis Areas) are geographic areas as mapped in Washington State's Forest Practices Rules (WAC 222-16-086). Each delimited SOSEA polygon contains the specified goal for that area to provide for demographic and/or dispersal support as necessary to complement the northern spotted owl protection strategies on federal land within or adjacent to the SOSEA. These are private lands that have special protections for owl circles.

/2: "Satsop stepping stone" – a portion of the Satsop River watershed selected for evaluation of population response to increased connectivity that would potentially be provided by the inclusion of this area.

The barred owl encounter probabilities we established for modeling purposes do not represent predictions about conditions that will be achieved through management actions, nor are they estimates of what is likely to occur in the future. Instead, the assumed barred owl encounter probabilities were used to isolate the effects of habitat on simulated northern spotted owl populations and evaluate the critical habitat essential to recovery of the northern spotted owl, assuming that other, non-habitat based threats to the species have been addressed.

Environmental Stochasticity

The HexSim spotted owl model described in Appendix C of the Recovery Plan (USFWS 2011) uses 24 separate survival rates, distributed across 4 stage classes x 3 resources classes x 2 barred owl conditions (present / absent). For reproduction, the model uses 4 fecundity values, one for each stage class. Environmental stochasticity was added to the HexSim model by allowing survival rates to vary by up to 2.5 percent per year, and fecundity to vary by 50 percent per year. Stochastic survival and reproductive rates were selected independently (i.e., a good year for survival did not imply a good year for reproduction). From Forsman et al. (2011, Table 12) we calculated the mean variation as the ratio of 2*SE of adult survival divided by the mean adult survival. For each of the study areas for which data was presented mean variation 2.59% (range = 1.64 – 4.52%). We decided to use 2.5% as being quite close to this estimate. We allowed for this level of variation for each age class, even though separate calculations for younger age classes would have been much greater. Sample sizes were, however, much lower for younger age classes (3,545 adults, 903 2-yr old subadults, and 796 1-yr subadults; Forsman et al. 2011, p. 28). The 50% variation in fecundity was an attempt to allow for the wide variation in annual reproduction that is observed in many spotted owl population studies (Forsman et al. 2011). The survival rates used in the HexSim simulations prior to adding environmental stochasticity are shown in Table 5. If the collection of survival rates shown in Table 3 are placed into a vector S, then the family of survival rates used in the stochastic simulations could be represented as the set { 0.975 * S, 0.980 * S, 0.985 * S, 0.990 * S, 0.995 * S, S, 1.005 * S, 1.010 * S, 1.015 * S, 1.020 * S, 1.025 * S }. This set has 11 members, five of which represent survival rates lower than those in S, and five that represent survival rates higher than those in S. When the stochastic simulations were run, one member from this set was selected at random each year, and used to drive the survival decisions for that year.

Table 5. Spotted Owl Survival Rates

Without Barred Owls			With Barred Owls		
Stage Class	Resource Class	Survival Rate	Stage Class	Resource Class	Survival Rate
Stage 0	Low	0.366	Stage 0	Low	0.28
	Medium	0.499		Medium	0.413
	High	0.632		High	0.546
Stage 1	Low	0.544	Stage 1	Low	0.458
	Medium	0.718		Medium	0.632
	High	0.795		High	0.709
Stage 2	Low	0.676	Stage 2	Low	0.590
	Medium	0.811		Medium	0.725
	High	0.866		High	0.780
Stage 3	Low	0.819	Stage 3	Low	0.733
	Medium	0.849		Medium	0.763
	High	0.865		High	0.779

The reproductive rates used in the HexSim simulations prior to adding environmental stochasticity are shown in Table 6. If the collection of fecundities shown in Table 6 are placed into a vector F, then the family of reproductive rates used in the stochastic simulations could be represented as the set { 0.5 * F, F, 1.5 * F }. When the stochastic simulations were run, one member from this set of 3 elements was selected at random each year, and used to drive the reproductive decisions for that year.

Table 6. Spotted Owl Fecundity Rates

Stage Class	Fecundity
Stage 0	0
Stage 1	0.070
Stage 2	0.202
Stage 3	0.330

Adding stochasticity increases variability within and among HexSim replicates. In order to adequately assess these more variable results, we ran 100 replicates of each of the three network scenarios by two habitat change scenarios. Each replicate was run for

350 time-steps. The habitat network scenarios for Phase 2 were Composites 1 and 2, and the NWFP.

HexSim Population Performance Metrics and Criteria

Range-wide Comparisons

We evaluated the following population performance metrics:

1) total (mean of 100 replicates) population size at time-step 350;
2) percent population change between time-step 50 and time-step 350;
3) percentage of simulations during which the range-wide population fell to below 1,250 individuals;
4) percentage of simulations during which the range-wide population fell below 1,000 individuals;
5) percentage of simulations during which the range-wide population fell below 750 individuals; and
6) the grand mean of the population between time-steps 150 and 350.

Except for the second metric (percent change between time-steps 50 and 350) all other metrics were derived from time-steps 150 through 350. In most cases, our stochastic HexSim simulations had achieved steady-state by time step 150, and thus all but one of these metrics could be used to quantify the relative steady-state population size and distribution that should be associated with a proposed critical habitat network.

The "threshold" population sizes of 1,250, 1,000, and 750 represented population sizes that we believed to represent overall risk thresholds (Table 7). Connectivity/isolation, demographic stochasticity, competition, and other factors are more likely to have deleterious impacts on small populations. Furthermore, such population sizes would likely result in large areas of the currently-occupied range becoming unoccupied by owls. Although arbitrary, these thresholds provide a consistent way to compare the relative risk of various reserve networks. The population size at time-step 350 and the grand mean produced very similar results (see below).

We interpreted the percentage of simulations during which the population fell below each of the threshold range-wide population sizes (described above) to be equivalent to the probability of moderate population risk (1,250 females), high population risk (1,000 females) and extinction risk (750 females) (Table 7). We used these risk metrics to establish criteria for comparing range-wide population results among reserve designs.

Table 7. Categories of population and extinction risk used in comparisons of population modeling results

Risk Category	Description	Criteria
Range-wide Scale		
Moderate Population Risk	Probability of simulated population with < 1,250 females	< 20%
High Population Risk	Probability of simulated population with < 1,000 females	< 10%
Extinction Risk	Probability of simulated population with < 750 females	< 5%
Modeling Region Scale		
Moderate Population Risk	Probability of simulated population with < 250 females	N/A
High Population Risk	Probability of simulated population with < 100 females	N/A
Extinction Risk	Probability of simulated population reaching zero	N/A

Comparisons by Modeling Region

For each of the 11 modeling regions we evaluated the following population performance metrics of Phase 2 models:

1) percentage of replicates during which the population fell below 250 individuals;
2) percentage of replicates during which the population fell below 100 individuals;
3) percentage of replicates that went to extinction;
4) mean (of the 100 replicates) population size at time-step 350; and
5) grand mean of population size from time-steps 150 to 350.

We interpreted the percentage of simulations during which the population fell below each of the threshold modeling region population sizes (described above) to be equivalent to the probability of moderate population risk (250 females), high population risk (100 females) and extinction risk (0 females). We used these probability of population risk and extinction risk metrics to compare population results among habitat network designs; however, (unlike range-wide comparisons) we were unable to establish limits or *a priori* criteria for comparing modeling region-specific results because of the high variability in extent (area) and population sizes among modeling regions (hence the N/A in Table 7). Instead, we used the differences between risk probabilities to compare results among habitat network designs within modeling regions.

Because we introduced stochasticity into Phase 2, we ran 100 replicates of each potential network by habitat and barred owl scenario. Initial evaluations of 100 replicates showed that the grand population mean was relatively stable with 100 replicates and 350 time-steps.

As with Phase 1, we used a combination of quantitative output from HexSim and professional judgment to evaluate composite scenarios and the NWFP by "what if" RHS scenarios. We considered classifying HexSim output into categories representing the degree to which recovery goals were likely to be met. However, we did not carry through with this because there were circumstances when two results differed markedly, but both would be categorized as high risk (e.g., 33% vs. 78% of replicates falling below 250 individual females in a modeling region). In cases like this, the Service posited that 33% was much less risk than 78%. Therefore, we evaluated both the raw output data for each metric, as well as ranking each of the reserve scenarios. The rankings provided a relatively simple and consistent method to evaluate the performance of each scenario. We also estimated the difference in population performance between optimistic and pessimistic scenarios within each scenario and ranked the absolute value of the differences. This was done to evaluate how reliant a network's performance was on a particular habitat scenario – or its potential vulnerability to future uncertainty in habitat change. That is, if, within a habitat network scenario, population performance metrics were relatively similar (less variable) and relatively good in both optimistic and pessimistic scenarios, we might conclude that that network scenario was resilient to uncertainty in future habitat conditions. In contrast, if a habitat network scenario performed well under the optimistic scenario and poorly under the pessimistic, that would indicate that it was less resilient to the uncertainty of what will happen, regarding RHS change, in the future.

Phase 2 Results

In general, for most population metrics, and most modeling regions, the NWFP and Composite 2 performed worse than Composite 1 under the pessimistic habitat change scenario (Tables 6-8). Grand mean population size was greater in each modeling region and overall in Composite 1 (Tables 8-10). In modeling regions with small estimated owl populations (e.g., ECN, ECS, NCO, WCC, WCN) differences among habitat network designs were sometimes quite small (Tables 8-10).

Table 8. Modeling region-specific spotted owl population metrics from HexSim model of the NWFP with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Model Region	Population Metrics – NWFP				
	Percent of simulations with <250 females	Percent of simulations with <100 females	Percent of simulations that go to extinction	Mean (95% CI) population size at time-step 350	Grand mean population size time steps 150-350
NCO	100	100	19	60	67
OCR	99	62	0	186	195
ECN	100	100	2	47	61
ECS	100	100	0	81	79
WCN	100	100	79	5	8
WCC	100	100	31	25	32
WCS	66	20	0	368	415
KLE	78	7	0	359	364
KLW	19	0	0	629	628
ICC	10	3	0	445	441
RDC	100	100	0	75	74
Total				2088 (1919-2257)	2364

Table 9. Modeling region-specific spotted owl population metrics from HexSim model of Composite 1 with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Model Region	Population Metrics – Composite 1				
	Percent of simulations with <250 females	Percent of simulations with <100 females	Percent of simulations that go to extinction	Mean (95% CI) population size at time-step 350	Grand mean population size time steps 150-350
NCO	100	99	14	105	80
OCR	99	62	0	357	227
ECN	100	95	1	222	123
ECS	100	97	0	151	115
WCN	100	100	81	9	8
WCC	100	100	26	43	39
WCS	60	16	0	740	497
KLE	33	0	0	1016	554
KLW	7	0	0	1552	829
ICC	10	0	0	1212	650
RDC	65	0	0	766	421
Total				3216 (2988-3444)	3543

Table 10. Modeling region-specific spotted owl population metrics from HexSim model of Composite 2 with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Model Region	Population Metrics – Composite 2				
	Percent of simulations with <250 females	Percent of simulations with <100 females	Percent of simulations that go to extinction	Mean (95% CI) population size at time-step 350	Grand mean population size time steps 150-350
NCO	100	100	20	84	69
OCR	100	58	0	340	211
ECN	100	100	3	225	116
ECS	100	99	0	120	98
WCN	100	100	83	6	8
WCC	100	100	28	41	36
WCS	79	20	0	620	406
KLE	47	2	0	859	462
KLW	20	0	0	1261	663
ICC	23	0	0	1034	548
RDC	100	89	0	255	136
Total				2534 (2336-2731)	2753

Ranking of Scenarios

Not surprisingly, the optimistic RHS scenarios resulted in very minor differences among Composites 1 and 2, and the NWFP. All network scenarios performed quite well under the optimistic RHS scenarios; however, Composite 1 was consistently the best performing (Table 11).

The pessimistic RHS scenarios resulted in more dramatic differences among the network scenarios with Composite 1 performing much better than any other scenario and the NWFP performing poorest (Table 11). Furthermore, the optimistic minus pessimistic results showed that Composite 1 was least variable and the NWFP the most variable network scenario, with Composite 2 being intermediate (Table 11).

Table 11. Comparison of the rankings (range-wide) of Phase 2 network scenarios (Composites 1 and 2, and the Northwest Forest Plan [NWFP]) between optimistic and pessimistic habitat scenarios as well as optimistic minus-pessimistic (in gray). The SUM (summation) is of 61 individual rankings, whereas the mean is the mean rank of the 61 individual ranks. Lower numbers are better ranking.

RHS Scenario	Metric	NWFP	Composite 1	Composite 2
Optimistic	Sum	101	76	122
	Mean	1.7	1.2	2.0
Pessimistic	Sum	137	64	113
	Mean	2.2	1.0	1.9
Optimistic - Pessimistic	Sum	133	74	100
	Mean	2.2	1.2	1.6

Conclusions from Phase 2

Before moving on to Phase 3 comparisons, we assessed general patterns apparent in the population results from Phase 1 and 2 modeling. In combination with current demographic information (Forsman et al. 2011), past conservation planning efforts for the owl (ISC 1990, USFWS 2011), and numerous other sources of information, these results provided the foundation of our subsequent process for developing habitat network designs and making comparisons. In particular, regional differences in spotted owl populations and their environments influenced the subsequent network scenarios we created, and our ability to establish and apply rangewide *a priori* evaluation criteria to use in comparing habitat network designs. As importantly, we recognized the uncertainty surrounding future barred owl encounter rates and their effects on spotted owl recovery within the various habitat network designs.

Several modeling regions exhibited consistently poor population performance regardless of network design. Modeling regions with simulated owl populations that performed poorly in all network designs and under both optimistic and pessimistic scenarios included the ECN, ECS, NCO, WCC, and WCN. In these modeling regions, 100 % of the replicates had estimated population sizes that fell below 250 females under optimistic and pessimistic RHS scenarios; estimated population sizes fell to below 100 females in 95-100 % of simulations in these modeling regions. Extinction risk was estimated to be highest (>70% of replicates went to extinction under all designs by RHS scenarios) in the WCN under both RHS scenarios, followed by WCC and NCO modeling regions. Simulated populations went to extinction in 14 to 83 percent of simulations, regardless of network design, in NCO, WCN, and WCC. These results are consistent with past conservation planning efforts that identified the North Cascades, North Cascades East, Olympic Peninsula, and Southwestern Washington as Areas of Special Concern due to low population sizes, sparse distribution of suitable habitat due to high elevations, high proportions of private industrial timberlands (SW WA), and past management practices (Thomas et al. 1990, pp. 66-68). More recently, colonization by barred owls and expansion of their populations (as indicated by high encounter rates) has exacerbated spotted owl population concerns in these areas.

Phase 2 modeling identified the OCR as exhibiting poor population performance, regardless of network design or habitat change scenario. Estimated population size fell below 250 females in 100 percent of simulations under optimistic and pessimistic scenarios; 58 to 63 percent of simulations fell below 100 females. Due to past timber harvest on private industrial timberlands, State forests, and (to a lesser degree) Federal lands, this modeling region supports relatively low proportions of spotted owl habitat. In addition, the "checkerboard" ownership pattern of private and most BLM land in this area, combined with poor connectivity with larger spotted owl populations in the WCS, KLW and KLE, act to further constrain population performance. These results are consistent with the Interagency Scientific Committee's (Thomas et al. 1990, pp. 66-68) description of the Oregon Coast Range Area of Special Concern.

Phase 2 modeling results also highlighted the ECS as an area with small population size and relatively high risk. Modeled populations fell to below 100 females in 87 to 100 % of simulations, regardless of network or habitat-change scenario. Spotted owl habitat is limited in portions of this modeling region due to natural conditions (extensive ponderosa pine forest, high elevations) combined with a long history of intensive timber management. The southern Deschutes and Shasta-McCloud Areas of Special Concern (ISC 1990, pp. 66-68) lie within the ECS. The Shasta-McCloud Area of Special Concern consists of the portion of the ECS that lies within California, along with a small portion of the KLE near Mount Shasta. This area has also been identified as providing poor connectivity between the southern ECS and larger spotted owl populations in the KLE and ICC.

The ISC (1990, pp 66-68) also identified North Coastal California, an area corresponding to RDC, to be of special concern due to the predominance of private ownership in this modeling region. This region was unique in that it supports a large population of spotted owls on privately owned industrial timberlands. This contrasts sharply with privately owned industrial timberlands in southwestern Washington and coastal Oregon, where commercial forest management has resulted in extremely low numbers of spotted owl territories. The fact that spotted owls in the RDC appear to respond very differently (compared to owls in other portions of their range) to intensive timber harvesting influenced the assumptions we used in developing habitat change scenarios and modeling population responses for this region. In Phase 2 modeling, RDC exhibited the largest differences in modeled population size and risk between optimistic and pessimistic habitat scenarios. This result was inconsistent with the current spotted owl location and demographic data available to us. To address this, we modified the pessimistic habitat change scenario to allow a proportion of RHS on private timberlands in RDC to remain above 35 (more closely resembling the estimated RHS changes from 1996 – 2006), resulting in a less pessimistic habitat change scenario and enabling simulated owls to establish territories and reproduce outside of the habitat network. In western Washington and the Oregon coast, on the other hand, we felt that the pessimistic scenario described for Phase 2 modeling was more reasonable.

In contrast to the northern modeling regions, the Klamath-Siskiyou region and southwestern Cascades supported relatively robust populations of spotted owls. Based on the grand population mean between time-steps 150 and 350, the ICC, KLE, KLW, RDC, and WCS modeling regions represented from 80-87% of the total range-wide population of spotted owls regardless of network or RHS scenario (though the percentage was larger in the optimistic scenario in all cases). These results were consistent with spotted owl location data available to us, as well as results from recent meta-analysis of demographic data (Forsman et al. 2011).

Uncertainty surrounding future barred owl encounter rates and their effects on spotted owl population performance within the various network designs also influenced our process for evaluating and comparing habitat network designs. Data from the spotted owl demographic study areas clearly indicate that barred owl densities (and subsequently estimated encounter rates) continue to increase. Studies of barred owl effects on territory occupancy by spotted owls (Dugger et al. 2011) suggest that increasing amounts of suitable habitat may act to ameliorate the effects of barred owl competition; however, it is unclear how long this benefit will operate if barred owl densities continue to increase. While it was necessary to select an assumed barred owl encounter rate for population modeling, we understood that our population results would be somewhat optimistic if barred owl encounter rates exceed the assumed rates described under Phase 2 modeling. We incorporated this unquantifiable potential 'bias' into our decision process by selecting conservatively among competing population risk metrics.

PHASE 3 MODELING

Phase 3 modeling consisted of iterative refinement and testing of potential critical habitat scenarios. In contrast to the model-driven processes used in Phases 1 and 2, evaluation processes in Phase 3 were based on model results obtained in the previous steps *combined with* other sources of information such as spotted owl location data, ancillary sources of habitat data, information regarding ecological conditions and disturbance regimes, and expert opinion from Service and other Federal biologists. In addition, aspects of spotted owl conservation such as future population connectivity, disturbance regimes, genetic linkages, and land ownership patterns that were not explicitly addressed by our modeling framework were evaluated at this step.

Use of expert opinion to refine the modeling products is consistent with the guidance in Appendix C of the Revised Recovery Plan (p. C-2): "While this framework represents state-of-the-art science, it is not intended to represent absolute spotted owl population numbers or be a perfect reflection of reality. Instead, it provides a comparison of the relative spotted owl responses to a variety of potential conservation measures and habitat conservation networks. The implementation of spotted owl recovery actions should consider the results of the modeling framework as one of numerous sources of information to be incorporated into the decision-making process." Further, Wintle et al. (2005) recommended when evaluating model output that: "Expert opinion can (and should) be used…for corroboration of a model's ecological realism, for ad hoc evaluation of model prediction, and for preparation of predictive maps for use in decision making…Consequently, the role of experts should be thought of as complementary to other, more data-driven methods, rather than as a competing alternative." The modeling cannot reliably be applied to critical habitat revision without going through this type of evaluation. We adopted a relatively conservative conservation approach, consistent with the recommendations of Reed et al. (2006) and other conservation-oriented modeling approaches (e.g., Beissinger et al. 2006).

Each composite developed and tested in Phase 3 represented the Service's effort to ensure that the reserve network accurately and efficiently reflected where the physical and biological features in habitat occupied at the time of listing are essential for conservation of the spotted owl as well as essential areas that may have been unoccupied at the time of listing. Furthermore, given the Endangered Species Act's direction to focus first on occupied habitat when identifying critical habitat, these composites represent occupied habitat to the greatest degree possible. The Service additionally sought suggestions from U.S. Forest Service and Bureau of Land Management professionals on Phase 3 scenarios as well (see below).

During Phase 3, the Service used technical knowledge and on-the-ground experience to evaluate and modify the composite maps relative to the following considerations:

Population Distribution – Because the modeling framework is based on current habitat conditions, we reviewed the composite maps to assess whether the habitat networks corresponded to the full ecological gradient of the historical range of the spotted owl. We considered whether substantial areas of formerly occupied habitat, potentially capable of supporting spotted owl populations in the future, needed to be incorporated into the network design.

Connectivity and Isolation – We evaluated whether the model-based critical habitat networks incorporated adequate population connectivity and did not exclude smaller, isolated populations from consideration. In particular, we reviewed "areas of special concern" described by the ISC (1990), as well as areas identified in field studies (e.g., Stralberg et al. 2009). In some cases, we reconfigured boundaries or identified additional areas of habitat to ensure adequate population connectivity and representation of isolated populations.

Efficiency – The Service reviewed each composite map and evaluated the extent to which the model-generated maps (Zonation) reflected efficient network designs. We found that under some circumstances the Zonation algorithm attempted to achieve preselected habitat objectives (e.g., 50%) by retaining relatively low RHS in some areas. In these cases we refined the boundaries to better match the distribution of habitat likely to support occupancy by spotted owls.

Disturbance Regimes and Spatial Redundancy – The Service assessed factors such as wildfire risk not directly addressed by the modeling framework. These factors are particularly important in the fire-prone Klamath and Eastern Cascades areas, where disturbances such as wildfire exert a strong influence on the distribution and quality of spotted owl habitat through time.

Land Ownership Patterns – Across most of the range the model-based network designs attempted to meet habitat and population objectives on public lands; however, we further attempted to focus the designs specifically onto Federal lands when the quality and distribution of habitat on Federal lands was adequate to meet spotted owl conservation objectives. In some areas where Federal lands were not adequate to achieve conservation goals, we identified non-federal lands as likely necessary for recovery of the spotted owl.

Logical Boundaries - Where possible, we sought to use existing boundaries of management units or other administrative or geographic lines.

Following each change, the resulting composite was evaluated in HexSim, and spotted owl population response metrics were compared to all other composites rangewide and per modeling region. The process ***did not consist of successive refinements***, however, because some composites contained suggestions or proposals from other Federal agencies which we evaluated in HexSim and either accepted, rejected, or modified based on the population modeling results. Our objective was to address the above considerations while simultaneously meeting the objectives described in the Critical Habitat Guiding Principles and the statutory requirements for the identification of critical habitat.

Composite 3

Our primary objective for Composite 3 was to develop a network design that incorporated recommendations from the US Forest Service to rely on the existing NWFP late-successional reserves in the mesic modeling regions (WCN, WCC, OCR, and the northern portion of the WCS), and retained (relatively low) levels of population risk similar to Composite 1. This proposal also included a suggestion, based on wildfire probability modeling conducted for the NWFP monitoring program (Davis et al. 2011), to consider the southern portion of the WCS as a fire-prone area and use a design approach similar to other fire-prone regions (KLW, KLE and ICC).

To accommodate wildfire-related changes in habitat quality and distribution through time, we retained the low-risk habitat network design from Composite 1 (Z50 PUB) in the fire-prone southern modeling regions (KLW, KLE, ICC and southern portion of WCS). In contrast to smaller areas with higher risk of habitat loss, this approach incorporated habitat redundancy and enables strategic landscape-level management to restore and maintain owl habitat through time.

In mesic modeling regions with limited habitat on Federal lands (WCN, OCR and portions of NCO), we added some State and private lands to evaluate their effect on population performance. In NCO and WCN, Spotted Owl Special Emphasis Areas (SOSEA; a mix of State and private lands) were added to the habitat network. In addition, we added two areas in SW Washington to evaluate their potential contribution to population connectivity between the Olympic National Forest and the western Cascades. In these areas, we increased future RHS to 0.4 to allow occupancy in HexSim. In the OCR, portions of the Elliott State Forest were included to decrease risk.

Table 12. Habitat network design elements and spatial extent by ownership of Composite 3.

Model Region	Network Design	Area within Networks (acres)				
		Total	Federal/1	Congr. Reserve/2	State	Non-public/3
NCO	Z70PUB with addition of SOSEAs and Satsop area 'stepping stone'	3,682,647	821,944	889,635	1,350,290	620,778
OCR	NWFP plus portion of Elliott State Forest	930,005	801,801	34,858	93,211	136
ECN	Z70PUB	3,311,356	2,232,861	1,078,453	0	41
ECS	Z70PUB	1,036,306	785,911	250,383	0	12
WCN	NWFP with addition of SOSEAs	1,913,451	705,508	1,207,853	49	41
WCC	NWFP	1,358,312	634,244	724,017	13	38
WCS	Z50PUB in fire-prone south, NWFP in mesic north	1,883,660	1,663,046	220,578	1	35
KLE	Z50PUB	1,394,234	1,247,161	147,041	1	30
KLW	Z50PUB	1,556,809	1,349,495	207,217	4	93
ICC	Z50PUB	1,565,650	1,248,030	317,565	0	55
RDC	Z30PUB plus HCPs	1,450,282	118,015	177,287	169,861	985,119
	Total	20,082,712	11,608,016	5,254,887	1,613,429	1,606,380

/1 USFS and BLM lands, excluding Congressional Reserves (Wilderness, National Parks)
/2 Congressional Reserves (Wilderness, National Parks)
/3 Privately owned lands, tribal lands

Modeling regions with the NWFP as their basic habitat network design included all Congressionally Reserved lands as "reserve" lands, and our area calculations include these lands. In previous critical habitat rules for the northern spotted owl, these lands were not included in critical habitat.

Composite 3 Population Results

Population modeling results suggested that overall, Composite 3 performed better than Composite 2 and NWFP, but not as well as Composite 1. Range-wide, population size (grand mean at time-step 350) in Composite 3 was greater than Composite 2 (2,753) and NWFP (2,364), but less than Composite 1 (3,541). In most modeling regions, population sizes in Composite 3 were intermediate between Composites 1 and 2. However, in OCR, ECN, and WCC, Composite 3 populations were substantially less than Composites 1 and 2.

Table 13. Modeling region-specific spotted owl population metrics from HexSim model of Composite 3 with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Model Region	Population Metrics – Composite 3				
	Percent of simulations with <250 females	Percent of simulations with <100 females	Percent of simulations that go to extinction	Mean (95% CI) population size at time-step 350	Grand mean population size time steps 150-350
NCO	100	99	9	54	74
OCR	100	73	0	158	178
ECN	100	100	4	44	63
ECS	100	99	0	118	116
WCN	100	100	75	5	8
WCC	100	100	35	17	27
WCS	59	21	0	372	481
KLE	39	3	0	509	507
KLW	12	0	0	777	761
ICC	18	1	0	616	606
RDC	73	2	0	404	396
Total				3074 (2857-3291)	3217

Regardless of reserve design, five modeling regions (NCO, WCN, WCC, ECN and ECS) exhibited uniformly high (greater than 95 percent) probability of high population risk (Table 13). In the OCR, however, population risk was higher in Composite 3 (73%) than in the other networks (58 to 62%). Probability of high population risk in WCS was moderate (16 to 21%) in all four habitat networks. Four modeling regions (NCO, ECN, WCN and WCC) had relatively high extinction risk. Four southern regions (KLE, KLW, and ICC) exhibited relatively low probability of high population risk (0 to 7%), with no simulations going to zero.

One objective of Composite 3 was to evaluate owl population response to increased connectivity between the Olympic Peninsula and populations in the western Cascades. Increased connectivity, provided by a series of hypothetical habitat areas ("stepping stones") on private and State lands in NCO , was associated with a decreased probability of extinction in Composite 3 (9 percent versus 14, 19 and 20 percent in NWFP and Composites 1 and 2, respectively).

Composite 4

Composite 4 was developed using Composite 3 as a starting point. In developing Composite 4, we sought to simultaneously improve the efficiency of potential critical habitat networks and reduce the level of population risk in NCO, OCR, ECN, ECS, WCN and WCC modeling regions, and to refine the networks in modeling regions with more robust population results. In some modeling regions, this involved reverting to modified versions of networks from Composite 1 or 2.

In Composite 4, the Composite 3 habitat network design for NCO was enhanced by the addition of Capitol State Forest, Joint Base Lewis-McChord (JBLM), and areas of Washington Department of Natural Resources (WA DNR) lands with existing habitat retention agreements. WA DNR lands with existing habitat retention agreements were also added to WCN and WCC (regions in which the NWFP rather than a Zonation network was the basis of Composite 3). We increased the habitat area in the OCR by reinstating Z50PUB (from Composite 1; instead of the NWFP area that had been used in Composite 3), and adding in mapped 'connectivity support areas' provided by BLM.

Within the Shasta-McCloud Area of Special Concern (ISC 1990) portion of ECS, we refined the habitat network (Z70PUB) to better reflect the distribution of RHS and areas capable of developing into spotted owl habitat.

We identified two populations at the extreme southern end of the spotted owl's range that were not included in the Zonation-based (Z30PUB, Z50PUB) networks for RDC and ICC. Based on mapped owl locations, RHS, and similar habitat modeling by Stralberg et al. (2009), we delineated two potential critical habitat units to conserve these isolated populations.

In all modeling regions in OR and CA, we trimmed areas of low RHS from identified habitat so that the boundaries conformed more closely with contiguous areas of moderate to high RHS, and small fragments were removed.

In general, the habitat networks within the fire-prone southern modeling regions (KLE, KLW and ICC), as well as RDC, did not change from Composite 3.

Table 14. Habitat network composition and spatial extent by ownership of Composite 4.

Model Region	Habitat Network	Area within Networks (acres)				
		MR Total	Federal/1	Congr. Reserve/2	State	Non-public/3
NCO	Z70PUB with addition of SOSEAs, Fort Lewis, Capitol State Forest, Satsop removed, RHS trimmed	2,682,070	806,747	889,561	874,756	111,006
OCR	Z50PUB (=Comp1), RHS trimmed, connectivity additions	912,424	810,124	22,773	79,527	0
ECN	Z70PUB plus some WA State lands, RHS trimmed	3,741,864	2,359,240	1,046,819	82,115	253,690
ECS	Z70PUB (=Comp1), revised reserves in Shasta-McCloud AOC	763,619	596,620	166,987	0	12
WCN	NWFP plus SOSEAs, additional WA State lands	2,039,187	705,843	1,207,853	121,736	3,756
WCC	NWFP plus SOSEAs, additional WA State lands	1,525,920	634,273	724,017	165,639	1,992
WCS	Z50PUB (=Comp1), RHS trimmed	1,884,020	1,662,364	220,572	929	155
KLE	Z50PUB (=Comp3), RHS trimmed	1,393,595	1,246,482	147,041	41	30
KLW	Z50PUB (=Comp3), RHS trimmed	1,566,682	1,357,579	207,211	1,799	93
ICC	Z50PUB (=Comp3), added in isolated population in Napa Co, RHS trimmed	1,656,444	1,247,996	317,140	4,119	87,188
RDC	Z30PUB plus HCPs (=Comp3), added in isolated population in Sonoma Co., RHS trimmed	1,530,783	118,309	174,024	170,169	1,068,281
	Rangewide Total	19,696,609	11,545,577	5,123,998	1,500,830	1,526,203

/1 USFS and BLM lands, excluding Congressional Reserves (Wilderness, National Parks)
/2 Congressional Reserves (Wilderness, National Parks)
/3 Privately owned lands, tribal lands. Small acreage (<1,000 acres) of non-public land within a modeling region are the result of map errors and are not included in networks.

Composite 4 Population Results

Population modeling results for Composite 4 indicate that the reduction of risk we sought was realized in some modeling regions (OCR, ECN, WCC), whereas risk remained unchanged (ECS) or increased (NCO, WCN) in others. In OCR, risk (quasi-extinction100) decreased by 18 percent, and population size (grand mean years 150-350) in Composite 4 increased by 19 percent from Composite 3. Conversely, extinction risk (percent of simulations going to zero) in NCO and WCN increased by 120 percent and 20 percent, respectively, in Composite 4; population size declined by 33 percent in WCN.

Table 15. Modeling region-specific spotted owl population metrics from HexSim model of Composite 4 with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Model Region	Population Metrics – Composite 4				
	Percent of simulations with <250 females	Percent of simulations with <100 females	Percent of simulations that go to extinction	Mean (95% CI) population size at time-step 350	Grand mean population size time steps 150-350
NCO	100	100	20	50	74
OCR	100	62	0	190	212
ECN	100	98	2	72	101
ECS	100	97	0	120	124
WCN	100	100	90	3	6
WCC	100	100	21	22	31
WCS	41	14	0	450	547
KLE	28	2	0	552	552
KLW	9	0	0	827	806
ICC	17	0	0	669	662
RDC	50	3	0	434	435
Total				3390 (3152-3628)	3550

Relative to Composite 3, population sizes in Composite 4 increased (and risk levels decreased) in 8 of 11 modeling regions. Modeled population increases in modeling regions whose habitat area did not change from Composite 3 (KLE, KLW, ICC and RDC) likely resulted from increased dispersal and recruitment from populations in modeling regions that improved in Composite 4 (OCR, WCS).

Composite 5

This composite was primarily intended to evaluate an alternative habitat network suggested by the BLM for their lands in western Oregon. The BLM provided shapefiles for proposed areas in the NCO, OCR, WCS, ECS and the northern portions of KLW and KLE. Their objectives were to incorporate the results of their forest growth modeling into the habitat network, reduce the extent of NWFP matrix lands in potential critical habitat (relative to Composites 3 and 4), and to improve connectivity.

In addition, we incorporated revisions to the Composite 4 habitat network in the NCO, OCR and WCS suggested by the USFS. Specifically, the USFS requested that we evaluate a habitat network that included only NWFP late-successional reserves on the Mount Hood, Siuslaw, and Olympic National Forests. Yakima Tribal lands were removed from reserves in ECN, WCC.

To evaluate the potential effect on connectivity and population size at the southern extreme of ICC, RDC, we removed the areas associated with the Napa and Sonoma County isolated populations for this comparison.

Table 16. Habitat network elements and spatial extent by ownership of Composite 5.

Model Region	Habitat Network	Area within Networks (acres)				
		MR Total	Federal/1	Congr. Reserve/2	State	Non-public/3
NCO	Z70PUB with addition of SOSEAs, Fort Lewis, Capitol State Forest, removed NWFP matrix lands on Olympic NF, Satsop removed, BLM proposal substituted on BLM lands (minor)	2,446,749	571,455	889,560	874,755	110,978
OCR	Z50PUB (=Comp1), BLM proposal substituted on BLM lands, removed NWFP matrix lands on Siuslaw NF, RHS trimmed	742,404	640,108	22,754	79,527	15
ECN	Composite 4, removed NWFP matrix lands on Mt Hood NF, removed Yakima tribal lands (test)	3,373,540	2,220,748	1,046,819	82,115	23,858
ECS	Composite 4	696,765	529,768	166,987	0	9
WCN	Composite 4	2,039,187	705,843	1,207,853	121,736	3,756
WCC	Composite 4, removed NWFP matrix lands on Mt Hood NF	1,525,914	634,273	724,017	165,639	1,986
WCS	Composite 4, BLM proposal substituted on BLM lands, RHS trimmed	1,648,427	1,429,283	218,055	929	160
KLE	Composite 4, BLM proposal substituted on BLM lands	1,200,672	1,053,407	147,041	41	184
KLW	Composite 4, BLM proposal substituted on BLM lands, RHS trimmed	1,606,227	1,396,351	207,210	1,798	868
ICC	Composite 4, removed Napa reserve (test)	1,566,400	1,247,446	317,140	1,757	57
RDC	Composite 4, removed Sonoma reserve (test)	1,445,198	118,290	174,024	169,862	983,021
	Rangewide Total	18,291,483	10,546,974	5,121,459	1,498,157	1,124,893

/1 USFS and BLM lands, excluding Congressional Reserves (Wilderness, National Parks)
/2 Congressional Reserves (Wilderness, National Parks)
/3 Privately owned lands, tribal lands. Small acreage (<1,000 acres) of non-public land within a modeling region are the result of map errors and are not included in networks.

Composite 5 Population Results

Rangewide mean population size at time 350 in Composite 5 was greater than Composite 2 and the NWFP, but lower than all other composites. Extinction risk was fairly low overall; however, specific modeling regions (NCO, OCR, ECN, ECS, WCN, and WCC) exhibited higher extinction risk.

Table 17. Modeling region-specific spotted owl population metrics from HexSim model of Composite 5 with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Model Region	Population Metrics – Composite5				
	Percent of simulations with <250 females	Percent of simulations with <100 females	Percent of simulations that go to extinction	Mean (95% CI) population size at time-step 350	Grand mean population size time steps 50 - 350
NCO	100	98	26	46	67
OCR	100	78	0	143	165
ECN	100	100	1	53	78
ECS	100	99	0	99	104
WCN	100	100	78	4	8
WCC	100	100	30	18	28
WCS	63	9	0	376	505
KLE	55	3	0	424	452
KLW	9	0	0	783	798
ICC	12	1	0	636	645
RDC	60	1	0	417	420
Total				2999 (2795-3202)	3270

Because the primary changes made between Composite 4 and 5 involved BLM lands in four modeling regions (OCR, WCS, KLE and KLW) in western Oregon, population differences between Composites 4 and 5 were largely confined to that area. Probability of moderate risk increased by 96 percent in KLE and 54 percent in WCS. In Composite 5, probability of high population risk increased by 26 percent in OCR. Grand mean population sizes in OCR, KLE, and WCS declined by 22 percent, 18 percent, and 8 percent, respectively.

Changes in the habitat network associated with the Mount Hood (ECN and WCC), Siuslaw (OCR), and Olympic (NCO) National Forests between Composites 4 and 5 also appeared to have influenced population results. Reduction of areas identified in NWFP matrix lands on the Siuslaw NF likely contributed to the previously-described increase in risk exhibited in OCR. Extinction risk in the NCO and WCC increased by 30 percent and 43 percent, respectively. Grand mean population sizes were reduced by 16 percent, and 23 percent in NCO and ECN, respectively.

Composite 6

In general, Composite 6 represented further refinement of Composite 4, based on comparison of population modeling results for Composites 3 through 5.

In Composite 6 we sought to develop and evaluate a more efficient habitat network for WCN, WCC, and ECN that remedied the overly broad network resulting from Zonation-based designs. Spotted owl habitat in those modeling regions tends to be sparsely distributed, its occurrence conforming to river drainages and lower elevations. When this pattern occurs, the Zonation algorithm appeared to aggregate some areas of low RHS to as it attempted to reach the cumulative habitat objective (e.g., 30%, 50%). To remedy this, we used the RHS maps directly to delineate potential critical habitat boundaries that more closely conformed to the distribution of moderate-high RHS and mapped spotted owl locations. We used a GIS-based elevation mask from the NWFP Monitoring Program (Davis et al. 2011) to further eliminate high-elevation areas unlikely to be occupied by spotted owls.

Composite 4 was reinstated as the basic habitat network in OCR. Based on expert opinion from BLM biologists, we revised the habitat areas identified in OCR and northern portions of KLW and KLE to more closely reflect lands most likely to support owls, and further refined by removing small isolated habitat patches.

To address connectivity issues resulting from a partial habitat gap in the area affected by the 2005 Biscuit Fire Area, we added in some areas that supported moderate to high RHS and occupied spotted owl locations in 1996.

In the RDC, we evaluated the population response to using only public lands and private lands with Habitat Conservation Plans or other formal agreements intended to conserve spotted owl habitat. In addition, we refined the habitat change scenario for RDC, based on estimated changes in RHS between 1996 and 2006, to better reflect habitat suitability in intensively managed redwood forests. We modified the pessimistic scenario as follows. Habitat suitability (RHS) within networks remained constant at its estimated 2006 level, whereas RHS outside of networks was reduced by 5 percent in each of two 20 year time-steps (not compounded).

In RDC and ICC, we reinserted slightly modified versions of the lands in Sonoma and Napa Counties intended to conserve specific isolated populations.

Table 18. Habitat network elements and spatial extent by ownership of Composite 6.

Model Region	Habitat Network	Area within Networks (acres)				
		MR Total	Federal/1	Congr. Reserve/2	State	Non-public/3
NCO	Removed low RHS	1,765,443	734,119	723,445	306,918	961
OCR	Composite 4, some low-RHS BLM lands removed	891,166	790,443	22,782	77,941	0
ECN	Removed low RHS	1,936,625	1,356,593	368,903	57,589	153,540
ECS	Composite 4, minor trimming	526,815	417,763	109,040	2	11
WCN	Removed low RHS	760,955	543,603	165,419	49,645	2,288
WCC	Composite 4 (NWFP), added high RHS matrix lands,	1,336,694	923,740	324,970	38,342	49,642
WCS	Composite 4, some low-RHS BLM lands removed	1,869,525	1,593,297	275,889	183	156
KLE	Composite 4	1,357,354	1,214,381	142,912	40	20
KLW	Composite 4, modified	1,695,874	1,396,892	296,127	2,383	472
ICC	Composite 4, Napa reserve reinstated	1,576,186	1,195,969	318,031	2,359	59,826
RDC	Public lands and HCPs only, Sonoma reserve reinstated	1,561,575	114,531	185,046	201,099	1,060,900
	Rangewide Total	15,278,211	10,281,331	2,932,564	736,499	1,327,816

/1 USFS and BLM lands, excluding Congressional Reserves (Wilderness, National Parks)

/2 Congressional Reserves (Wilderness, National Parks)

/3 Privately owned lands, tribal lands. Small acreage (<500 acres) of non-public land within a modeling region are the result of map errors and are not included in networks.

Composite 6 Population Results

At range-wide scales, population risk results for Composite 6 were very similar to Composite 5. All range-wide population size metrics were slightly larger for Composite 6; grand mean population size was 3,533 (7% larger) in Composite 6 versus 3,270 in Composite 5.

Population modeling results for most individual modeling regions were similar to Composite 5. Population sizes increased somewhat in eight modeling regions and were unchanged in three.

In northern modeling regions with small spotted owl populations, substantial refinement and reduction of the habitat network area either resulted in improved population results or did not influence population results (Table 17). By removing areas of low RHS, the area in the network was reduced by 28 percent and 12 percent in NCO and WCC, respectively, whereas extinction risk declined by 31 percent and 30 percent because we added in some areas of higher RHS not included in the Zonation networks. Levels of population or extinction risk were not appreciably influenced by 43 percent and 24 percent reductions of habitat network area in ECN and ECS, respectively. However, extinction risk in WCN increased 10 percent in response to a 63 percent reduction in network area.

Table 19. Modeling region-specific spotted owl population metrics from HexSim model of Composite 6 with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Model Region	Population Metrics – Composite 6				
	Percent of simulations with <250 females	Percent of simulations with <100 females	Percent of simulations that go to extinction	Mean (95% CI) population size at time-step 350	Grand mean population size time steps 50 - 350
NCO	100	100	18	39	64
OCR	98	66	0	167	205
ECN	100	99	2	65	98
ECS	100	99	0	117	122
WCN	100	100	86	4	8
WCC	100	100	21	23	39
WCS	56	12	0	392	529
KLE	28	3	0	513	539
KLW	8	0	0	797	820
ICC	14	2	0	620	644
RDC	45	4	0	452	464
Total				3190 (2958-3422)	3533

In Composite 6 we used habitat networks from Composite 4 in OCR, KLE, KLW, and WCS, resulting in improved population performance relative to Composite 5. Probability of moderate population risk was reduced 49 percent in KLE and 11 percent in WCS; population sizes (grand mean) in KLE, KLW, and WCS increased 3 percent, 5 percent, and 19 percent, respectively. More importantly, probability of high population risk in OCR was reduced 15 percent, and population size increased by 24 percent

Composite 7: Proposed Critical Habitat

The primary objective of Composite 7 was to evaluate the effect of relatively large refinements of habitat networks in the southern fire-prone modeling regions (KLE, KLW, ICC, and WCS). In this exercise, we used topographic features (major ridges, elevation), RHS maps, and administrative boundaries on Federal lands to subdivide the larger areas into separate units more closely corresponding to higher-quality habitat (RHS) and the distribution of occupied spotted owl sites. This refinement resulted in 18 percent, 24 percent, 19 percent and 13 percent reductions of habitat area in these four modeling regions, respectively.

At the extreme south end of RDC and ICC, we revised the Sonoma and Napa areas to more closely match the distribution of higher RHS and to reduce the amount of high-density subdivisions (parcels < 40 acres) within the identified network area.

Based on new information regarding Habitat Conservation Plans and other habitat management strategies in the State of Washington, we made a number of changes to State (WA DNR) and private lands in SOSEAs in NCO, WCN, WCC and ECN so that the habitat network better reflected State lands managed for spotted owl habitat.

Table 20. Habitat network elements and spatial extent by ownership of Composite 7.

Model Region	Habitat Network	Area within Networks (acres)				
		MR Total	Federal/1	Congr. Reserve/2	State/3	Non-public/4
NCO	Composite 6, WA state/private lands refined	1,595,821	734,119	723,445	137,964	938
OCR	Composite 6, WA state/private lands refined	891,154	790,433	22,782	77,939	0
ECN	Composite 6, WA state/private lands refined	1,919,469	1,656,601	68,890	58,281	129,760
ECS	Composite 6,	526,810	417,770	109,040	2	0
WCN	Composite 6, WA state/private lands refined	820,832	543,615	165,407	111,329	0
WCC	Composite 6, WA state/private lands refined	1,353,045	923,742	324,966	62,220	41,680
WCS	Composite 6, modified	1,624,836	1,371,170	253,666	183	155
KLE	Composite 6, modified	1,111,679	1,018,352	90,487	2,840	0
KLW	Composite 6, modified	1,291,606	1,128,755	152,390	10,461	437
ICC	Composite 6, modified, refined Napa unit	1,276,450	978,599	250,575	12,123	40,118
RDC	Composite 6, refined Sonoma unit	1,550,747	114,523	185,025	224,491	1,030,796
	Rangewide Total	13,962,449	9,374,497	2,646,671	697,834	1,243,885

/1 USFS and BLM lands, excluding Congressional Reserves (Wilderness, National Parks)
/2 Congressional Reserves (Wilderness, National Parks)
/3 Includes County, Municipal lands
/4 Privately owned lands, tribal lands

Composite 7 Population Results

Although Composite 7 was 8.6 percent smaller in area than Composite 6, range-wide population results for the two composites were very similar (Table 22). Probability of high population risk and extinction risk were very low in both composites; population size (grand mean) for Composite 7 was 1.9 percent lower than Composite 6. Composite 7 was 30.5 percent smaller in area than the largest reserve design (Composite 3), but exhibited consistently lower risk metrics and similar population sizes (Figures 4 and 5).

Table 21. Modeling region-specific spotted owl population metrics from HexSim model of Composite 7 with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Model Region	Population Metrics – Composite 7				
	Percent of simulations with <250 females	Percent of simulations with <100 females	Percent of simulations that go to extinction	Mean (95% CI) population size at time-step 350	Grand mean population size time steps 150-350
NCO	100	99	21	52 (42-62)	74
OCR	99	58	0	173 (150-196)	212
ECN	100	95	3	66 (58-75)	97
ECS	100	95	0	112 (105-119)	120
WCN	100	100	80	4 (3-5)	8
WCC	100	100	28	25 (20-30)	38
WCS	59	14	0	375 (328-423)	501
KLE	38	0	0	473 (440-507)	522
KLW	9	0	0	732 (685-779)	776
ICC	12	0	0	596 (559-632)	641
RDC	46	2	0	442 (414-471)	475
Total				3051(2834-3268)	3464

The **North Coast and Olympic Peninsula modeling region (NCO)** consistently exhibited small population sizes and high extinction risk, with probability of extinction ranging from 9 percent (Composite 3) to 26 percent (Composite 5) under pessimistic habitat scenarios. Probability of extinction under Composite 7 was 21 percent; more than double that of Composite 3. Lower extinction probabilities in Composites 1 and 3 were correlated with large amounts of State and private land added to those networks to evaluate population effects of increased connectivity to the Olympic Peninsula. Because most of the hypothetical State and private habitat areas ("stepping stones") evaluated in Composite 3 did not meet criteria for critical habitat (no currently suitable habitat and no records of occupancy by spotted owls), they were not incorporated into subsequent composites. Composite 7 therefore contains roughly 95 percent less State and private land than Composite 3. Grand mean population size was less than 100 females (range 64 to 80; 74 in Composite 7) in all networks and under both optimistic and pessimistic habitat change scenarios, suggesting that populations are limited by habitat availability and population isolation, as well as the moderate influence of barred owl (0.375 encounter rate) used in HexSim simulations. Most of the suitable spotted owl habitat within the NCO occurs on Federal lands at relatively low elevations in the Olympic National Park and adjacent Olympic National Forest; suitable habitat is extremely limited on State and private lands in the coast ranges of Washington and northern Oregon.

In the **Oregon Coast Range modeling region (OCR)**, probability of high population risk (less than 100 females) was consistently high (58 to 78 percent of simulations) among habitat networks. Probability of high population risk under Composite 7 was 58 percent. Extinction risk was zero in all networks. Grand mean population size ranged from 178 to 222 females among networks (212 in Composite 7). The relatively small variation in population size among networks and between optimistic/pessimistic scenarios suggests that spotted owl populations in the OCR are limited by the amount and distribution of suitable habitat. Most of the habitat networks for OCR contained a large proportion of the available suitable habitat (RHS > 35) and known spotted owl locations on Federal lands, limiting our ability to improve risk metrics or substantially increase population size by increasing area within networks.

Climate and elevation in the **Eastern Cascades North (ECN) modeling region** act to limit the amount and distribution of forest types suitable for spotted owls. Probability of high population risk ranged from 91 percent to 100 percent among networks and between optimistic and pessimistic habitat scenarios. Under pessimistic habitat change scenarios, probability of extinction ranged from zero (Composite 7) to 4 percent (Composite 3). Population size under Composite 7 (97 females) was slightly less than Composite 4 (101 females), despite Composite 7 being roughly half the area of Composite 4.

Similar to ECN, the **Eastern Cascades South (ECS) modeling region** supports limited amounts and distribution of suitable spotted owl habitat. Probability of high population risk in Composite 7 was 99 percent for pessimistic habitat scenarios (79 percent for optimistic); overall among habitat networks in ECS, probability of high population risk ranged from 73 to 89 percent for optimistic habitat scenarios and 95-100 percent in pessimistic habitat scenarios. Extinction risk was zero for all reserve designs. Population size for Composite 7 (120 females) was similar to Composites 1, 4 and 6 (123, 124 and 122 females); but Composite 7 was approximately 50 percent smaller than Composite 1.

Although much of the **Western Cascades North modeling region (WCN)** is comprised of National Park and wilderness areas, the amount and distribution of forest types suitable for spotted owls is strongly limited by elevation and climate. The WCN supports the smallest and most at-risk spotted owl population within the species' range; probability of high population risk was 100 percent for all reserve designs and both optimistic and pessimistic habitat scenarios. Extinction risk (percent of simulations going to zero) ranged from 75 to 90 percent for optimistic habitat scenarios, and 77 to 89 percent for pessimistic scenarios. Population sizes among all reserve designs and habitat change scenarios ranged from 6 to 8 females; however, Composite 7 was 60 percent smaller than Composites 4 and 5. The high degree of similarity among population results for different reserve designs suggests that most suitable habitat is contained within reserves and few options exist for improving population outcomes, given the assumed level of barred owl effects.

Habitat availability and population metrics for spotted owls in the **Western Cascades Central (WCC) modeling region** were similar to the WCN. The WCC exhibited a 100 percent probability of moderate and high population risk under all networks and habitat change scenarios. Probability of extinction among habitat networks ranged from 12 to 26 percent under optimistic habitat scenarios and 21 to 35 percent under pessimistic habitat scenarios. While population sizes (grand mean at time-step 350) for Composite 7 were small (44 and 38 females for optimistic and pessimistic habitat scenarios), they were the largest among all networks and habitat scenarios (range 27 to 44 females).

The **Western Cascades South (WCS) modeling region** is dominated by Federal lands and supports extensive areas of suitable spotted owl habitat. Probability of moderate population risk for pessimistic habitat scenarios under Composite 7 was 50 percent; other networks ranged from 41 to 79 percent. Probability of high population risk for Composite 7 under pessimistic habitat scenarios was 14 percent; other networks ranged from 9 to 21 percent. Probability of extinction risk was zero for all habitat networks. Population size (grand mean at time-step 350) for Composite 7 was 648 and 501 females for optimistic and pessimistic habitat scenarios, respectively.

Habitat network and population characteristics were similar among the fire-prone **Eastern Klamath (KLE), Western Klamath (KLW) and Northern California Interior Coast Ranges (ICC)** modeling regions in the southern portion of the spotted owl's geographic range. Probability of moderate population risk under Composite 7 was 2 percent (ICC), 8 percent (KLE) and 5 percent (KLW) for optimistic habitat scenarios, and 12, 38 and 9 percent, respectively, for pessimistic habitat scenarios. Probability of high population risk was zero for Composite 7, as was extinction risk. Population sizes (grand mean at time-step 350) for Composite 7 were 973 (ICC), 770 (KLE) and 901 (KLW) under optimistic habitat scenarios and 641 (ICC), 522 (KLE) and 776 (KLW) under pessimistic scenarios.

Because private timberlands constitute a large majority of the **Redwood Coast (RDC) modeling region**, population modeling results varied widely among networks and habitat change scenarios applied to public versus non-public lands. A pessimistic habitat change scenario specific to RDC was used in population modeling for Composites 6 and 7 (see Composite 6 description); therefore pessimistic scenario results from these composites were not directly comparable to earlier networks identified. Probability of moderate population risk for Composite 7 was 3 percent and 46 percent under optimistic and pessimistic scenarios, respectively. Probability of high population risk was consistently low under optimistic habitat scenarios, but ranged from 100 percent to 1 percent under pessimistic habitat scenarios. This variation was the result of differing assumptions regarding habitat quality on private timberlands through time. Probability of high population risk under Composite 7 and pessimistic habitat change scenarios was 2 percent. Extinction risk was zero for all networks and habitat change scenarios. Population size for Composite 7 was 781 females and 475 females for optimistic and pessimistic scenarios, respectively.

OVERVIEW OF PHASE 3 RANGEWIDE HABITAT NETWORK COMPARISONS

In this section we present an overview of our comparisons of population performance (HexSim results) across all seven composites and also with NWFP. We sought efficient potential critical habitat networks based (to the maximum extent feasible) on public lands, with a particular emphasis on Federal lands, that met the conservation objectives described in the Guiding Principles presented earlier in this document. While larger habitat networks had highest overall population performance, we were able to develop smaller, more efficient networks of critical habitat that supported similar population performance and thus meet the goal of providing for the conservation of the northern spotted owl (Table 22; Figures 4 and 5). Composite 7 represents the critical habitat network that was the basis for our proposed revision of critical habitat for the northern spotted owl, published March 8, 2012 (77 FR 14062).

Table 22. Range-wide spotted owl population metrics from HexSim model of Composites 1- 7 and NWFP with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Population Metric	Conservation Habitat Network Design							
	NWFP	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7
N (time-step 50) /1	6861	6760	7193	6879	7012	7204	7268	6077
N (time-step350)	2088	3216	2534	3074	3390	2999	3190	3051
N350/N50 x 100/2	30	48	35	45	48	42	44	50
% of simulations N <1250	43	11	26	20	14	11	10	12
% of simulations N <1000	24	5	15	11	8	5	6	3
% of simulations N <750	11	0	2	1	0	2	3	1

/1 : N = number of female individuals

/2 : Percent of time-step 50 population at time-step 350

As noted above, efficiency of the habitat network was one of the Service's goals. One method of evaluating efficiency is to compare habitat scenario area to owl population size. Figures 4 and 5 show this relationship for each of the seven Composite network scenarios and the NWFP.

Figure 4. Total area and number of female owls present in population at time-step 350 for Composites 1-7 and the Northwest Forest Plan (NWFP) using the pessimistic habitat scenario.

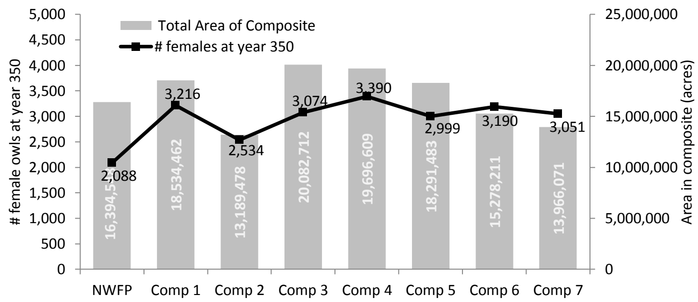
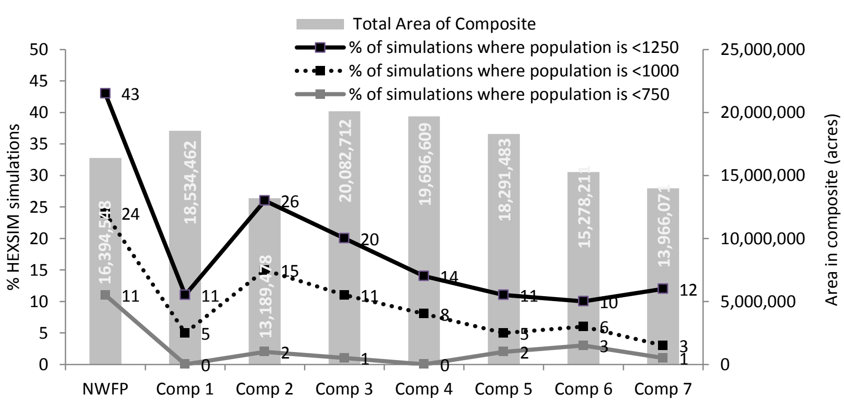


Figure 5. Total area and percent of HexSim simulations (pessimistic habitat scenario) where spotted owl populations fell below 1250, 1000, and 750 total owls for Composites 1-7 and the Northwest Forest Plan (NWFP).



Levels of population risk (Figure 5) followed a pattern similar to that shown in Figure 4; with Composite 7 as the most efficient of the scenarios we evaluated.

INTRODUCTION TO PHASE 4 MODELING

In Phase 4 we used the HexSim spotted owl population model to compare each of four scenarios to a single baseline (Composite 7; Proposed Critical Habitat). The primary objective of Phase 4 comparisons was to evaluate the effects of incorporating peer review and public comments, additional input from federal agencies, and exclusions into the proposed critical habitat. One of the networks we evaluated (Composite 8) was solely a function of requests from other federal agencies. The preponderance of changes among Composites consisted of exclusions under Section 4(b)2 of the Endangered Species Act. As we moved closer to articulating the final CH network we also made fine-scale refinements to subunit boundaries such that implementation and understanding of CH boundaries would be easier.

Section 4(b)2 exclusions result in a fundamental change in the way comparisons are made. Exclusions act to reduce the spatial extent of designated critical habitat, but many do not influence the availability of habitat resources and subsequently have little influence on simulated population outcomes. This is because 4(b)2 exclusions are generally made for areas such as Wilderness, National Parks, Wild and Scenic River corridors, State Parks and Natural Areas, and private lands with Habitat Conservation Plans (HCPs) or Safe Harbor Agreements (SHAs) that are expected to retain habitat value regardless of whether they are designated as critical habitat or not. In HexSim, this results in application of habitat (RHS) change scenarios to three functional categories: 1) critical habitat (reserve), 2) other reserve habitat (excluded areas such as Congressionally Reserved Lands, HCPs, etc.) and 3) non-reserved areas.

Composite 8

The primary objective of Composite 8 was to evaluate formal comments from the BLM and US Forest Service (USFS) suggesting the modification of specific subunits of proposed critical habitat in California, Oregon and Washington. USFS Regions 5 and 6 provided GIS files with suggested boundary edits to better match administrative boundaries and identified areas in proposed critical habitat that had either burned in recent fires or did not provide good owl habitat. In addition, Service staff met with USFS biologists in Region 5 to review maps and identify lands to remove from or add to the network based on habitat suitability and administrative boundaries. In moist forest types in Oregon and Washington (ORC, NCO, WCN, WCC, WCS), this proposal included removal of lands designated as Matrix and Adaptive Management Areas under the NWFP, as well as Experimental Forests, from the network. Similarly, the BLM provided maps of lands they suggested be included in or removed from the network in western Oregon (KLE, KLW, ORC, WCS). We combined all changes proposed by USFS and BLM into a single map (Composite 8) for evaluation in HexSim (Table 23).

Some State and privately owned lands with Habitat Conservation Plans (HCPs) and Safe Harbor Agreements (SHAs) were excluded from the network in Composite 8. In Washington, approximately 15,000 acres (Fort Lewis IMRMP and WA DNR HCP) were excluded in NCO; 71,328 acres were excluded in ECN (WA DNR HCP, Plum Creek HCP, others); 111,135 acres were excluded in WCN (WA DNR HCP); and 89,000 acres were excluded in WCC (WA DNR HCP, Plum Creek HCP, other HCPs). In California, 812,000 acres were excluded in RDC, including Green Diamond, Humboldt Redwood and Mendocino Redwood HCP and several smaller HCPs, and SHAs. As previously described in *Introduction to Phase 4 Modeling*, these exclusions do not influence population results in HexSim because habitat conditions in these areas are expected to continue to support conservation of NSO. (Note that the use of the word "excluded" here is in the sense of "removed," and should not be interpreted as the application of section 4(b)(2) of the Endangered Species Act).

Table 23. Habitat network elements and spatial extent by ownership of Composite 8.

Model Region	Habitat Network	Area within Networks (acres)				
		MR Total	Federal/1	Congr. Reserve/2	State/3	Non-public/4
NCO	Composite 7, USFS edits; HCPs, State parks, WA DNR excluded	1,385,156	539,370	708,598	137,188	0
OCR	Composite 7, USFS, BLM edits	804,335	703,675	22,783	77,877	0
ECN	Composite 7, USFS edits; HCPs, State parks, WA DNR excluded	1,580,044	1,190,221	352,816	239	36,768
ECS	Composite 7, USFS edits	432,859	331,793	101,065	0	0
WCN	Composite 7, USFS edits; HCP and WA DNR lands excluded	704,251	538,803	165,449	0	0
WCC	Composite 7, USFS edits; HCP and WA DNR lands excluded	906,256	582,797	318,829	0	4,630
WCS	Composite 7, USFS, BLM edits	1,460,093	1,206,025	253,884	183	0
KLE	Composite 7, USFS, BLM edits	999,401	906,721	89,841	2,840	0
KLW	Composite 7, USFS edits	1,133,889	985,206	138,457	10,227	0
ICC	Composite 7, USFS edits	1,079,837	794,816	243,217	11,739	30,065
RDC	Composite 7, HCP/SHA lands excluded	709,454	90,821	184,337	219,420	214,876
	Rangewide Total	11,195,574	7,870,248	2,579,275	459,712	286,339

/1 USFS and BLM lands, excluding Congressional Reserves (Wilderness, National Parks)
/2 Congressional Reserves (Wilderness, National Parks)
/3 Includes County, Municipal lands
/4 Privately owned lands, tribal lands

Composite 8 Population Results

Overall, spotted owl performance was quite poor under Composite 8 (Table 24), with substantially lower population sizes and greater extinction risks than in Composite 7 (Table 21; Figure 6). Mean population size at time-step 350 for Composite 8 was 39 percent smaller than Composite 7; 95 percent confidence intervals did not overlap. Population risk (quasi-extinction 1250) under Composite 8 (56%) was 4.6 times greater than under Composite 7 (12%).

Table 24. Modeling region-specific spotted owl population metrics from HexSim model of Composite 8 with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Model Region	Population Metrics – Composite 8				
	Percent of simulations with <250 females	Percent of simulations with <100 females	Percent of simulations that go to extinction	Mean (95% CI) population size at time-step 350	Grand mean population size time steps 150-350
NCO	100	99	26	32 (25-40)	57
OCR	100	78	1	123 (106-141)	155
ECN	100	100	8	29 (24-34)	52
ECS	100	100	0	62 (57-66)	70
WCN	100	100	81	3 (2-4)	7
WCC	100	100	37	12 (9-15)	26
WCS	89	39	0	219 (191-246)	318
KLE	94	16	0	261 (241-281)	300
KLW	38	1	0	443 (411-475)	507
ICC	56	3	0	390 (364-417)	433
RDC	95	13	0	274 (255-294)	306
Total				1,850 (1,711-1,988)	2,231

Composite 9

Using Composite 7 as a starting point, we evaluated the suggested edits proposed by BLM and USFS (see Composite 8) and incorporated a limited subset of these edits to remove areas of low RHS due to recent harvests and wildfire events, improve connectivity among specific modeling regions and refine subunit boundaries. We also conducted additional refinement of specific subunits in WA to remove private and State lands not providing suitable habitat.

Composite 9 retained the exclusions of HCPs and SHAs on State and private lands described under Composite 8. As mentioned previously in *Introduction to Phase 4 Modeling*, these exclusions do not influence population results in HexSim because habitat conditions in these areas are expected to continue to support conservation of NSO.

Table 25. Habitat network elements and spatial extent by ownership of Composite 9.

Model Region	Habitat Network	Area within Networks (acres)				
		MR Total	Federal/1	Congr. Reserve/2	State/3	Non-public/4
NCO	Composite 7; HCPs, State parks, WA DNR excluded	1,535,712	697,594	708,998	129,120	0
OCR	Composite 7; refined	874,704	778,879	22,783	73,041	0
ECN	Composite 7; HCPs, State parks, WA DNR excluded	1,727,616	1,339,184	351,422	241	36,769
ECS	Composite 7; refined, USFS edits	466,312	365,213	101,099	0	0
WCN	Composite 7 HCPs, State parks, WA DNR excluded;	708,682	543,233	165,449	0	0
WCC	Composite 7; HCPs, State parks, WA DNR excluded	1,239,671	910,095	324,943	0	4,634
WCS	Composite 7; refined	1,592,190	1,338,055	253,952	183	0
KLE	Composite 7 ; refined	1,137,506	1,040,237	94,430	2,840	0
KLW	Composite 7; refined	1,270,967	1,123,941	136,550	10,440	0
ICC	Composite 7; refined	1,242,652	958,326	242,518	11,739	30,065
RDC	Composite 7; HCP/SHA lands excluded	737,787	113,348	185,069	224,491	214,879
	Rangewide Total	12,533,798	9,208,105	2,587,212	452,096	286,346

/1 USFS and BLM lands, excluding Congressional Reserves (Wilderness, National Parks)
/2 Congressional Reserves (Wilderness, National Parks)
/3 Includes County, Municipal lands
/4 Privately owned lands, tribal lands

Composite 9 Population Results

Rangewide, spotted owl populations performed quite well with the Composite 9 network (Table 26). Performance was very similar to owl performance under the Composite 7 network (Table 21; Figure 6).

Table 26. Modeling region-specific spotted owl population metrics from HexSim model of Composite 9 with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Model Region	Population Metrics – Composite 9				
	Percent of simulations with <250 females	Percent of simulations with <100 females	Percent of simulations that go to extinction	Mean (95% CI) population size at time-step 350	Grand mean population size time steps 150-350
NCO	100	100	19	44 (35-53)	65
OCR	99	63	0	174 (153-195)	203
ECN	100	99	0	57 (50-65)	89
ECS	100	100	0	114 (106-122)	119
WCN	100	100	81	4 (3-5)	8
WCC	100	100	26	20 (16-24)	36
WCS	58	17	0	368 (326-410)	482
KLE	38	2	0	516 (476-555)	533
KLW	9	0	0	747 (694-801)	768
ICC	17	2	0	598 (559-637)	616
RDC	51	2	0	454 (425-484)	462
Total				3,097 (2873-3321)	3,378

Composite 10a

This composite differs from all previous maps because it is based on a revised ownership map layer consisting of updated State and Federal ownership data. This refinement was in response to numerous public comments describing mapping errors that resulted in many, generally, small areas of critical habitat being inadvertently proposed on private lands adjacent to public lands. This revision resulted in some shifting of critical habitat boundaries, particularly in landscapes with complex ownership patterns, and at the boundaries of some National Parks.

In addition to the exclusions described for Composites 8 and 9, all Congressionally Reserved Lands (National Parks, Wilderness, Wild and Scenic Rivers, National Monuments), State Parks and Natural Areas, and were excluded from critical habitat in Composite 10a. These exclusions resulted in a 2,587,212-acre reduction in critical habitat area; however, because habitat conditions in these areas are expected to continue to support conservation of NSO regardless of their status, they do not influence population results in HexSim (see *Introduction to Phase 4 Modeling).*

In response to peer review and public comments as well as input from Federal biologists, we further refined subunit boundaries to: 1) better conform to the distribution of high-RHS and occupied spotted owl habitat, 2) better conform to landscape features and other identifiable boundaries, and 3) improve connectivity in specific portions of the spotted owl's range.

Table 27. Habitat network elements and spatial extent by ownership of Composite 10a.

Model Region	Habitat Network	Area within Networks (acres)				
		MR Total	Federal/1	Congr. Reserve/2	State/3	Non-public/4
NCO	Composite 9; CR excluded	825,017	696,230	0	128,270	517
OCR	Composite 9; CR excluded	859,864	788,919	0	70,945	0
ECN	Composite 9; CR excluded	1,382,826	1,338,988	0	6,534	37,303
ECS	Composite 9; CR excluded	368,381	368,380	0	0	0
WCN	Composite 9; CR excluded	542,274	541,476	0	798	0
WCC	Composite 9; CR excluded	914,379	908,861	0	825	4,693
WCS	Composite 9; CR excluded	1,355,198	1,354,989	0	209	0
KLE	Composite 9; CR excluded	1,052,731	1,049,826	0	2,905	0
KLW	Composite 9; CR excluded	1,197,389	1,186,750	0	10,639	0
ICC	Composite 9; CR excluded	971,203	940,721	0	848	29,635
RDC	Composite 9; CR excluded	395,332	111,258	0	69,596	214,477
	Rangewide Total	9,864,594	9,286,399	0	291,570	286,625

/1 USFS and BLM lands, excluding Congressional Reserves (Wilderness, National Parks)
/2 Congressional Reserves (Wilderness, National Parks)
/3 Includes County, Municipal lands
/4 Privately owned lands, tribal lands

Composite 10a Population Results

Rangewide, spotted owl population performance was again quite good under the Composite 10a network (Table 28), with performance being very similar to that seen under the Composite 7 network (Table 21; Figure 6).

Table 28. Modeling region-specific spotted owl population metrics from HexSim model of Composite 10a with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Model Region	Population Metrics – Composite 10a				
	Percent of simulations with <250 females	Percent of simulations with <100 females	Percent of simulations that go to extinction	Mean (95% CI) population size at time-step 350	Grand mean population size time steps 150-350
NCO	100	100	24	39 (31-48)	60
OCR	99	60	0	179 (155-203)	210
ECN	100	97	3	59 (50-67)	89
ECS	100	99	0	112 (105-119)	121
WCN	100	100	84	4 (3-5)	8
WCC	100	100	26	20 (16-24)	37
WCS	63	17	0	375 (327-424)	484
KLE	25	1	0	517 (481-553)	548
KLW	7	0	0	777 (725-830)	813
ICC	12	0	0	607 (571-644)	630
RDC	45	0	0	441 (415-468)	466
Total				3,131 (2,904-3,358)	3,466

Composite 11: Designated Revised Critical Habitat

The final designation differs from Composite 10a solely in the exclusion of private lands in RDC (214,477 acres), ICC (29,635 acres), WCC (4,693 acres), ECN (37,303 acres), and NCO (517 acres) from critical habitat.

Table 29. Habitat network elements and spatial extent by ownership of Composite 11.

Model Region	Habitat Network	Area within Networks (acres)				
		MR Total	Federal/1	Congr. Reserve/2	State/3	Non-public/4
NCO	Composite 10; excluded private lands	824,500	696,230	0	128,270	0
OCR	Composite 10	859,864	788,919	0	70,945	0
ECN	Composite 10; excluded private lands	1,345,523	1,338,988	0	6,534	0
ECS	Composite 10a	368,381	368,380	0	0	0
WCN	Composite 10a	542,274	541,476	0	798	0
WCC	Composite 10a; excluded private lands	909,687	908,861	0	825	0
WCS	Composite 10a	1,355,198	1,354,989	0	209	0
KLE	Composite 10a	1,052,731	1,049,826	0	2,905	0
KLW	Composite 10a	1,197,389	1,186,750	0	10,639	0
ICC	Composite 10a; excluded private lands in Napa subunit	941,568	940,721	0	848	0
RDC	Composite 10a; excluded private lands in Sonoma subunit and	180,855	111,258	0	69,596	0
	Rangewide Total	9,577,969	9,286,399	0	291,570	0

/1 USFS and BLM lands, excluding Congressional Reserves (Wilderness, National Parks)
/2 Congressional Reserves (Wilderness, National Parks)
/3 Includes County, Municipal lands
/4 Privately owned lands, tribal lands

Composite 11 Population Results

Spotted owl population performance under the Composite 11 network (Table 30) was very similar to that observed under the Composite 7 network (Table 21, Figure 6). Mean population size at time-step 350 for Composite 11 (3,224 females) was slightly higher than Composite 7 (3,051 females), but confidence intervals overlapped broadly. Grand mean population size differed by roughly 4 percent. Overall, risk metrics for Composite 11 were somewhat higher than Composite 7; moderate population risk (quasi-extinction 1250) for Composites 7 and 11 was 12 percent and 19 percent, respectively.

Table 30. Modeling region-specific spotted owl population metrics from HexSim model of Composite 11 with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 4.

Model Region	Population Metrics – Composite 11				
	Percent of simulations with <250 females	Percent of simulations with <100 females	Percent of simulations that go to extinction	Mean (95% CI) population size at time-step 350	Grand mean population size time steps 150-350
NCO	100	100	22	44 (35-53)	63
OCR	100	63	0	185 (161-208)	203
ECN	100	100	4	63 (53-73)	86
ECS	100	100	0	120 (112-128)	120
WCN	100	100	83	4 (3-6)	7
WCC	100	100	29	24 (19-30)	36
WCS	68	19	0	375 (326-425)	455
KLE	31	1	0	539 (501-578)	539
KLW	7	0	0	818 (760-876)	801
ICC	22	2	0	612 (571-652)	596
RDC	63	5	0	440 (408-471)	425
Total				3,224 (2,977-3,472)	3,331

The **North Coast and Olympic Peninsula modeling region (NCO)** consistently exhibited small population sizes and high extinction risk; probability of extinction was similar for Composite 11 (22 percent) and Composite 7 (21 percent) under pessimistic habitat scenarios. Grand mean population size for Composite 11 (63 females) was slightly less than Composite 7 (74 females). Grand mean population size was fewer than 100 females (range 57 to 80) in all networks and under both optimistic and pessimistic habitat change scenarios, suggesting that populations are limited by habitat availability and population isolation, as well as the moderate influence of barred owl (0.375 encounter rate) used in HexSim simulations. Most of the suitable spotted owl habitat within the NCO occurs on Federal lands at relatively low elevations in the Olympic National Park and adjacent Olympic National Forest; suitable habitat is extremely limited on State and private lands in the coast ranges of Washington and northern Oregon.

In the **Oregon Coast Range modeling region (OCR)**, probability of high population risk (less than 100 females) was consistently high (58 to 78 percent of simulations) among habitat networks. Mean population sizes at time step 350 for Composite 11 was slightly higher than Composite 7 (173 and 185 females, respectively); but probability of high population risk under Composite 11 (63 percent) was slightly higher than Composite 7 (58 percent). Extinction risk was zero in both composites. The relatively small variation in population size among networks and between optimistic/pessimistic scenarios suggests that spotted owl populations in the OCR are limited by the amount and distribution of suitable habitat. Most of the habitat networks for OCR contained a large proportion of the available suitable habitat (RHS > 35) and known spotted owl locations on Federal lands, limiting our ability to improve risk metrics or substantially increase population size by increasing area within networks. However, evaluation of patterns of dispersal flux in HexSim suggested that spotted owl populations in OCR are dependent on source populations in WCS, KLE and KLW (Figure 3); and that connectivity and the condition of those source populations, in addition to the amount of habitat, influence populations in OCR.

Climate and elevation in the **Eastern Cascades North (ECN) modeling region** act to limit the amount and distribution of forest types suitable for spotted owls. Probability of high population risk under pessimistic habitat scenarios was 95 percent and 100 percent for Composites 7 and 11, respectively. Under pessimistic habitat change scenarios, probability of extinction was very low in Composites 7 and 11 (3 and 4 percent). Mean population size at time-step 350 were similar for Composites 7 and 11 (95% confidence intervals broadly overlap).

Similar to ECN, the **Eastern Cascades South (ECS) modeling region** supports limited amounts and distribution of suitable spotted owl habitat. Probability of high population risk in Composites 7 and 11 (and all networks evaluated) were over 95 percent. Extinction risk was zero for Composites 7 and 11. Mean population size at time-step 350 for Composite 11 (120 females) was slightly higher than Composite 7 (112 females) but confidence intervals overlapped broadly.

Although much of the **Western Cascades North modeling region (WCN)** is comprised of National Park and wilderness areas, the amount and distribution of forest types suitable for spotted owls is strongly limited by elevation and climate. The WCN supports the smallest and most at-risk spotted owl population within the species' range; probability of high population risk was 100 percent for all reserve designs and both optimistic and pessimistic habitat scenarios. Extinction risk (percent of simulations going to zero) was 80 and 83 percent, respectively, for Composites 7 and 11. Mean population sizes at time-step 350 (4 females) were the same for Composites 7 and 11. The high degree of similarity among population results for different reserve designs suggests that most suitable habitat is contained within reserves and few options exist for improving population outcomes, given the assumed level of barred owl effects.

Habitat availability and population metrics for spotted owls in the **Western Cascades Central (WCC) modeling region** were similar to the WCN. Probability of moderate and high population risk was 100 percent for Composites 7 and 11; and probability of extinction was 28 and 29 percent, respectively, under pessimistic habitat scenarios. Both grand mean and time-step 350 population size were the same for Composites 7 and 11.

The **Western Cascades South (WCS) modeling region** is dominated by Federal lands and supports extensive areas of suitable spotted owl habitat. Probability of moderate population risk for pessimistic habitat scenarios under Composites 7 and 11 were 58 and 68 percent, respectively; probability of high population risk was 14 and 19 percent. Probability of extinction risk was zero for both Composites. Mean population sizes at time-step 350 (375 females) were similar for Composites 7 and 11.

Population characteristics were similar among the fire-prone **Eastern Klamath (KLE), Western Klamath (KLW) and Northern California Interior Coast Ranges (ICC)** modeling regions in the southern portion of the spotted owl's geographic range. Probability of moderate population risk under Composite 11 was 22 percent (ICC), 31 percent (KLE) and 7 percent (KLW) under pessimistic habitat scenarios. Probability of high population risk was ≤ 2 percent for Composites 7 and 11, and extinction risk was zero. Mean population sizes under pessimistic scenarios in ICC (612 females), KLE (539) and KLW (818) for Composite 11 were somewhat higher than Composite 7(596 in ICC, 475 in KLE and 732 in KLW), but confidence intervals overlapped.

Because Congressionally Reserved lands (Redwood National and State Parks, Headwaters Forest Ecological Reserve and others) and private timberlands with HCPs (Humboldt Redwoods, Mendocino Redwood Company, Green Diamond Resource Company and others) constitute the majority of proposed critical habitat**,** final critical habitat **was** strongly influenced by 4(b)2 exclusions in the **Redwood Coast (RDC) modeling region**. The total area of critical habitat designated in RDC fell from 1,554,836 acres in Composite 7 to 180,855 acres in Composite 11; however, modeled population results were only slightly changed because, as discussed above, habitat conditions in Congressionally reserved lands and lands covered by HCPs are expected to continue to support conservation of NSO. Probability of moderate population risk under pessimistic habitat scenarios increased from 46 percent in Composite 7 to 63 percent in Composite 11. Probability of high population risk for Composites 7 and 11 was consistently low (2 and 5 percent, respectively) under pessimistic habitat scenarios; extinction risk was zero for both. Mean population size at time-step 350 for Composites 7 and 11 (pessimistic scenarios) were very similar (442 and 440 females, respectively) and 95 percent confidence intervals were nearly identical. Grand mean population size under pessimistic scenarios for Composite 7 (475 females) was somewhat higher than Composite 11 (425 females). Despite the dramatic reduction in area designated as critical habitat in RDC, changes in modeled population performance between Composites 7 and 11 are relatively small because the majority of lands excluded between Composites 7 and 11 are expected to continue to provide adequate habitat to conserve the species.

Changes Between Proposed Critical Habitat and Designated Critical Habitat

Changes to spatial extent of critical habitat

Final critical habitat (Composite 11) is approximately 4,384,662 acres smaller in size than the proposed critical habitat (Composite 7). The majority of this difference (4,271,291 acres) consists of Section 4(b)2 exclusions. About 225,894 acres of relatively low-suitability habitat on BLM and USFS lands were removed from Composite 7 because we determined that they did not meet the definition of critical habitat; 74 percent (167,161acres) of these were matrix lands. Composite 11 contains approximately 382,027 acres that were not within Composite 7, all of which were within the proposed critical habitat units; this area consists of 1) areas of Federal land added to the network as a consequence of corrected ownership data, 2) areas of high RHS habitat on Federal lands added during refinement of subunit boundaries, and 3) areas of high RHS on Federal lands added to improve population connectivity in specific areas, response to peer review comments. These changes are further explained below. All of these lands were added as a result of comments responding to our request in the proposed rule for information on areas that should be included or not included in the designation. All additional lands are under Federal ownership, and the majority are within Late-successional Reserves (LSRs). The end result is a net reduction in the amount of matrix lands included in critical habitat; the offset with increased high value habitat identified in LSRs maintains population performance in the final designation.

In response to comments and to increase efficiency and ensure that the designation focused on high-suitability habitat, we further refined the boundaries of some subunits by shifting them to incorporate high-value habitat while simultaneously reducing relatively lower-value habitat in the network. To the greatest degree possible, (i.e., while still meeting recovery goals and our guiding principles) we removed matrix lands and incorporated habitat in LSRs in this process.

In response to peer review comments about connectivity and population issues we identified specific areas providing high-suitability habitat that were required to better achieve population objectives in specific lower-performing modeling regions. The additional areas consisted solely of Federal lands, primarily USFS LSR lands, that were essential to provide connectivity between populations in the Oregon Coast Ranges and adjacent regions with larger spotted owl populations, as pointed out in peer review and public comments, and supported by results of population modeling. In many cases, areas added were specifically identified by the USFS or BLM as lands that should be added to compensate for removal of other, lower value lands. To the degree possible, we attempted to situate additions within LSRs and balanced additions by removing lower-quality areas in matrix land allocations. No additional State or private lands were designated in this process, and all areas are within the critical habitat units as described in the proposed rule.

We further refined the critical habitat boundaries to better conform to identifiable landscape features or administrative boundaries, and to improve consistency with our goal of prioritizing higher value Federal lands to include in critical habitat while removing relatively lower value lands in all ownerships. In this way, we ensure that the desgination includes only what is essential to conservation of the species. The USFS provided a number of specific suggestions in their public comment for these refinements. Overall, these refinements resulted in a small net reduction of critical habitat area on Federal lands.

Although Composite 11 is 4.4 million acres smaller than Composite 7, the amounts of RHS available to spotted owl populations are very similar between the two Composites (Table 32). In terms of overall area and proportion of RHS in each category, Composite 11HS is 2 to 3 percent smaller than Composite 7HS. This is largely due to Section 4(b)2 exclusions of Congressionally Reserved areas, State parks, and private lands with HCPs (see above) that were not included in the final rule but were still considered to maintain their RHS value for spotted owls. When applying our pessimistic scenario, RHS was not assumed to be retained on approximately 165,861 acres of private lands (without HCPs or SHAs) that were excluded in Composite 11.

Table 32. Comparison of Composite 7 (proposed Critical Habitat) and Composite 11 (final Critical habitat) with regard to the distribution of relative habitat suitability (RHS). The values under the 5 RHS bins represent the percentage of the total area within the northern spotted owl's geographic range that are included in A) in the total reserved area (CH plus exclusions), and B) in the actual critical habitat network. The first two networks (Comp 7HS and Comp 11HS) represent the amount of area that was considered to be reserved by HexSim when our simulations were run and represents the habitat available to northern spotted owls across their range for these networks. This includes all Congressionally Reserved lands, all state parks, and lands with signed conservation agreements regardless of whether they are designated. The second two networks (Comp7 and Comp 11) represent the RHS value of habitat actually designated. The differences between A) and B) illustrate that there are lands outside designated critical habitat that will provide resources for northern spotted owls. The last row in each section (Range (acres)) represents the total number of acres (million) within each RHS bin within the entire geographic range of the northern spotted owl.

A) Critical Habitat plus Exclusions		RHS Bin (white rows = % of bin in network, brown rows = acres)				
Network	Size (million acres)	0-20	20-40	40-60	60-80	>80
Comp 7HS	19.09	20.01	44.07	65.32	82.72	90.02
Comp 11HS	18.52	19.62	42.12	63.83	80.93	88.34
Range (acres)	57.16	36.70	10.13	7.35	2.83	0.15

B) Designated Critical Habitat Only						
Comp 7	**13.96**	**8.76**	**38.06**	**60.94**	**80.35**	**88.23**
Comp 11	**9.57**	**5.27**	**26.62**	**44.26**	**56.66**	**56.07**
Range (acres)	**57.16**	**36.70**	**10.13**	**7.35**	**2.83**	**0.15**

Population results

Results of spotted owl population modeling for Composites 7, 9, 10a and 11 were very similar, with broadly overlapping confidence intervals (Table 33, Figure 6). Population sizes at time-step 350 were highest for Composite 11; however, population risk metrics were also somewhat higher but were within the population criteria established for our comparisons (Table 7). This increased risk may have resulted from removal of private lands without conservation agreements from the network in Composite 11 which resulted in greater variation in population performance (and consequently slightly higher occurrences of population levels dropping below 1250, 1000, or 750. Because confidence intervals overlapped broadly across all composites and and modeled population size for Comp11 was higher than other composites, we considered Composite 11 to be the top performing or equivalent to the top performing composites in this comparison.

Table 33. Range-wide spotted owl population metrics from HexSim model of Composites 7-11 and NWFP with 'pessimistic' habitat change scenario and barred owl encounter rates from Table 2.

Population Metric	Conservation Habitat Network Design					
	NWFP	Comp7/3	Comp8	Comp9	Comp10a	Comp11/4
N (time-step 50) /1	6861	6077	4360	6168	5876	5996
N (time-step350)	2088	3051	1850	3097	3109	3224
N350/N50 x 100/2	30	50	42	50	53	54
% of simulations N <1250	43	12	56	12	17	19
% of simulations N <1000	24	3	31	7	7	10
% of simulations N <750	11	1	14	3	3	3

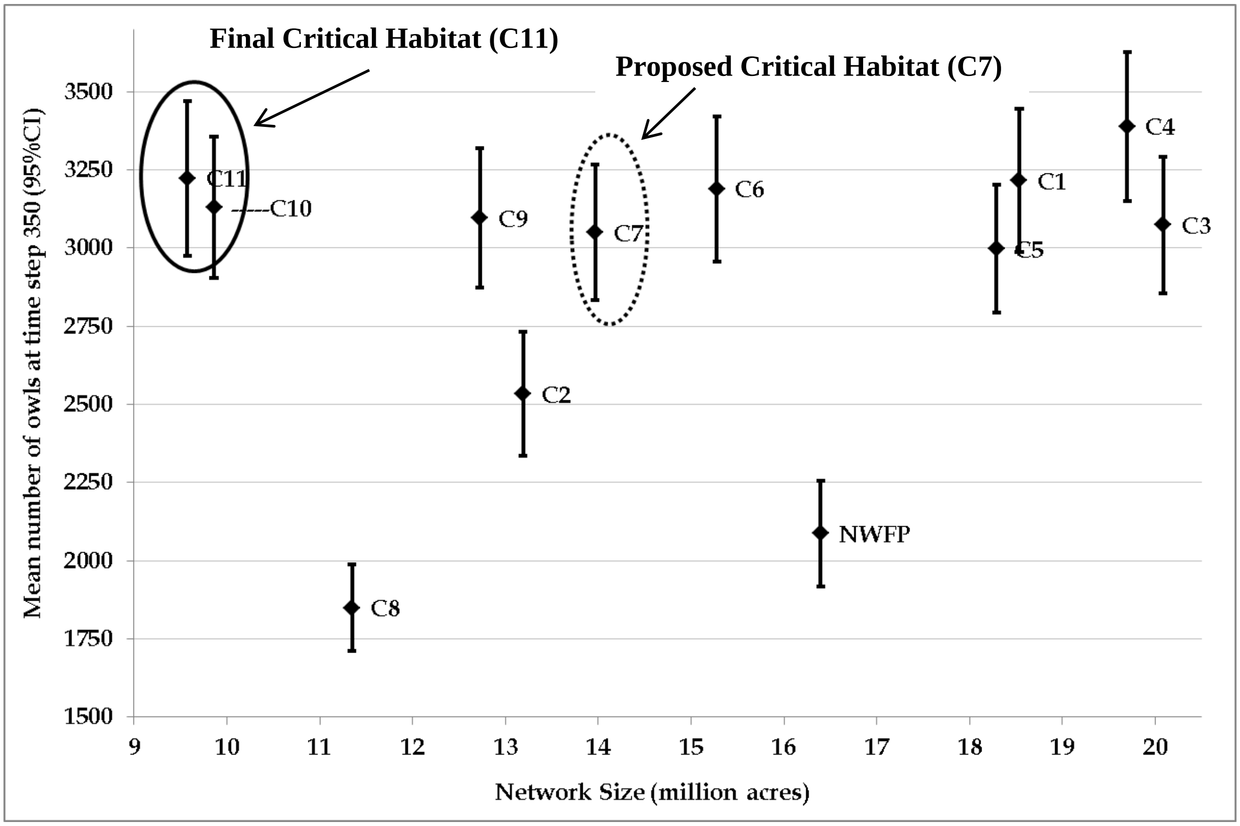
/1: N = number of female individuals

/2: Percent of time-step 50 population at time-step 350

/3: Proposed Critical Habitat

/4: Designated Critical Habitat

Figure 6. Display of efficiency of alternative potential critical habitat networks and the Northwest Forest Plan (NWFP). The alternative potential critical habitat networks are Composites 1-11 (C1-C11) for the pessimistic relative habitat suitability scenario. This representation of network efficiency evaluates the mean time-step 350 (last time-step) population sizes among 100 replicate runs relative to network size (in millions of acres). Error bars are 95% confidence intervals.



Summary

In response to peer review, public comments, and input from Federal and State agencies, and we evaluated changes to the proposed critical habitat (Composite 7), including exclusion decisions made by the Secretary under Section 4(b)2 and refinements aimed at increasing the efficiency of the network while simultaneously maintaining spotted owl performance measures obtained in Composite 7. Section 4(b)2 exclusions represent the preponderance of these changes, reducing the size of the proposed designation by 4,271,291 acres. Refinements to proposed critical habitat consisted of many small adjustments to subunit boundaries identified in the proposed rule. The final designation represents a strong emphasis on population characteristics that meet the Recovery Criteria presented in the 2011 Revised Recovery Plan for the Northern Spotted Owl and our *Guiding Principles* (see Introduction), as well as efficiency (i.e., including only what is essential to conservation of the species as informed by the Revised Recovery Plan) (Figure 6). In the modeling process, efficiency represented the balancing of population goals and the extent and distribution of critical habitat to determine which areas are essential to the conservation of the northern spotted owl.

SUMMARY AND CONCLUSION

The Service employed a 4-phase modeling process to evaluate potential critical habitat networks for the northern spotted owl. Phase 1 began with a coarse-filter comparison of 84 habitat networks, RHS change, and barred owl scenarios. Based on the results of these comparisons, we created two composite scenarios for more detailed and rigorous evaluation in Phase 2. In Phase 3, we used an iterative process of developing and testing alternative potential critical habitat networks, evaluating spotted owl population performance in 176 modeling region-specific scenarios, including the Northwest Forest Plan reserve network. Most composite scenarios represented the Service's effort to maximize efficiency and realism by reduce the area of potential critical habitat designation to only what is essential to the species' conservation, focusing on well-connected areas of high RHS (Table 34) while maintaining the population performance that met our criteria (Table 7). The last scenario in Phase 3 (Composite 7; Proposed Critical Habitat) performed substantially better than the NWFP and very similar to other composites that were 25 to 30 percent larger (Table 22, Figure 6), and represented a robust potential critical habitat network that conformed with the statutory definition of critical habitat. After reviewing public and peer-review comments as well as weighing the economic and other relevant impacts, Phase 4 consisted of evaluating 4 additional composite networks (Composites 8-11) in relation to Composite 7 (proposed critical habitat).

Composite 8 was the result of formal comments from Federal agencies; simulated owl populations performed comparatively poorly under this potential critical habitat network. Composites 9, 10a, and 11 represented a series of refinements to Composite 7, based on peer-review and public comments, an updated land ownership map, and exclusions under Section 4(b)2. Even with these modifications, our modeling showed that spotted owl population performance was very similar between the proposed rule (Composite 7) and final proposed critical habitat (Composite 11; Table 33, Figure 6). We believe the critical habitat network that comprises the final revised designation best meets the statutory definition of critical habitat for the northern spotted owl, and contributes to the conservation of the species in an efficient habitat network that focuses on public lands.

Tables 34A and B. Comparison of Composites (Comp) 1-11 and NWFP for : A) the percentage of the total RHS among 5 bins included in each potential critical habitat network and B) the potential critical habitat network plus lands in Congressional Reserves and with Habitat

Conservation Plans (thus "Network +" as the first column heading of Table B). Total amount of RHS was estimated from the ~57 million acre geographic range of the NSO. For example, in table A, Comp 7 included 80.35% of the total area within the NSO's range that had RHS between 60 and 80. The last row in Tables A&B include the total acres (millions) estimated to exist within each RHS bin within the entire geographic range of the northern spotted owl (e.g., there are 36.7 million acres with RHS from 0-20 and 151,158 acres with RHS >80).

A.

		RHS Bin				
Network	Size (million acres)	0-20	20-40	40-60	60-80	>80
NWFP	16.39	22.43	33.57	43.01	52.94	63.26
Comp 1	18.54	15.18	50.92	70.78	86.87	96.29
Comp 2	13.19	13.20	28.33	45.42	70.65	90.06
Comp 3	20.08	22.96	46.09	63.33	78.06	80.49
Comp 4	19.69	21.28	45.76	65.41	81.49	90.43
Comp 5	18.29	20.19	41.50	59.89	75.94	82.63
Comp 6	15.28	9.58	43.55	66.42	82.67	88.97
Comp 7	13.96	8.76	38.06	60.94	80.35	88.23
Comp 8	11.34	7.33	30.44	48.71	66.30	78.12
Comp 9	12.72	7.95	34.41	55.42	74.86	86.29
Comp 10a	9.86	5.39	27.48	45.75	58.27	56.90
Comp 11	9.57	5.27	26.62	44.26	56.66	56.07
Range (acres)	57.16	36.70	10.13	7.35	2.83	0.15

B.

		RHS Bin				
Network +	Size (million acres)	0-20	20-40	40-60	60-80	>80
NWFP	16.39	22.43	33.57	43.01	52.94	63.26
Comp 1	22.96	25.59	54.94	73.16	87.57	96.35
Comp 2	17.33	21.82	33.82	50.29	72.93	90.31
Comp 3	22.33	27.74	49.24	65.44	78.69	80.53
Comp 4	21.72	25.46	48.84	67.50	82.10	90.47
Comp 5	20.30	24.37	44.56	61.94	76.53	82.67
Comp 6	19.99	20.63	47.77	68.96	83.88	89.95
Comp 7	19.09	20.01	44.07	65.32	82.72	90.02
Comp 8	17.33	19.14	38.61	57.11	73.21	80.65
Comp 9	18.66	19.75	42.48	63.56	81.41	88.76
Comp 10a	18.87	19.74	42.98	65.31	82.53	89.16
Comp 11	18.52	19.62	42.12	63.83	80.93	88.34
Range (acres)	57.16	36.70	10.13	7.35	2.83	0.15

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Appendix A: Summary of Technical Modeling Comments and Responses

We requested written comments from the public on the proposed revised designation of critical habitat for the northern spotted owl during an initial 90-day public comment period, which opened with the publication of the proposed revised rule on March 8, 2012 (77 FR 14062), and closed on June 6, 2012. On June 1, 2012 (77 FR 32483), we extended the comment period for the proposed rule an additional 30 days, through July 6, 2012, thereby providing a total comment period of 120 days. During this 120 day comment period, we also invited public comment on the modeling framework that we used, in part, to inform our revised designation of critical habitat for the northern spotted owl, as summarized in Dunk *et al*. 2012a.

During the comment period(s), we received over 33,000 comments (the majority of which were form letters), directly addressing the proposed revised critical habitat designation. During the June 20, 2012, public hearing held in Portland, Oregon, eight individuals or organizations provided comments on the proposed revised designation. All substantive information provided by commenters has either been incorporated directly into the final designation or is addressed in the *Summary of Comments and Responses* section of the final designation of revised critical habitat for the northern spotted owl. We grouped the comments received into general categories specifically relating to the proposed revised critical habitat designation; most of the comments received specific to the modeling framework that we used in conjunction with the identification of critical habitat are addressed directly in the final rule itself. However, we also received some highly technical comments regarding the modeling process. These more technical questions are addressed here, in an attempt to reduce the length and improve the readability of the final rulemaking for the general public.

In addition, in accordance with our peer review policy published on July 1, 1994 (59 FR 34270), we solicited expert opinions on the science underlying our proposed revision of critical habitat from 40 knowledgeable individuals with scientific expertise that included familiarity with the species, the geographic region in which the species occurs, and conservation biology principles. We received responses from 15 of the peer reviewers. Peer review comments are summarized and presented in the final rule in the section *Comments from Peer Reviewers*. The peer reviewers generally supported the modeling process used to inform the identification of critical habitat and the resulting size and distribution of the proposed revised designation.

Here we present a summary of the more technical comments received from both peer reviewers and the public on our modeling framework. As noted above, the majority of comments received specific to the models used, in part, to inform the final designation of revised critical habitat for the northern spotted owl are provided in that final rule.

Comments Pertaining to Relative Habitat Suitability Modeling

Some reviewers of the proposed critical habitat rule questioned the appropriateness of using MaxEnt for modeling relative habitat suitability, expressing concern that other methods might be better or produce different results. Some reviewers believed our MaxEnt models were overfit. Others had misunderstandings of our use of MaxEnt and the resulting RHS values.

Regarding the contention that MaxEnt doesn't perform well or that other analytical techniques would be superior, we based our decision to use MaxEnt on its proven (and very good to excellent) performance on a wide range of species, sample sizes, and areas; especially relative to the performance of many other modeling techniques (see Elith et al. 2006, Wisz et al. 2008). Furthermore, our critical evaluation of our MaxEnt models' performance using cross-validation and independent data showed that the models we developed performed very well for the purposes that we used them for (identifying relative habitat suitability). The fact that all of our MaxEnt models performed well under cross-validation and (when available) with independent data undercuts the contention that they are overfit.

Aarts et al. (2012) noted that (1) many popular methods for analyzing habitat selection are "motivated by the same underlying exponential IPP model, and thus that the IPP model provides a useful unifying framework for modeling species distribution and habitat preference data." (IPP = inhomogenous Poisson point process); and (2) there is a common misconception about resource selection function models, that their predictions are proportional to occupancy. Instead, Aarts et al. (2012) argue, that such models are proportional to the density of observations. Our evaluation of our MaxEnt models' calibration is effectively an evaluation of the expected density of spotted owls among various RHS classes. That is, our strength of selection evaluation was done by dividing the proportion of the spotted owl locations found in a particular RHS bin (or class) by the areal extent of that RHS bin in the modeling region (i.e., the density of NSO locations). If spotted owls used RHS bins proportionate to their extent (i.e., the percentage of the landscape they occur on), the strength of selection would be flat (a horizontal line) and suggest no selection for one bin or another. Instead, we found strong selection against low RHS bins and strong selection for high RHS bins (or low densities of owls in low RHS bins and high densities in high RHS bins) (see pages C-38 and C-39, and Figure C-5 in the Revised Recovery Plan).

Lastly, we reiterate that we used MaxEnt to predict areas of varying (relative) habitat suitability, not occupancy per-se. We do not believe that the variables within each model are the only features that spotted owls respond to or need – the variables we used contributed to the predicted RHS. All models are simplifications of reality, and ours are no different. Our MaxEnt models help predict areas with higher or lower suitability. The actual suitability of an area is a function of many more variables that are not represented in the model.

Comment (1)**:** One reviewer suggested that the MaxEnt models are over-parameterized, that variable structure is strongly affected by forcing (based on expert opinion) of NR and F variables into the models *a priori*, and that models using different scales and methods are equally good or better than MaxEnt but utilize completely different predictive variable structures. They suggest the MaxEnt models are not unique and cannot be relied upon for inference about the biological characteristics of critical habitat.

Our Response: We disagree with these comments, which appear to be based on misinterpretation of the information presented in Appendix C of the Revised Recovery Plan. As described thoroughly in Appendix C, we tested a number of Nesting/Roosting and Foraging models and selected the "best" models as candidate variables in the full models; neither Nesting/Roosting nor Foraging was "forced" into the models. The commenter has not demonstrated that there are "equally good or better" models, and we maintain that the MaxEnt models we created and rigorously tested had good predictive ability and were reliable for the purpose of identifying spotted owl habitat. All modeling region's MaxEnt models met these goals and detailed methods and results are presented in Appendix C of the Revised Recovery Plan and the Modeling Supplement (Dunk *et al.* 2012b).

Comment (2)**:** In a comparison of MaxEnt with the Relative Frequency Function (RFF) tool, one reviewer found that the RFF model obtained a good solution in all 11 modeling regions (between 75 and 88 percent accuracy) and were more parsimonious. This may show that, in MaxEnt, some of the variables are correlated with each other or that variables with marginal significance were forced into the model. In contrast with MaxEnt results, no forest composition variables entered any model, perhaps because composition covaried with variables like elevation and canopy cover, or because in the RFF analysis more than a single structure variable could enter the model at multiple scales. This means that the variables in the MaxEnt models may not necessarily be predictive and therefore cannot necessarily be interpreted as indicative of northern spotted owl habitat.

Our Response**:** It is not surprising that alternative modeling methods found similar results ("good solutions, 75-88 percent accuracy) to our RHS models; there are many species distribution models available. That the models were more parsimonious than our RHS models in no way suggests, however, that our models were "overfit." The commenter's suggestion that our RHS models "may not necessarily be predictive" ignores the extensive evaluations of model calibration and predictive accuracy assessments described in Appendix C of the Revised Recovery Plan (USFWS 2011, pp. C-38 to C-41).

Comment (3)**:** Two peer reviewers suggested that providing covariate response curves for the different MaxEnt models would be useful.

Our Response**:** Our purpose for the MaxEnt models was to create reliable models that predicted spotted owl relative habitat suitability. In Appendix C of the Revised Recovery Plan (USFWS 2011) we show that we succeeded in doing so (pp. C-29 to C-32). We utilized a large amount of published literature on northern spotted owl habitat selection and use in the development of our models. Because we were not attempting to test various hypotheses about the northern spotted owl's niche, but to accurately predict northern spotted owl habitat (RHS) throughout the northern spotted owl's range, we believe that it is not necessary to present the response curves. Presenting response curves might suggest to readers that we were, in fact, attempting to use the modeling to test hypotheses about the northern spotted owl's niche.

Comment (4)**:** One reviewer suggested that the models' AUC value (the area under the receiver operating characteristic curve, a measure of a model's discrimination ability) must be tested against a null distribution of expected AUC values based on randomly collected data, and recommended that this test be done of the current northern spotted owl habitat models for each modeling region.

Our Response: The AUC values we evaluated for the MaxEnt models were based on the comparison of owl locations to available locations (a random draw of available locations) within each modeling region. In our case, AUC is a measure of the model's ability to discriminate between locations of northern spotted owl presence and available locations (not discrimination of presence versus absence locations). This approach is well documented and supported in the distributional modeling literature. A comparison of random locations to other random locations should, theoretically, give an AUC value of 0.5, which is the expectation for a model whose discriminatory ability is what would be expected by random chance. All of the models we developed had substantially higher AUC values using both the full data sets, and with the cross-validated data. A detailed explanation is provided in Appendix C of the Revised Recovery Plan for the Northern Spotted Owl (USFWS 2011, pp. C-30 to C-31).

Comment (5)**:** One reviewer suggested that if MaxEnt output (RHS) is truly related to northern spotted owl population performance, a reasonably strong pattern of increasing rate of occupancy and reproductive success by owl pairs with increasing RHS values would be expected. They found no strong relationship between RHS values and the number of years that sites were occupied during 1993-1996 by at least 1 northern spotted owl ($t = 0.804$, $P = 0.427$). Some owl sites with RHS values < 35 were consistently occupied, and there was greater variation in occupancy for sites with RHS

< 35 than for those with RHS> 35. Although average fecundity rates were comparatively low, there was no pattern of increasing RHS values with increasing reproductive rates among owls at Springfield (R = 0.002, t = 0.013, P = 0.99).
Dr. Irwin compared the results of intensive on-the-ground spotted owl surveys for two areas he has been researching since 1990. He found that the MaxEnt process did a very poor job of predicting where owls actually were and also where they might not be. The overall combined error rate was over 40 percent. He also found no strong relationship between RHS values and the number of years sites were occupied by NSOs or with average reproductive rates.

Our Response: There any many possible reasons that an organism (northern spotted owl in this case) may not occupy suitable habitat (e.g., death, competition, population is not at equilibrium with its environment), and that it might occupy sub-optimal habitat (e.g., territoriality). Our modeling showed that, throughout each modeling region, northern spotted owls disproportionately used high RHS value areas, and used low RHS value areas much less than expected based on its extent in the landscape. We did not treat the landscape in a binary (yes/no) manner, nor did we expect owls to only occupy high RHS, and never occupy low RHS areas. We did not use the RHS values to predict the number of years a site would be occupied. Furthermore, reproduction, in our northern spotted owl HexSim model, was solely a function of age class (and not RHS). The RHS layers we developed have been subjected to rigorous cross-validation and testing with independent data (see Appendix C of the Revised Recovery Plan for the Northern Spotted Owl (USFWS 2011)).

Comment (6)**:** One reviewer was critical that the Service did not evaluate the rate that at which MaxEnt may mistakenly assign owl-site status to locations that do not contain northern spotted owls. They suggested that using MaxEnt output could lead to including relatively large tracts of habitat that were unoccupied in 1990 in the Springfield study area, and also lead to excluding an unsatisfying proportion of productive owl sites along the eastern Washington Cascades.

Our Response: We believe the commenter is mistaken in their characterization of our use of MaxEnt. We did not use MaxEnt to assign occupancy status; we used MaxEnt to identify relative habitat suitability (RHS). The MaxEnt models were rigorously evaluated (see Response to Comment Y) and found to reliably predict NSO habitat. In addition, we evaluated the proportion of each critical habitat subunit that was occupied at the time of listing and did not find large tracts of unoccupied habitat as this commenter claims. Without additional information about the Springfield and Eastern Washington areas referenced, we cannot further address the comment.

Aarts et al. (2012) noted that (1) many popular methods for analyzing habitat selection are "motivated by the same underlying exponential IPP model, and thus that the IPP model provides a useful unifying framework for modeling species distribution and habitat preference data." (IPP = inhomogenous Poison point process); and (2) there is a common misconception about resource selection function models, that their predictions are proportional to occupancy. Instead, Aarts et al. (2012) argue, that such models are proportional to the density of observations. Our evaluation of our MaxEnt models' calibration is effectively an evaluation of the expected density of spotted owls among various RHS classes. That is, our strength of selection evaluation was done by dividing the proportion of the spotted owl locations found in a particular RHS bin (or class) by the areal extent of that RHS bin in the modeling region (i.e., the density of NSO locations). If spotted owls used RHS bins proportionate to their extent (i.e., the percentage of the landscape they occur on), the strength of selection would be flat (a horizontal line) and suggest no selection for one bin or another. Instead, we found strong selection against low RHS bins and strong selection for high RHS bins (or low densities of owls in low RHS bins and high densities in high RHS bins) (see pages C-38 and C-39, and Figure C-5 in the Revised Recovery Plan). The fact that our MaxEnt models were all very well calibrated suggests that they are unlikely to identify large areas of land as being highly suitable for spotted owls when they are not.

***Comment (7)*:** One reviewer stated that the Service created 10 potential definitions of nesting/roosting (NR) and foraging (F) habitats for each of the modeling regions, which were really just best guesses as to what factors influence NSO selection of habitat, and that the potential definitions were programmed into MaxEnt which determined what the "best" definition was. The reviewer claims these definitions were not tested to see how they relate to actual occupancy, survival, etc., and asserts that the Service did not validate them, and the scientific record does not indicate a strong, predictive relationship between measures of habitat conditions and any indicators of spotted owl performance.

***Our Response*:** The RHS map we developed in MaxEnt served as a proxy for the amount of resources available to simulated NSO at a sub-territory spatial scale. The development of potential NR and F definitions (*a priori* models) for testing in MaxEnt are thoroughly described in Appendix C (pp. C-5 to C-43) and hardly constitute a "best guess". The NR and F submodels were developed specifically for use as MaxEnt candidate variables and this application did not necessitate the development of statistical relationships with occupancy or other demographic rates. Indeed, a relationship between "habitat conditions" (in our vernacular "relative habitat suitability" or RHS) and simulated NSO population performance is an assumption in our modeling process, and is described on pages C-56 and 57. But the basis for this assumption can be found in widely accepted ecological theory. Simply stated, organisms will select habitat in order to maximize fitness, and patterns of habitat selection should therefore correlate with demographic rates such as recruitment and survival.

The commenter is further incorrect in claiming that the scientific record does not support a predictive relationship between measures of habitat and NSO population performance; at least three studies (Franklin et al. 2000, Dugger et al. 2005, and Dugger et al. 2011) demonstrated clear relationships between high-quality habitat and rates of adult survival or occupancy. These studies recognize that other factors such as climate and competition can also influence demographic rates. Based on this peer-reviewed research, we designed our simulation model to ensure that habitat suitability had an effect on territory acquisition, and on survival rates via resource acquisition. But habitat quality is not the only variable in our simulations affecting population growth rates. These feedbacks between RHS and spotted owl performance also serve to introduce density dependence in an ecologically meaningful (mechanistic) way. RHS influences our simulated NSO's territory establishment and resource acquisition. Resources can also be constrained through conspecific competition (one element of density dependence), and based on resource availability, our simulated owls are placed in one of three broad resource availability classes (low, medium, high). Resource availability, in turn, had an effect on survival rates, but did so in conjunction with exposure to barred owls. Reproduction was not influenced by resource acquisition, and thus was not influenced by RHS. Individual studies (*e.g.*, Franklin *et al*. 2000) and meta-analyses have reported influences of habitat on survival and in some cases fecundity (see Forsman *et al*. 2011). Factors we could not include in our models due to data limitations included spatially-explicit data on competitors, prey, predators.

Comment (8): One reviewer recommended that we conduct a test of preferential sampling (Raes and ter Steege 2007) and report the results.

Our Response: A "test of preferential sampling" is indicated when relatively small samples of species presence locations are used to model species distributions across large areas or gradients of environmental conditions. The sampling situation addressed by Raes and ter Steege (2007) bears no resemblance to our spotted owl modeling. The amount, distribution, and quality of northern spotted owl data available for our modeling effort is far greater than that tested by Raes and ter Steege (2007), who evaluated tropical tree species with at least five (5) locations per species. The tremendous sampling effort, especially during the period of 1993-1999 (1996 +/- 3 yrs) for which we used northern spotted owl location data, resulted in 3,783 site center locations that we used in the modeling. Given the high density of surveyed areas and broad representation of habitat types on both public and private lands, we have determined that the location data we used are an accurate representation of the gradient of conditions in which spotted owls are found. In addition, because our model-building process was founded upon well-established species-habitat relationships information for the owl, we do not rely strictly on the RHS models to determine what habitat (physical and biological features) for the owl is. Therefore, we do not believe a test of preferential sampling is necessary.

Comment (9)**:** One reviewer indicated that it is important to note that spatial auto-correlation remains in the final models and that thinning northern spotted owl locations to a 3-km separation is sufficient to fully account for spatial-autocorrelation.

Our Response: In Appendix C of the Revised Recovery Plan (USFWS 2011), we describe how we attempted to balance the competing effects of sample size reduction and spatial autocorrelation when we decided on the 3 km thinning distance. Other reviewers of Appendix C to the northern spotted owl Recovery Plan, however, criticized our decision of thinning at 3 km as too extreme (i.e., too far). One of the reasons this thinning was done was to de-emphasize those areas that had intensive sampling conducted relative to other locations within each modeling region. Because our models performed well in both cross-validation and when tested against on independent data sets, we elected not to conduct further evaluations of sampling bias. Our MaxEnt models were developed at a 200-ha scale (~0.8 km radius circle around each point).

Comments Pertaining to Population Modeling

Comment (10)**:** One reviewer had difficulty in determining whether the correct estimates of environmental variation were incorporated into the model. The reviewer asked why the temporal process variation for the various demographic parameters was not used to build distributions for those parameters, which could in turn be used to estimate environmental stochasticity, which could have a considerable effect on the results. Second, they noted that parameter estimates for survival in Table 3 seem to be misleading, and stated that if these estimates are taken from Forsman *et al.* 2011, then the estimates without barred owls probably already include a barred owl effect because almost all of the study areas from which they are estimated have barred owls. Thus, reviewer claims the estimates with barred owls may be biased lower than they should be.

Our Response**:** One of the benefits of using the northern spotted owl HexSim model that we did, and the way that we used it, is that the relative differences in northern spotted owl population performance are unlikely to be influenced by changes we might make to varying amounts of environmental stochasticity. Because we used the same underlying parameters in HexSim (for a particular RHS and barred owl scenario) for each potential Critical Habitat network, any biases would occur in each network (e.g., estimates of population size would be consistently higher or lower), but the ranking or relative performance of the networks are unlikely to be influenced.

Our goal was to build stochasticity into our simulations in the simplest way possible. For that reason, we developed collections of both survival rates and fecundities that represented bad, average, and good years. Our survival rates still varied based on stage class, resource acquisition class, and barred owl presence. Thus each type of year (bad, average, good) represented a family of survival rates consisting of 24 individual values (see Table 3). We could have developed (and used) survival distributions that reflected temporal process variation. But doing so would have meant constructing and using 24 separate distributions just to simulate yearly survival. And this would introduce many additional unknowns: perhaps the variation in survival rates should be higher in the presence of barred owls, or when resource availability is high vs. low. Answers do not exist for such questions. Our parsimonious approach to adding environmental stochasticity was comparatively simple and easy to understand. Given the methodology we implemented for evaluating the performance of candidate reserve strategies to determine what is essential to owl conservation, a complex approach to simulating environmental stochasticity is not warranted.

ATTACHMENT 1

Appendix C of the Revised Recovery Plan for the Northern Spotted Owl, U.S. Fish and Wildlife Service 2011

Appendix C. Development of a Modeling Framework to Support Recovery Implementation and Habitat Conservation Planning

Introduction by U.S. Fish and Wildlife Service

The Service believes a spatially explicit demographic model would greatly improve recovery planning and implementation for the spotted owl. Peer reviewers were critical of the 2008 Recovery Plan's habitat conservation network strategy and the general lack of updated habitat modeling capacity. The Service considered this criticism and concluded that a spatially explicit demographic model would greatly improve recovery implementation for the spotted owl, as well as other land use management decisions.

For this Revised Recovery Plan, the Service appointed a team of experts to develop and test a modeling framework that can be used in numerous spotted owl management decisions. This spatially-explicit approach is designed to allow for a more in-depth evaluation of various factors that affect spotted owl distribution and populations**.** This approach also allows for a unique opportunity to integrate new data sets, such as information from the NWFP 15-year Monitoring Report (Davis and Dugger in press) and the recent spotted owl population meta-analysis (Forsman *et al.* 2011).

The Service expects this modeling framework will be applied by Federal, State, and private scientists to make better informed decisions concerning what areas should be conserved or managed to achieve spotted owl recovery. Specifically, the modeling framework can be applied to various spotted owl management challenges, such as to:

1) Inform evaluations of meeting population goals and Recovery Criteria.
2) Develop reliable analysis and modeling tools to enable evaluation of the influence of habitat suitability and barred owls on spotted owl demographics.
3) Support future implementation and evaluation of the efficacy of spotted owl conservation measures described in various recovery actions.
4) Provide a framework for landscape-scale planning by both Federal and non-federal land managers that enables evaluation of potential demographic responses to various habitat conservation scenarios, including information that could be used in developing a proposed critical habitat rule.

These and other potential applications of the modeling framework described herein represent a significant advancement in spotted owl recovery planning. Although the completed model framework will be included in the Revised Recovery Plan, the Service hopes that future application of this modeling approach will lead to refinement and improvements, such as incorporation of population connectivity and source-sink dynamics, over time as experience and new scientific insights are realized.

To meet these objectives, the Service established the Spotted Owl Modeling Team (hereafter the "modeling team") to develop and apply modeling tools for the Service's use in designing and evaluating various conservation options for achieving spotted owl recovery. The modeling team was informally organized along lines of function and level of participation. Jeffrey Dunk (Humboldt State University), Brian Woodbridge (USFWS), Bruce Marcot (USFS, Pacific Northwest Research Station), Nathan Schumaker (USEPA), and Dave LaPlante (a contractor with Natural Resource Geospatial) composed the primary group which was responsible for conducting the data analyses and modeling. They were assisted by spotted owl researchers, agency staff and modeling specialists who individually provided data sets and advice on particular issues within their areas of expertise, and reviewed modeling processes and outputs. These experts were: Robert Anthony (Oregon State University), Katie Dugger (Oregon State University), Marty Raphael (USFS, Pacific Northwest Research Station), Jim Thrailkill (USFWS), Ray Davis (USFS, Northwest Forest Plan Monitoring Group), Eric Greenquist (BLM), and Brendan White (USFWS). Additionally, technical specialists—Craig Ducey (BLM), Karen West (USFWS) and Dan Hansen and M.J. Mazurek (contractors with Humboldt State University Foundation) conducted literature reviews and assisted with data collection and analyses.

To ensure that the modeling effort was based on the most current information, scientific knowledge and opinion, the modeling team also sought the assistance of numerous individual scientists and habitat managers from government, industry and a non-profit conservation organization (listed in acknowledgements) in development of habitat descriptions, modeling regions and many other aspects of spotted owl and forest ecology. To facilitate this effort, the Service held a series of meetings with spotted owl experts (habitat expert panels) to obtain additional information, data sets, and expertise regarding spotted owl habitats.

Representatives of the modeling team have prepared this Appendix to provide a thorough description of the modeling framework developed by the team, the results of model development and testing, and examples of how the modeling process can be used to evaluate habitat conservation scenarios and their relative contribution to recovery.

While this framework represents state-of-the-art science, it is not intended to represent absolute spotted owl population numbers or be a perfect reflection of reality. Instead, it provides a comparison of the relative spotted owl responses to a variety of potential conservation measures and habitat conservation networks. The implementation of spotted owl recovery actions should consider the results of the modeling framework as one of numerous sources of information to be incorporated into the decision-making process.

General Approach

The spotted owl modeling team (hereafter "modeling team" or "we") employed state-of–the-art modeling tools in a multi-step analysis similar to that proposed by Heinrichs *et al.* (2010) and Reed *et al.* (2006) for designing habitat conservation networks and evaluating their contributions to spotted owl recovery. In addition to this objective, the modeling tools in this framework, individually or in combination, are designed to enable evaluation of the efficacy of spotted owl conservation measures such as Recovery Action 10 and management of barred owls**.**

Our conservation planning framework integrates a spotted owl habitat model, a habitat conservation planning model, and a population simulation model. Collectively, these modeling tools allow comparison of estimated spotted owl population performance among alternative habitat conservation network scenarios under a variety of potential conditions. This will enable the Service and other interested managers to use relative population viability (timing and probability of population recovery) as a criterion for evaluating habitat conservation network scenarios and other conservation measures for the spotted owl.

The evaluation approach the modeling team developed consists of three main steps (Figure C1):

> **Step 1** – Create a map of spotted owl habitat suitability throughout the species' U.S. range, based on a statistical model of spotted owl habitat associations.
>
> **Step 2** – Develop a spotted owl conservation planning model, based on the habitat suitability model developed in Step 1, and use it to design an array of habitat conservation network scenarios.
>
> **Step 3** – Develop a spatially explicit spotted owl population model that reliably predicts relative responses of spotted owls to environmental conditions, and use it to test the effectiveness of habitat conservation network scenarios designed in step 2 in recovering the spotted owl. The simulations from this spotted owl population model are not meant to be estimates of what will occur in the future, but provide information on trends predicted to occur under differing habitat conservation scenarios.

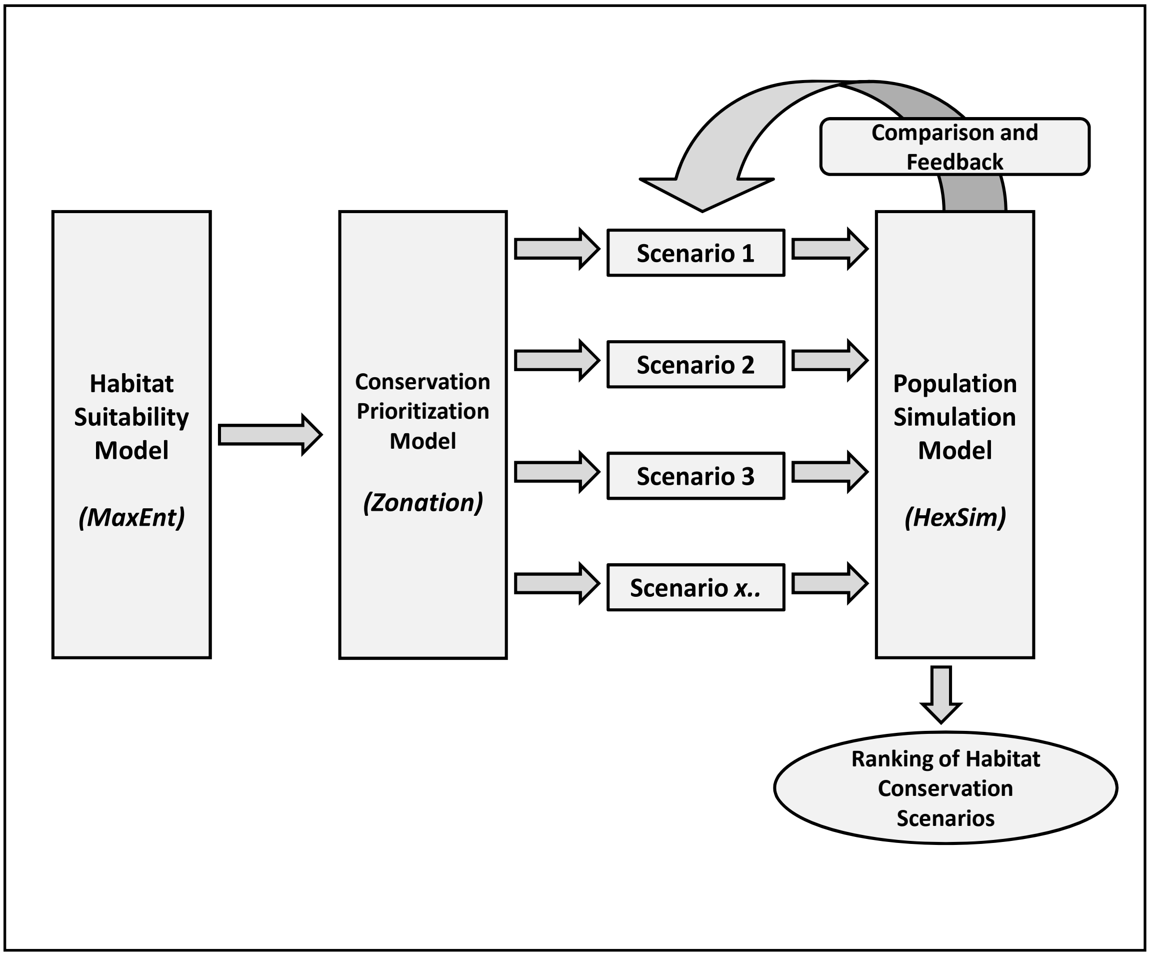
The Service or other practitioners can use the population simulation model developed in Step 3 to test the degree to which various recovery actions and habitat conservation network scenarios contribute to recovery of the spotted owl. For example, it can be used to evaluate relative population size and trend, as well as distribution and connectivity of modeled spotted owl populations through time.

Each of the steps noted above involved statistical and/or mathematical modeling and is not meant to be exact predictions of what currently exists or what will occur in the future, but represent our best estimates of current conditions and relationships. These models allow the use of powerful, up-to-date scientific tools in a repeatable and scientifically accepted manner to develop and evaluate habitat conservation networks and other conservation measures to recover the spotted owl. We view the benefit and utility of such models in the same way that Johnson (2001) articulated, "*A model has value if it provides better insight, predictions, or control than would be available without the model*." The modeling tools described herein meet this standard.

The overall framework and evaluations outlined in Figure C1 are somewhat similar to Raphael *et al.* (1998). Our modeling process differs fundamentally from the conservation planning approach used by the ISC (Thomas *et al*. 1990), 1992 Draft Recovery Plan (USFWS 1992b), FEMAT (1993), and the 2008 Recovery plan (USFWS 2008b), which were based on *a priori* rule sets derived from best expert judgment regarding the size of reserves or habitat conservation blocks, target number of spotted owl pairs per reserve or block, and targeted spacing between reserves or blocks. The new modeling framework we developed instead uses a series of spatially explicit modeling processes to develop habitat conservation networks (or "reserves") based on the distribution of habitat value. Issues of habitat connectivity and population isolation are identified within the population simulation model outputs.

The spotted owl modeling team has completed the development and evaluation of the overall modeling framework described in Steps 1 through 3 above. The *use* of the modeling framework, for example, to inform design and evaluation of various habitat conservation network scenarios (including potential effects of barred owl management), other conservation measures described in recovery actions, and evaluate potential effects of climate change will be completed as a part of recovery plan implementation or other analytical and regulatory processes.

Figure C-1. **Diagram of stepwise modeling process for developing and evaluating habitat conservation scenarios for the spotted owl.**



Modeling Process Step 1 – Create a spotted owl habitat suitability map covering the U.S. range of the subspecies based on a statistical model of spotted owl habitat associations.

Habitat modeling objective and overall approach:

A variety of methods are available for modeling species-habitat relationships (Morrison *et al*. 1992, Elith *et al.* 2006), with divergent assumptions and underlying statistical bases (Breiman 2001). The selection of a modeling tool is influenced foremost by the objectives of the modeling exercise, and by the characteristics of data available for modeling. The primary objective of our recovery plan modeling was to develop a map that reliably predicts relative habitat suitability for the spotted owl. Our primary goals were to develop predictive models that: 1) had good discriminatory ability, 2) were well calibrated, 3) were robust, and 4) had good generality. Our modeling was not an attempt to quantify or refine our understanding of the spotted owl's niche; but instead focused on predictions. Because we were primarily focused on obtaining reliable predictions, we were less concerned about covariates and their associated parameter estimates, or the relative importance of each habitat variable. This objective enabled us to consider newer algorithmic modeling approaches that emphasize prediction (Breiman 2001).

The nature of the spotted owl data available to us also influenced our choice of a modeling approach. We gathered several datasets which resulted in a large number of spotted owl locations, but only a relatively small subset of those data sets also had survey effort information (that could be used for occupancy modeling) and absence data (locations that were adequately sampled and where spotted owls were not detected). Because the majority of spotted owl data available was best characterized as 'presence-only' data, we elected not to employ occupancy modeling approaches.

Our objectives and the nature of the data available to us lead us to choose the species distribution model MaxEnt (Phillips *et al*. 2006, Phillips and Dudik 2008) to model spotted owl relative habitat suitability. MaxEnt is specifically designed for presence-only data. Moreover, MaxEnt has been thoroughly evaluated on a number of taxa, geographic regions, and sample sizes and has been found to perform extremely well (Elith *et al.* 2006, Wisz *et al*. 2008).

Distributional Models and the Spotted Owl:

Species distributional models are used to evaluate species-habitat relationships, evaluate an area's suitability for the species, and to predict a species' presence (Elith and Leathwick 2009). These models, also called environmental (or ecological) niche models, correlate environmental conditions with species distribution and thereby predict the relative suitability of habitat within some geographic area (Warren and Seifert 2011). When translated into maps depicting the spatial distribution of predicted habitat suitability, these models have great utility for evaluating conservation reserve design and function (Zabel *et al.* 2002, Zabel *et al*. 2003, Carroll and Johnson 2008, Carroll *et al.* 2010). Because the spotted owl is one of the most studied raptors in the world; we had available hundreds of peer-reviewed papers on various aspects of the species' ecology, including habitat use and selection (see reviews by Gutiérrez *et al.* 1995, Blakesley 2004). Only a few range-wide (in the U.S.) evaluations of habitat association (Carroll and Johnson 2008) or habitat distribution (Davis and Lint 2005, Davis and Dugger in press) have been conducted. While we capitalized on this large body of literature and other information to build models for conservation planning purposes, we were primarily interested in using such models to map relative habitat suitability rather than to provide new ecological understanding of spotted owl habitat associations.

Meetings with spotted owl habitat experts and review of literature and data sets:

Because the spotted owl is among the most-studied birds in the world, there is a wealth of information on its ecology and habitat associations. To ensure that the modeling effort was based on this scientific foundation, our first step was to conduct an extensive review of published and unpublished information on the species. Concurrent with this effort, team members travelled throughout the spotted owl's range and met with researchers and biologists with extensive experience studying spotted owls. Some of these meetings were one-on-one, and at other times we held meetings with several experts at one time to seek their individual advice. We have sometimes referred to these meetings as "expert panels." At these meetings, biologists were each asked to identify (1) the environmental factors to which spotted owls respond within particular physiographic provinces (*e.g.* Klamath Mountains of southern Oregon and northern California, Olympic Peninsula, Redwood Coast), and (2) regions believed to be distinct where spotted owls may be responding to conditions uniquely. In order to identify distinct modeling areas and definitions of spotted owl habitat (see below), we used both empirical findings (*i.e.*, published information) and the professional judgment of spotted owl experts.

Modeling regions - Partitioning the species' range:

Several authors have noted that spotted owls exhibit different habitat associations in different portions of their range, which is often attributed to regional differences in forest environments and factors such as important prey species (Carey *et al.* 1992, Franklin *et al.* 2000, Noon and Franklin 2002, Zabel *et al.* 2003), or presence of Douglas-fir dwarf mistletoe (expert panels). The distribution of these features is likely influenced by relatively large east-west and north-south gradients in ecological conditions (*e.g.*, temperature, precipitation, net primary productivity) and subsequent variation in forest environments. Hence, we developed and evaluated region-specific habitat suitability models under the assumption that spotted owls *within* a modeling region respond to habitat conditions more similarly than do spotted owls *between* modeling regions where conditions differ.

For monitoring, management and regulatory purposes, the spotted owl's range has historically been divided into 12 physiographic provinces (USDI 1992, Davis and Lint 2005) based largely on the regional distribution of major forest types and state boundaries. Based on differences and similarities in spotted owl habitat, we combined some provinces (California and Oregon Klamath provinces), retained others, and divided some provinces into smaller modeling regions (see Figure C2). We did not establish modeling regions or develop models for the Puget Lowlands, Southwestern Washington, and Willamette Valley, where spotted owls are almost completely absent and sample sizes were too small to support for model development. Instead, we projected the models developed for the closest adjacent area to those areas. This decision had the influence of allowing those regions to have at least some potential value to simulated spotted owls as opposed to assuming zero value.

The predictive ability and accuracy of habitat suitability models are influenced by the range of environmental conditions that are incorporated into the training data used in model development. Models developed from data sets encompassing broad environmental gradients tend to be overly general; conversely, models developed with data representing a small subset of conditions have limited applicability across the species' larger distribution. The practice of partitioning a species' range into "modeling regions" that encompass relatively dissimilar subsets of species-habitat relationships and developing models specific to each region was used to reduce this source of variability. The challenge is balancing the high degree of variability within large regions against the tendency to create many small modeling regions (with potentially small sample sizes) based on locally unique environmental conditions.

We queried experts to suggest potential modeling region boundaries, and they provided input on broad-scale patterns in climate, topography, forest communities, spotted owl habitat relationships, and prey-base that supported delineation of the draft spotted owl modeling regions (Figure C2). Franklin and Dyrness (1973), Kuchler (1977) and other published sources of information on the distribution of major ecological boundaries were also consulted. Using information provided through our discussions with the expert panels and existing ecological section and subsection boundaries (McNab and Avers 1994), we delineated 11 spotted owl modeling regions (Figure C2).

In general, the spotted owl modeling regions varied in terms of these ecological features:

1) Degree of similarity between structural characteristics of habitats used by spotted owls primarily for nesting/roosting and habitats used for foraging and other nocturnal activities. This similarity is largely influenced by habitat characteristics of the spotted owl's dominant prey (proportion of flying squirrels versus woodrats).
2) Latitudinal patterns of topography and climate. For example, in the WA Cascades, spotted owls are rarely found at elevations above 1,219-1,372 m, whereas in southern Oregon and the Klamath province spotted owls commonly reside up to 1,830 m.
3) Regional patterns of topography, climate, and forest communities.
4) Geographic distributions of habitat elements that influence the range of conditions occupied by spotted owls. For example, several panelists pointed out that the distribution of dwarf mistletoe influences the range of stand structural values associated with spotted owl use. Other examples include the geographic distribution of elements such as evergreen hardwoods, Oregon white oak woodlands, and ponderosa pine-dominated forests.

Modeling Region Descriptions:

North Coast Ranges and Olympic Peninsula (NCO): This region consists of the Oregon and Washington Coast Ranges Section M242A (McNab and Avers 1994). This region is characterized by high rainfall, cool to moderate temperatures, and generally low topography (448 to 750 m). High elevations and cold temperatures occur in the interior portions of the Olympic Peninsula, but spotted owls in this area are limited to the lower elevations (<900 m.). Forests in the NCO are dominated by western hemlock, Sitka spruce, Douglas-fir, and western red cedar. Hardwoods are limited in species diversity (consist mostly of bigleaf maple and red alder) and distribution within this region, and typically occur in riparian zones. Root pathogens like laminated root rot (*Phellinus weirii*) are important gap formers, and vine maple, among others, fills these gaps. Because Douglas-fir dwarf mistletoe is unusual in this region, spotted owl nesting habitat consists of stands providing very large trees with cavities or deformities. A few nests are associated with western hemlock dwarf mistletoe. Spotted owl diets are dominated by species associated with mature to late-successional forests (flying squirrels, red tree voles), resulting in similar definitions of habitats used for nesting/roosting and foraging by spotted owls. This region contains the Olympic Demographic Study Area (DSA).

Oregon Coast Ranges (OCR): This region consists of the southern 1/3 of the Oregon and Washington Coast Ranges Section M242A (McNab and Avers 1994). We split the section in the vicinity of Otter Rock, OR, based on gradients of increased temperature and decreased moisture that result in different patterns of vegetation to the south. Generally this region is characterized by high rainfall, cool to moderate temperatures, and generally low topography (300 to 750 m.). Forests in this region are dominated by western hemlock, Sitka spruce, and Douglas-fir; hardwoods are limited in species diversity (largely bigleaf maple and red alder) and distribution, and are typically limited to riparian zones. Douglas-fir and hardwood species associated with the California Floristic Province (tanoak, Pacific madrone, black oak, giant chinquapin) increase toward the southern end of the OCR. On the eastern side of the Coast Ranges crest, habitats tend to be drier and dominated by Douglas-fir. Root pathogens like laminated root rot (*P. weirii*) are important gap formers, and vine maple among others fills these gaps. Because Douglas-fir dwarf mistletoe is unusual in this region, spotted owl nesting habitat tends to be limited to stands providing very large trees with cavities or deformities. A few nests are associated with western hemlock dwarf mistletoe. Spotted owl diets are dominated by species associated with mature to late-successional forests (flying squirrels, red tree voles), resulting in similar definitions of habitats used for nesting/roosting and foraging by spotted owls. One significant difference between OCR and NCO is that woodrats comprise an increasing proportion of the diet in the southern portion of the modeling region. This region contains the Tyee and Oregon Coast Range DSAs.

Redwood Coast (RDC): This region consists of the Northern California Coast Ecological Section 263 (McNab and Avers 1994). This region is characterized by low-lying terrain (0 to 900 m.) with a maritime climate; generally mesic conditions and moderate temperatures. Climatic conditions are rarely limiting to spotted owls at all elevations. Forest communities are dominated by redwood, Douglas-fir-tanoak forest, coast liveoak, and tanoak series. The vast majority of the region is in private ownership, dominated by a few large industrial timberland holdings. The results of numerous studies of spotted owl habitat relationships suggest stump-sprouting and rapid growth rates of redwoods, combined with high availability of woodrats in patchy, intensively-managed forests, enables spotted owls to maintain high densities in a wide range of habitat conditions within the Redwood zone. This modeling region contains the Green Diamond and Marin DSAs.

Western Cascades North (WCN): This region generally coincides with the northern Western Cascades Section M242B (McNab and Avers 1994), combined with western portion of M242D (Northern Cascades Section), extending from the U.S. - Canadian border south to Snoqualmie Pass in central Washington. It is similar to the Northern Cascades Province of Franklin and Dyrness (1974). This region is characterized by high mountainous terrain with extensive areas of glaciers and snowfields at higher elevation. The marine climate brings high precipitation (both annual and summer) but is modified by high elevations and low temperatures over much of this modeling region. The resulting distribution of forest vegetation is dominated by subalpine species, mountain hemlock and silver fir; the western hemlock and Douglas-fir forests typically used by spotted owls are more limited to lower elevations and river valleys (spotted owls are rarely found at elevations greater than 1,280 m. in this region) grading into the mesic Puget lowland to the west. Root pathogens like laminated root rot (*P. weirii*) are important gap formers, and vine maple, among others, fills these gaps. Because Douglas-fir dwarf mistletoe occurs rarely in this region, spotted owl nests sites are limited to defects in large trees, and occasionally nests of other raptors. Diets of spotted owls in this northern region contain higher proportions of red-backed voles and deer mice than in the region to the south, where flying squirrels are dominant (expert panels). There are no Demographic Study Areas in this modeling region.

Western Cascades Central (WCC): This region consists of the midsection of the Western Cascades Section M242B (McNab and Avers 1994), extending from Snoqualmie Pass in central Washington south to the Columbia River. It is similar to the Southern Washington Cascades Province of Franklin and Dyrness (1974). We separated this region from the northern section based on differences is spotted owl habitat due to relatively milder temperatures, lower elevations, and greater proportion of western hemlock/Douglas-fir forest and occurrence of noble fir to the south of Snoqualmie Pass. Because Douglas-fir dwarf mistletoe occurs rarely in this region, spotted owl nest sites are largely limited to defects in large trees, and occasionally nests of other raptors. This region contains the Rainier DSA and small portions of the Wenatchee and Cle Elum DSAs.

Western Cascades South (WCS): This region consists of the southern portion of the Western Cascades Section M242B (McNab and Avers 1994) and extends from the Columbia River south to the North Umpqua River. We separated this region from the northern section due to its relatively milder temperatures, reduced summer precipitation due to the influence of the Willamette Valley to the west, lower elevations, and greater proportion of western hemlock/Douglas-fir forest. The southern portion of this region exhibits a gradient between Douglas-fir/western hemlock and increasing Klamath-like vegetation (mixed conifer/evergreen hardwoods) which continues across the Umpqua divide area. The southern boundary of this region is novel and reflects a transition to mixed conifer sensu Franklin and Dyrness (1974). The importance of Douglas-fir dwarf mistletoe increases to the south in this region, but most spotted owl nest sites in defective large trees, and occasionally nests of other raptors. The HJ Andrews DSA occurs within this modeling region.

Eastern Cascades North (ECN): This region consists of the eastern slopes of the Cascade range, extending from the Canadian border south to the Deschutes National Forest near Bend, OR. Terrain in portions of this region is glaciated and steeply dissected. This region is characterized by a continental climate (cold, snowy winters and dry summers) and a high-frequency/low-mixed severity fire regime. Increased precipitation from marine air passing east through Snoqualmie Pass and the Columbia River results in extensions of moist forest conditions into this region (Hessburg *et al.* 2000b). Forest composition, particularly the presence of grand fir and western larch, distinguishes this modeling region from the southern section of the eastern Cascades. While ponderosa pine forest dominates lower and middle elevations in both this and the southern section, the northern section supports grand fir and Douglas fir habitat at middle elevations. Dwarf mistletoe provides an important component of nesting habitat, enabling spotted owls to nest within stands of relatively younger, small trees. This modeling region contains the Wenatchee and Cle Elum DSAs.

Eastern Cascades South (ECS): This region incorporates the Southern Cascades Ecological Section M261D (McNab and Avers 1994) and the eastern slopes of the Cascades from the Crescent Ranger District of the Deschutes National Forest south to the Shasta area. Topography is gentler and less dissected than the glaciated northern section of the eastern Cascades. A large expanse of recent volcanic soils (pumice region: Franklin and Dyrness 1974), large areas of lodgepole pine, and increasing presence of red fir and white fir (and decreasing grand fir) along a south-trending gradient further supported separation of this region from the northern portion of the eastern Cascades. This region is characterized by a continental climate (cold, snowy winters and dry summers) and a high-frequency/low-mixed severity fire regime. Ponderosa pine is a dominant forest type at mid-to lower elevations, with a narrow band of Douglas-fir and white fir at middle elevations providing the majority of spotted owl habitat. Dwarf mistletoe provides an important component of nesting habitat, enabling spotted owls to nest within stands of relatively younger, smaller trees.

The Warm Springs DSA and eastern half of the South Cascades DSA occur in this modeling region.

Western Klamath Region (KLW): This region consists of the western portion of the Klamath Mountains Ecological Section M261A (McNab and Avers 1994). A long north-south trending system of mountains (particularly South Fork Mountain) creates a rainshadow effect that separates this region from more mesic conditions to the west. This region is characterized by very high climatic and vegetative diversity resulting from steep gradients of elevation, dissected topography, and the influence of marine air (relatively high potential precipitation). These conditions support a highly diverse mix of mesic forest communities such as Pacific Douglas-fir, Douglas-fir tanoak, and mixed evergreen forest interspersed with more xeric forest types. Overall, the distribution of tanoak is a dominant factor distinguishing the Western Klamath Region. Douglas-fir dwarf mistletoe is uncommon and seldom used for nesting platforms by spotted owls. The prey base of spotted owls within the Western Klamath is diverse, but dominated by woodrats and flying squirrels. This region contains the Willow Creek, Hoopa, and the western half of the Oregon Klamath DSAs.

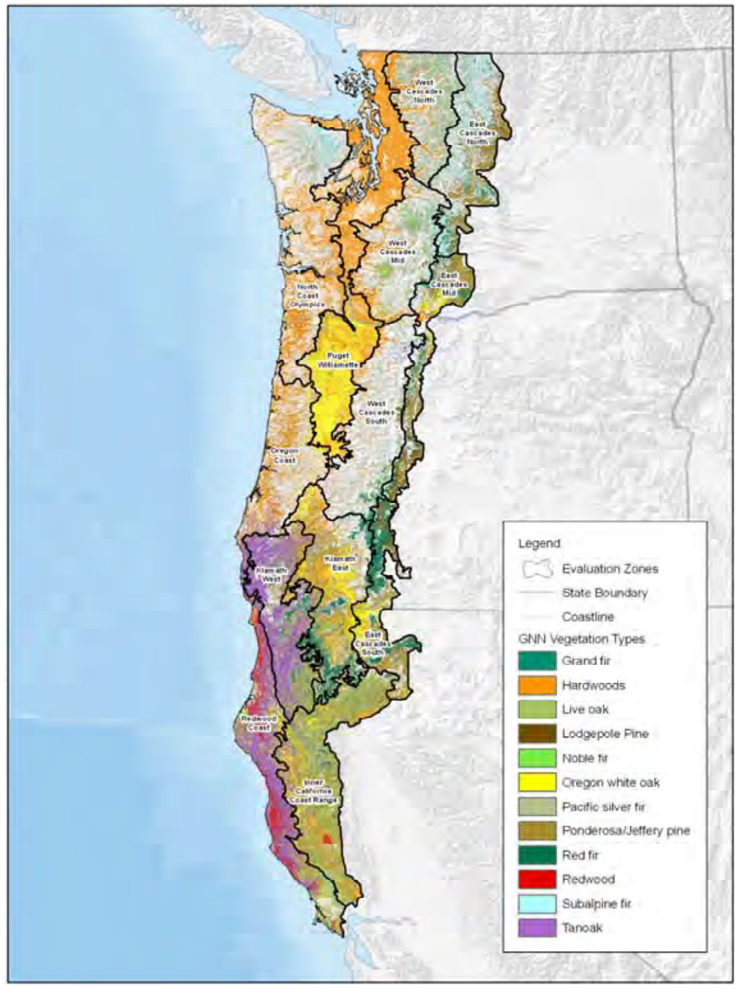
Eastern Klamath Region (KLE): This composite region consists of the eastern portion of the Klamath Mountains Ecological Section M261A (McNab and Avers 1994) and portions of the Southern Cascades Ecological Section M261D in Oregon. This region is characterized by a Mediterranean climate, greatly reduced influence of marine air, and steep, dissected terrain. Franklin and Dyrness (1974) differentiate the mixed conifer forest occurring on the "Cascade side of the Klamath from the more mesic mixed evergreen forests on the western portion (Siskiyou Mountains), and Kuchler (1977) separates out the eastern Klamath based on increased occurrence of ponderosa pine. The mixed conifer/evergreen hardwood forest types typical of the Klamath region extend into the southern Cascades in the vicinity of Roseburg and the North Umpqua River, where they grade into the western hemlock forest typical of the Cascades. High summer temperatures and a mosaic of open forest conditions and Oregon white oak woodlands act to influence spotted owl distribution in this region. Spotted owls occur at elevations up to 1,768 m. Dwarf mistletoe provides an important component of nesting habitat, enabling spotted owls to nest within stands of relatively younger, small trees. The western half of the South Cascades DSA and the eastern half of the Klamath DSA are located within this modeling region.

Northern California Interior Coast Ranges Region (ICC): This region consists of the Northern California Coast Ranges ecological Section M261B (McNab and Avers 1994), and differs markedly from the adjacent redwood coast region. Marine air moderates winter climate, but precipitation is limited by rainshadow effects from steep elevational gradients (100 to 2,400 m.) along a series of north-south trending mountain ridges. Due to the influence of the adjacent Central Valley, summer temperatures in the interior portions of this region are among the highest within the spotted owl's range. Forest communities tend to be relatively dry mixed conifer, blue and Oregon white oak, and the Douglas-fir-tanoak series. Spotted owl habitat within this region is poorly known; there are no DSAs and few studies have been conducted here. Spotted owl habitat data obtained during this project suggests that some spotted owls occupy steep canyons dominated by liveoak and Douglas-fir; the distribution of dense conifer habitats is limited to higher-elevations on the Mendocino National Forest.

Figure C-2. Modeling regions used in development of relative habitat suitability models for the spotted owl.

Modeling Regions

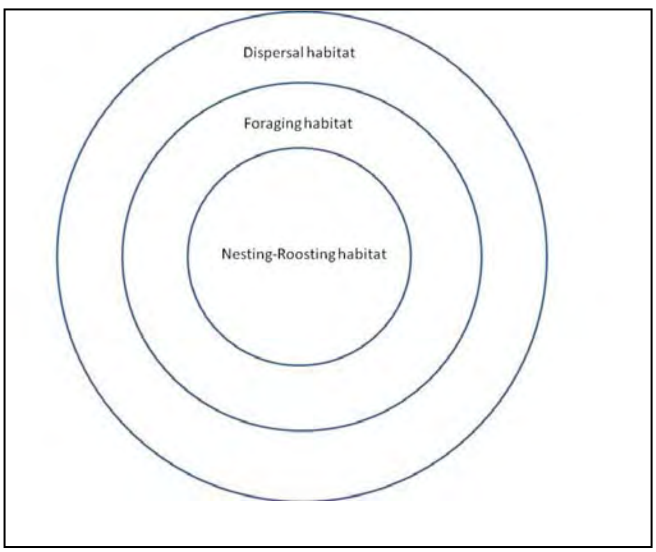
CODE	Description
NCO	North Coast and Olympic
OCR	Oregon Coast
RDC	Redwood Coast
WCN	Western Cascades - North
WCC	Western Cascades - Central
WCS	Western Cascades - South
ECN	Eastern Cascades - North
ECS	Eastern Cascades - South
KLW	Klamath-Siskiyou - West
KLE	Klamath-Siskiyou - East
ICC	Interior California Coast



Habitat Modeling Process

Because spotted owl habitat use is influenced by factors occurring at different spatial scales, we developed habitat suitability models in two stages. In the first stage we used information from our literature review and experts to develop a series of alternative models of forest conditions corresponding to nesting-roosting habitat and foraging habitat within each modeling region. We used statistical modeling to test the effectiveness of these models and identify the forest structural models that best predicted the relative likelihood of a spotted owl territory being present. Spotted owl habitat is often subdivided into distinct components including: nesting habitat, roosting habitat, foraging habitat, and dispersal habitat. Habitats used for nesting and roosting are very similar, and so we combined them into nesting-roosting. Such areas are used for nesting, roosting, foraging, and dispersal by spotted owls, and are usually forests with more late-seral forest characteristics than "foraging" or "dispersal" habitat. Foraging habitat is thought to be largely used for foraging and other nocturnal activities, but also for dispersal (USFWS 1992; see Figure C3). Dispersal habitat is thought to largely have value for dispersal, to lack nest/roost sites and to provide few foraging opportunities. These categories are not absolutes, but instead represent generalizations (*e.g.*, one should not infer that spotted owls never roost in "foraging" habitat). That said, it is important to understand that

Figure C-3. Venn diagram of relationships among spotted owl nesting-roosting, foraging, and dispersal habitats.



nesting-roosting habitat is generally considered to provide all or most habitat requirements, whereas foraging and dispersal habitats are considered to provide only a subset of the spotted owl's habitat requirements. For this effort, we attempted to accurately model the suitability of breeding habitat for spotted owls. Thus, we evaluated and modeled nesting-roosting and foraging habitat, but not dispersal habitat. While we recognized that dispersal plays an important role in population performance, we elected not to formally model dispersal habitat. This is because relatively little is known about habitat selection during dispersal and, more importantly, the likely influences of habitat conditions on dispersal success. The influence of habitat on dispersal and population performance is treated within the HexSim portion of the modeling framework (see Overview of HexSim Spotted Owl Scenario, page C-56).

Spatial scale for developing and evaluating models:

To determine the spatial scale at which to develop habitat models, the modeling team sought a uniform analysis area size that generally corresponded to large differences between use and availability. Spotted owls have been found to respond to habitats at a variety of spatial scales (Solis and Gutiérrez 1990, Meyer *et al.* 1998, Franklin *et al*. 2000, Swindle *et al.* 1999, Thome *et al*. 1999, Zabel *et al.* 2003). Spotted owls do not build their own nests, but primarily utilize broken-top snags, tree cavities, dwarf mistletoe witch's brooms, or nests made by other species (Gutiérrez *et al.* 1995). Spotted owl habitat selection in the immediate vicinity of the nest (tens of meters around the nest tree) has been found to be strongly non-random, and largely associated with late-seral forest characteristics (Solis and Gutiérrez 1990, Meyer *et al.* 1998, Swindle *et al.* 1999). Areas at this small spatial scale are necessary, but often not sufficient to be selected by spotted owls because areas at larger spatial scales around the nest-site must contain attributes that also contribute to their survival and reproductive success (*e.g.*, Franklin *et al*. 2000, Olson *et al.* 2004, Dugger *et al.* 2005).

Ripple *et al.* (1991), Carey *et al.* (1992), Hunter *et al.* (1995), Thome *et al.* (1999), Meyer *et al*. (1998), and Zabel *et al.* (2003) all evaluated spotted owl habitat selection at a variety of spatial scales beyond the nest site itself. Spatial scales evaluated in these studies were based on the distribution of radio telemetry locations, presumed territorial behavior (nearest-neighbor distances), or various 'nested rings'. All studies found differences between spotted owl-centered (nest or activity center) locations and random or unoccupied locations across the range of spatial scales examined. However, the largest differences were often found in areas approximately the size of what Bingham and Noon (1997) defined as "core areas" (areas of the home range that received disproportionately more use than would be expected). An area of 158 to 200-ha has been used to describe/define spotted owl 'territory core areas', in western Oregon and the Klamath region (Hunter *et al.* 1995, Meyer *et al.* 1998, Franklin *et al*. 2000, Zabel *et al*. 2003, Olson *et al.* 2004, and Dugger *et al.* 2005). In northwestern Oregon, Glenn *et al.* (2005) found mean cumulative core areas to be 94 ha (SE = 14.9; n = 24). For the northern portion of the range we found little information directly comparable to the abovementioned studies, but estimated home range and core areas sizes and nearest-neighbor distances are larger in the extreme northern portion of the spotted owl's range (Forsman *et al*. 2005, Hamer *et al.* 2007, Davis and Dugger in press). Based on this review, we felt a 200-ha analysis area represented an area that is disproportionately used (more than expected) surrounding nest sites. We deal explicitly with geographic variation in home range size in HexSim (see below).

Data Used for Model Development and Testing

Vegetation data – the GNN-LT Database:

To develop rangewide models of relative habitat suitability for spotted owls, we required maps of forest composition and structure of sufficient accuracy to allow discrimination of attributes used for nesting, roosting and foraging by spotted owls. Past efforts to model, map and quantify habitat selection by spotted owls at regional scales have often suffered from lack of important vegetation variables, inadequate spatial coverage, and/or coarse resolution of available vegetation databases (Davis and Lint 2005). However, recent development of vegetation mapping products for the NWFP's Effectiveness Monitoring program (Hemstrom *et al*. 1998, Lint *et al.* 1999) provided detailed maps of forest composition and structural attributes for all lands within the NWFP area (coextensive with the range of the spotted owl). These maps were developed using Gradient Nearest Neighbor (GNN) imputation (Ohmann and Gregory 2002) and LandTrendr algorithms (Kennedy *et al.* 2007, 2010) and were available for two "bookend" dates (1996 and 2006 in Oregon and Washington, 1994 and 2007 in California).

The GNN approach is a method for predictive vegetation mapping that uses direct gradient analysis and nearest-neighbor imputation to ascribe detailed attributes of vegetation to each pixel in a digital landscape map (Ohmann and Gregory 2002). Forest attributes from inventory plots (Forest Inventory and Analysis, Current Vegetation Surveys, etc.) are imputed to map pixels based on modeled relationships between plots and predictor variables from Landsat thematic mapper imagery, climatic 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. The GNN models were developed for habitat modeling regions used for the NWFP northern spotted owl effectiveness monitoring modeling (Davis and Dugger in press). For the NWFP Effectiveness Monitoring program, GNN maps were created for the two bookend time periods mentioned above to 'frame' their analysis period for habitat status and trends. This novel bookend mapping approach presents challenges associated with spectral differences due to different satellite image dates, which might produce false vegetation changes. To minimize the potential for this, the bookend models were based on Landsat imagery that was geometrically rectified and radiometrically normalized using the LandTrendr process (Kennedy *et al.* 2007, 2010).

The large list of forest species composition and structure variables provided by GNN vegetation maps constitute an improvement in vegetation data for modeling and evaluating spotted owl habitat. For our modeling, we selected from a set of 163 variables, including basal area and tree density by size class and species, canopy cover of conifers and/or hardwoods, stand height, age, mean diameter and quadratic mean diameter by dominance class, stand density index, and measures of snags and coarse woody debris. Additional variables pertaining to stand structural diversity and variability proved particularly useful for modeling spotted owl habitat.

The reliability or accuracy of vegetation databases poses a primary concern for wildlife habitat evaluation and modeling. The GNN maps come with a large suite of diagnostics detailing map quality and accuracy; these are contained in model region-specific accuracy assessment reports available at the LEMMA website (http://www.fsl.orst.edu/lemma/). For developing *a priori* models of spotted owl nesting/roosting habitat and foraging habitat, we generally selected GNN structural variables with plot correlation coefficients > 0.5 for an individual modeling region (42% were >0.7). On a few occasions when expert opinion or research results suggested a particular variable might be important, we used variables with plot correlations from 0.31 to 0.5 (Table C-1). For species composition variables, we attempted to use only variables with Kappas > 0.3. However, because we combined species variables into groups that expert opinion and research results suggested may represent influential community types, we occasionally accepted variables with Kappas > 0.2 and < 0.3 for individual variables within a group (Table C-2).

The GNN vegetation database was specifically developed for mid- to large-scale spatial analysis (Ohmann and Gregory 2002), suggesting that accuracies at the 30-m pixel scale may be less influential to results obtained at larger scales. Because we were interested in the utility of GNN at our analysis area (200 ha) spatial scale, we conducted less formal assessments where we compared the distribution of GNN variable values at a large sample of actual locations (known spotted owl nest sites and foraging sites) to published estimates of those variables at the same scale. In addition, we received comparisons of GNN maps to a number of local plot-based vegetation maps prepared by various field personnel. Based on these informal evaluations, we determined that GNN represents a dramatic improvement over past vegetation databases used for modeling and evaluating spotted owl habitat, and used the GNN-LandTrendr maps as the vegetation data for our habitat modeling.

Table C-1. Pearson correlation coefficients for GNN structural variables used in modeling relative habitat suitability models for spotted owls.

Variable	Modeling region												
	ECN	ECS	ICC	KLE	KLW	NCO	ORC	RDC	WCC	WCN	WCS	AVG	STD
BAA_75_100			0.42									0.49	0.09
BAA_GE_100			0.37									0.46	0.12
BAA_GE_3	0.75					0.71			0.71	0.71		0.70	0.06
BAC_50_75								0.46				0.45	0.06
BAC_75_100								0.31				0.50	0.09
BAC_GE_100								0.57				0.47	0.12
BAC_GE_3					0.65							0.73	0.06
BAH_3_25			0.50									0.50	0.07
BAH_PROP					0.67							0.66	0.03
CANCOV	0.76	0.80	0.71	0.71	0.71			0.70	0.74	0.74	0.80	0.74	0.04
CANCOV_CON				0.67			0.73					0.74	0.07
DDI	0.65	0.73	0.65	0.65	0.65	0.77	0.74		0.77	0.77	0.73	0.69	0.08
QMDC_DOM	0.44	0.64	0.52	0.52	0.52						0.64	0.59	0.11
TPH_50_75				0.35			0.52		0.44	0.44		0.42	0.06
TPH_75_100		0.52		0.41		0.56	0.58		0.56	0.56	0.52	0.48	0.09
TPH_GE_100		0.48		0.45		0.57	0.63		0.57	0.57	0.48	0.49	0.10
TPHC_GE_100									0.57	0.57		0.50	0.10

Table C-2. Local scale accuracy assessments (kappa coefficients) for individual species variables within stand species composition variable groupings used in applicable modeling regions. N/A = variable not in best models for modeling region.

	GNN DOM SPP	Common Name	East Cascades North	East Cascades South	Inner California Coast Ranges	Klamath East	Klamath West	North Coast Olympics	Oregon Coast	Redwood Coast	West Cascades Central	West Cascades North	West Cascades South	Average Kappa
Evergreen hardwoods	ARME	Pacific madrone	n/a	n/a	0.43	n/a	0.43	n/a	0.49	n/a	n/a	n/a	n/a	0.45
	LIDE3	tanoak	n/a	n/a	0.58	n/a	0.58	n/a	0.72	n/a	n/a	n/a	n/a	0.63
	QUCH2	canyon live oak	n/a	n/a	0.35	n/a	0.35	n/a	0.46	n/a	n/a	n/a	n/a	0.39
	UMCA	California laurel	n/a	n/a	0.29	n/a	0.29	n/a	0.43	n/a	n/a	n/a	n/a	0.34
Northern Hardwoods	ACMA3	bigleaf maple	n/a	n/a	n/a	n/a	n/a	0.41	0.30	n/a	0.41	0.41	n/a	0.38
	ALRU2	red alder	n/a	n/a	n/a	n/a	n/a	0.44	0.33	n/a	0.44	0.44	n/a	0.41
Oak woodlands	QUDO	blue oak	n/a	n/a	0.68	0.68	0.68	n/a	n/a	0.41	n/a	n/a	n/a	0.62
	QUGA4	Oregon white oak	n/a	n/a	0.35	0.35	0.35	n/a	n/a	0.34	n/a	n/a	0.52	0.38
Pines	PICO	lodgepole pine	0.26	0.57	0.28	0.28	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.35
	PIJE	Jeffrey pine	n/a	0.27	0.28	0.28	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.28
	PIMU	Bishop pine	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	PIPO	ponderosa pine	0.62	0.58	0.34	0.34	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.47
Douglas-fir	PSME	Douglas-fir	0.47	0.65	n/a	0.31	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.48
Subalpine	ABAM	Pacific silver fir	0.66	0.59	n/a	n/a	n/a	0.53	n/a	n/a	0.53	0.53	0.59	0.57
	ABLA	subalpine fir	0.58	0.39	n/a	n/a	n/a	0.48	n/a	n/a	0.48	0.48	0.39	0.47
	ABMA	California red fir	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	ABPR	noble fir	0.29	n/a	n/a	n/a	n/a	0.32	n/a	n/a	0.32	0.32	n/a	0.31
	ABSH	Shasta red fir	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
	CHNO	Alaska cedar	0.29	0.19	n/a	n/a	n/a	0.28	n/a	n/a	0.28	0.28	0.19	0.25
Redwood	SESE3	redwood	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.59	n/a	n/a	n/a	0.59

Spotted owl location data:

Spotted owl data used in model development consisted of site center locations documented within three years (plus or minus) of the date of the GNN vegetation data. Site centers are the location of spotted owl nests or daytime roosts containing paired spotted owls. Site center data for the habitat suitability modeling was made available through the cooperation of a variety of sources throughout the spotted owl's range. Data come from long-term demographic studies as well as locations from other research projects, public, private, and tribal sources.

Substantial effort was expended on verification of both the spatial accuracy and territory status of each site center in the data set. We specifically requested and received very high-quality data from spotted owl demography study areas (DSAs). For areas outside of DSAs, we obtained a large set of additional locations from NWFP Effectiveness Monitoring program (Davis and Dugger in press); the majority of these site centers had been evaluated for spatial accuracy. We also obtained and verified data sets from private timber companies, USFS Region 5 NRIS database and a number of research and monitoring projects across the species' range.

Because of the spatial extent of our analysis area (>23 million ha), we do not have the luxury of having equal survey effort throughout the region. Instead we have data from research studies, monitoring of demographic rates, management efforts, and other sources. While spotted owl demographic study areas have been intensively and extensively studied for long periods of time (see Anthony *et al.* 2006 and Forsman *et al.* 2011) and provide the highest- quality data sets, they comprise ~12% of the spotted owl's geographic range (based on our masked modeling regions). As importantly, for some modeling regions the proportion of total area and/or spotted owl locations within DSAs is very low. Given the DSAs represent nearly the only areas within the spotted owl's range that have consistently been surveyed over long periods of time and that they represent a smaller portion of the species' geographic range, the data from them (at the scale of a modeling region) is generally spatially aggregated. Spotted owl site location data from the DSAs represent a much smaller portion of the spotted owl's range than the full data set we used (Table C-3), and the larger data set represents more fully the spectrum or gradient of biotic and abiotic features that spotted owls select for nesting and roosting. For example, the total number of spotted owl site locations inside DSAs was 1,199, and when thinned by 3 km was 755. In contrast, the total number of site locations outside of DSAs was 2,591, and when thinned was 2,110. With our 200-ha analysis area, if we would have sampled from only the DSAs we would have sampled ~151,000 ha around thinned DSA sites versus the 573,000 ha sampled around all thinned sites.

Table C-3. Comparison of area and spotted owl location data within modeling regions and demographic study areas (DSAs).

Modeling Region	Acronym	Percentage of Region in DSA	Number of NSO Sites in DSA	Number of NSO Sites Outside DSA
ALL MODELING REGIONS	ALL	12.34%	1199	2591
North Coast Olympics	NCO	7.29%	166	79
Oregon Coast	ORC	30.88%	352	102
East Cascades South	ECS	20.49%	78	45
East Cascades North	ECN	23.45%	132	84
West Cascades North	WCN	0.92%	3	77
West Cascades Central	WCC	19.21%	57	157
West Cascades South	WCS	6.58%	57	435
Klamath East	KLE	10.31%	98	374
Klamath West	KLW	15.24%	127	335
Inner California Coast Ranges	ICC	0.75%	8	300
Redwood Coast	RDC	10.23%	121	603

Outside of DSAs, the quantity and density of site center data varies widely. While we have attempted to compile a large sample of site centers that is broadly representative of the entire distribution of spotted owls, the overall distribution of sample sites is somewhat clumped. Areas with few nest locations are a result of: 1) few surveys being conducted, 2) the absence of spotted owls, or 3) data being unavailable. We did not want the modeling results to be a function of the intensity of spotted owl sampling throughout the region, but to be as close of an approximation as possible of spotted owl-habitat relationships. Phillips *et al*. (2009) noted that spatially biased survey data present major challenges to distributional modeling by over-weighting areas where intensive sampling has occurred. Therefore, within each modeling region we "thinned" the spotted owl nest locations such that the minimum distance between nest locations would be 3.0 km (thinning with a 3 km distance resulted in removing ~25% of the locations available to us). Carroll *et al.* (2010) used a similar approach in their modeling of other species whereby clusters of records were identified and one record from the cluster was randomly selected from the set. Using a 3 km thinning distance retained 75% of the total data, and did not have a large effect on those modeling regions with small initial sample sizes (<100) of site center locations (Table C4).

Table C-4. Sample size of spotted owl site center locations (1993-1999) by modeling region and the impact of various thinning distances (minimum allowable distance between site centers) on sample size.

		Thinning Distance					
Modeling Region	**Total Sites**	**1 km**	**1.5 km**	**2 km**	**2.5 km**	**3 km**	**4 KM**
NCO	241	236	229	221	209	196	162
OCR	454	430	414	371	325	281	202
RDC	724	716	670	547	461	392	284
WCN	80	80	79	78	77	77	74
WCC	214	211	205	195	182	173	144
WCS	489	489	487	482	477	470	342
ECN	216	215	209	203	195	184	155
ECS	123	122	119	112	104	93	67
KLW	462	460	454	440	414	358	275
KLE	472	468	463	455	434	381	285
ICC	308	308	307	300	286	253	199
Total	**3783**	**3735**	**3636**	**3404**	**3164**	**2858**	**2189**
Percentage of total	**100**	**98.7**	**96.1**	**90.0**	**83.6**	**75.5**	**57.9**

Due to the increased influence of the barred owl on spotted owls, we followed, in part, the modeling approach used by Davis and Dugger (in press) to reduce the influence of barred owls on apparent habitat associations of spotted owls. For our effort, we wanted our models to identify areas with more or less nesting suitability for spotted owls. Because barred owls have apparently displaced many spotted owls from previously-occupied nesting areas, sometimes into habitat types/conditions that spotted owls only rarely used prior to the barred owl's invasion (Gremel 2005, Gutiérrez *et al.* 2007), we did not want to evaluate their "displaced habitat use", but instead their use of habitat without the larger, current impact of barred owls. Although barred owls were known to be widely distributed in the northern portion of the spotted owl's range in 1996, Gremel (pers. comm. 2010) suggested barred owl densities were substantially lower in 1996 than in 2006. Pearson and Livezey (2003) reported that barred owls had increased by an average of 8.6% per year between 1982 and 2000 on parts of the Gifford Pinchot National Forest (GPNF), Washington. Subsequently, Livezey *et al.* (2007) reported that the 98 known barred owl sites on the GPNF in 2001 had increased to 143 sites in 2006. Thus, in an attempt to reduce the influence of barred owls on spotted owl habitat use, we developed and tested models using GNN vegetation data from 1996 (assumed to be the period with lower barred owl influence) along with spotted owl location information plus or minus three years from 1996. Those models were then projected to the most current (2006) GNN layer to predict contemporary relative habitat suitability (RHS). Each region's model was then tested by comparing with RHS values at independent sites from the 2006 spotted owl locations (only those that did not overlap with the 1996 locations).

Developing Habitat Definitions:

<u>Nesting and roosting habitat</u>

Prior to developing models, we attempted to synthesize both the literature and information from experts. From the literature, we emphasized studies evaluating habitat selection over those that described habitat features (associations) around spotted owl locations, but did not evaluate selection. This synthesis resulted in the development of a series of definitions of spotted owl nesting-roosting and foraging habitat. For example, several published studies concluded that nesting spotted owls strongly select for areas with canopy cover >70% and many large trees nearby and strongly select against areas with lower amounts of canopy cover and few or no large trees nearby. We therefore created definition "NR_1" (nesting-roosting definition number 1) based on canopy cover and density of large trees (*e.g.*, trees >75 cm dbh). Because experts and/or other published studies typically supported several (i) alternative NR definitions, we created roughly ten alternative NR habitat definitions (NR_2, NR_3, $NR_{i,}$ etc.) per modeling region. We used an identical process to develop a series of foraging (F) habitat definitions for each modeling region (Tables C5 and C6 provide an example of this process). It is important to recognize that these habitat definitions are binary for each pixel; either the pixel contained each of the features in the definition (and was therefore considered habitat), or it did not (it was considered non-habitat).

Table C-5. Spotted owl nesting-roosting habitat variables for the northern Coast Ranges and Olympic Peninsula.

Habitat characteristics from expert panel, literature	GNN Variable expression
Canopy cover of conifers is ≥ than 80%	CANCOV_CON_GE_80
Mean stand diameter is ≥ than 50cm	MNDBHBA_CON_GE_50
Structure should include ≥ 70 medium trees/ha	TPH_GE_50_GE_70
Structure should include ≥ 20 larger trees/ha	TPH_GE_75_GE_20
Very large remnant trees are important (≥5/ha)	TPH_GE_100_GE_5
Canopy layering/diversity is important	DDI_GE_6 *

*DDI = Diameter Diversity Index (ranges from 1-10)

Table C-6. Sample definitions of spotted owl nesting-roosting habitat based on variables and values from Table 5.

	Candidate nesting/roosting habitat definitions
NR_1	CANCOV_CON_GE_80 + MNDBHBA_CON_GE_50 + DDI_GE6
NR_2	CANCOV_CON_GE_80 + MNDBHBA_CON_GE_50 + TPH_GE_75_GE_20 + TPH_GE_100_GE_5 + DDI_GE_6
NR_3	CANCOV_CON_GE_80 + TPH_GE_50_GE_70 + TPH_GE_75_GE_20 + TPH_GE_100_GE_5 + DDI_GE_6
NR_4	CANCOV_CON_GE_70 + MNDBHBA_CON_GE_50 + TPH_GE_75_GE_20 + DDI_GE_5

Foraging habitat

Foraging habitat definitions were informed by published and unpublished literature and input from experts. In this process, foraging habitat was, by definition, different than nesting-roosting habitat. This is not to suggest that spotted owls do not forage in nesting-roosting habitat, but for the sake of being explicit in this process, foraging habitat was distinct from nesting-roosting habitat. In general, foraging habitat definitions had lower thresholds of canopy cover, tree size, and canopy layering than nesting-roosting definitions (Tables C7 and C8 provide an example of this process).

Table C-7. Spotted owl foraging habitat variables for the northern Coast Ranges and Olympic Peninsula.

Habitat characteristics from expert panel, literature	**GNN Variable expression**
Canopy cover of conifers is ≥ than 70%	CANCOV_CON_GE_70
Mean stand diameter is ≥ than 40 cm	MNDBHBA_CON_GE_40
Structure should include ≥ 50 medium trees/ha	TPH_GE_50_GE_50
Structure should include ≥ 8 larger trees/ha	TPH_GE_75_GE_8
Canopy layering/diversity is important	DDI_GE_4 *

*DDI = Diameter Diversity Index (ranges from 1-10)

Table C-8. Sample definitions of spotted owl foraging habitat based on variables and values from Table C7.

	Candidate nesting/roosting habitat definitions
F_1	CANCOV_CON_GE_70 + MNDBHBA_CON_GE_40 + DDI_GE_4
F_2	CANCOV_CON_GE_70 + MNDBHBA_CON_GE_40 + TPH_GE_75_GE_8 + DDI_GE_6
F_3	CANCOV_CON_GE_70 + TPH_GE_50_GE_50 + TPH_GE_75_GE_8 + DDI_GE_4
F_4	CANCOV_CON_GE_60 + MNDBHBA_CON_GE_40 + TPH_GE_75_GE_8 + DDI_GE_4

Because attributes of habitat such as amount of edge and core area have been shown to influence both habitat selection and fitness (Franklin *et al.* 2000) of spotted owls, we also included NR "core" and "edge" metrics.

Abiotic variables

Because published literature and information from experts suggested that abiotic features might be important in determining spotted owl habitat use and selection, we evaluated a series of abiotic features known or suspected to influence spotted owl habitat selection and use (Table C9). Numerous studies have shown that local geographic features such as slope position, aspect, distance to water, and elevation have been found to influence spotted owl site selection (Stalberg *et al.* 2009, Clark 2007). Several authors (Blakesley *et al.* 1992, Hershey *et al.* 1998, LaHaye and Gutiérrez 1999) have noted the absence of spotted owls above particular elevational limits (whether this limit is due to forest structure, prey, competitors, parasites, diseases, and/or extremes of temperature or precipitation is not known). At broader scales, temporal variation in climate has been shown to be related to fitness (Franklin *et al.* 2000, Olson *et al.* 2004, Dugger *et al.* 2005, Glenn *et al.* 2010), suggesting that spatial variation in climate may also influence habitat suitability for spotted owls. Ganey *et al.* (1993) found that Mexican spotted owls (*S. o. lucida*) have a narrow thermal neutral zone and others (*e.g.*, Franklin *et al*. 2000) have assumed the northern spotted owl to be similar in this regard. Furthermore, the spotted owl's selection for areas with older-forest characteristics has been hypothesized to, in part, be related to its needing cooler areas in summer to avoid heat stress (Barrows and Barrows 1978). Temperature extremes (winter low and summer high) as well as potential breeding-season specific stressors (spring low temperature and high spring precipitation) are also considered potentially useful predictor variables for our purposes (Carroll 2010, Glenn *et al.* 2010). By including climate variables as candidate variables in our habitat suitability modeling, we evaluated whether climate effects on spotted owl fitness are translated into patterns of the species' distribution.

Developing models:

MaxEnt compares the characteristics (variables included in the models) of the training data sites to a random selection of ~10,000 random "background" (available) locations. We only used the linear, quadratic, and threshold features within MaxEnt (*i.e.,* hinge and product features were not used).

We used the following model-building and evaluation process within each modeling region

1) Each nesting-roosting habitat definition is a single-variable model. Thus, if we developed 10 nesting-roosting habitat definitions for a region, we compared 10 nesting-roosting habitat models for that region. We used MaxEnt to determine the best nesting-roosting habitat definition within each region (see model evaluation, below).

2) Within each modeling region that has foraging habitat definitions, we combined the best nesting-roosting habitat definition(s) with each foraging habitat definition to evaluate whether the addition of foraging habitat improved model performance. Models were considered to have been improved if the addition of foraging habitat increases the ranking of the model. If the addition of foraging habitat improved the model's performance, we used the nesting-roosting + foraging habitat model for step 3 (below). If not, we used the best nesting-roosting model(s) for step 3.

3) For abiotic variables, we developed univariate or multivariate models using the variables in Table C9. Carroll (2010) found that mean January precipitation, mean July precipitation, mean January temperature, and mean July temperature were the variables in the best, of 30, climate models he evaluated. He found the two precipitation metrics were the most influential of the four. Franklin *et al.* (2000) also found climate variables to influence spotted owl survival and reproduction. We included three climate models: 1) the four variables Carroll (2010) reported, 2) mean January precipitation and mean July precipitation, 3) mean January precipitation and mean January temperature. We "challenged" the best model(s) after step 2 by adding each abiotic model to it (*sensu* Dunk *et al.* 2004), in an attempt to improve its predictive ability. The abiotic models were not compared to each other, but were compared in order to see if their addition to the best biotic (nesting-roosting or nesting-roosting + foraging) model resulted in an improved model (see step 2). If the biotic plus abiotic model was an improvement over the biotic-only model, we used the combination model, otherwise we used the biotic-only model. The reason abiotic-only models were not evaluated is that it is illogical to suggest that spotted owls (a species that nests in trees) might only respond to abiotic factors when selecting nesting areas. In contrast, we could develop a logical biological argument that spotted owls might respond only to biotic features when selecting nesting areas. We could also develop logical biological arguments

articulating how a combination of biotic and abiotic factors might influence the selection of nesting areas.

Model-building hierarchy

The spatial distribution of spotted owl territories is influenced by a wide variety of environmental gradients operating at different spatial scales. At the smallest scale we evaluated, features such as the amount of nesting-roosting and/or foraging habitat within a core area, the amount of edge between spotted owl habitat and non-habitat, or amount of "core habitat" (*sensu* Franklin *et al*. 2000) have all be shown to influence spotted owl distribution, abundance, or fitness. Each of those variables, however, is a structural variable. That is, they are based on habitats comprised of various structural elements (*e.g.*, large trees, high canopy cover). However important and influential these variables are to spotted owls, other variables such as plant species composition (broadly speaking), topographic position, climate, and/or elevation are also likely to influence their distribution, abundance, and perhaps fitness (Franklin *et al.* 2000, Olson *et al*. 2004, Dugger *et al.* 2005, Glenn 2009).

In part, the partitioning of the spotted owl's geographic range into 11 modeling regions should act to reduce the influence of broad patterns in plant species composition, climate and/or elevation on the species. Nonetheless, we were interested in evaluating whether habitat suitability is influenced by local variation in these non-structural variables.

Stand structure and the spatial arrangement of forest patches have been found to influence spotted owl fitness (Franklin *et al*. 2000, Olson *et al*. 2004, Dugger *et al*. 2005). Edge between nesting-roosting habitat and other habitat types is thought to afford foraging spotted owl opportunities when habitats, but which are rarely used, are juxtaposed closely with habitats spotted owls use. "Core" habitat includes those areas of spotted owl nesting habitat not subjected to edge-effects. Franklin *et al*. (2000) estimated core habitat by buffering all spotted owl habitat (largely mature forest areas) by 100 m and estimating the size of the habitat excluding the 100 m buffer.

Spotted owl experts noted that mid-scale or landscape level patterns such as tree species composition and topography may also influence the local distribution and density of spotted owls. For example, within many of the modeling regions, there exists variation in tree species composition, but forests with different species compositions may still have similar structural attributes (*e.g.*, high canopy cover, multi-storied, large trees). Some forest types (regardless of their structural attributes) are rarely, if ever, used by spotted owls, so we attempted to account for this variation by evaluating models that include some compositional variables.

Many of our 11 modeling regions contain high-elevation areas above the elevational extremes normally used by spotted owls. In some higher elevation areas there exist structurally complex, multi-storied forests with large trees – areas with similar structural characteristics to those used by spotted owls.

However, spotted owls rarely if ever use such areas. Our intention was to attempt to account for this in our modeling.

We recognize the hierarchical nature of these environmental factors and their possible influence on spotted owl distribution. Our model building approach took this into consideration, by starting at the smallest scale and sequentially "challenging" models with variables from larger spatial scales. In order to focus on environmental features most directly linked to territory location, habitat selection, and individual fitness of spotted owls, we employed a bottom-up approach to building models (Table C9).

Table C-9. Categories of candidate variables, variable names, and order of the entry of variables into modeling process.

Category	Variable	Order
Best climate/elevation model	Mean July Precipitation	↑
	Mean July Temperature	
	Mean July Precipitation	
	Mean July Temperature	
	Mean Elevation	
Topographic position	Curvature	
	Insolation	
	Slope Position	
Compositional variables (percent of basal area)	Redwood	
	Oak Woodland	
	Pine-dominated	
	Northern Deciduous Hardwoods	
	Evergreen Hardwoods	
	Douglas-fir	
	Subalpine forest	
Habitat pattern	Core of NR habitat	
	Edge of NR habitat	
Habitat structure	Foraging Habitat Amount	
	Nesting/Roosting Habitat	

Goals of MaxEnt Modeling:

Our goals for the relative habitat suitability models were to find models that: 1) had good discriminatory ability, 2) were well calibrated, 3) were robust, and 4) had good generality. We sought models that were not over-fit, the consequences of which would be to have models that fit the developmental data very closely, but which would not have worked well on data that were not used in their development. That is we sought models with good generality (*i.e.*, models that worked well in the modeling regions in general, not simply at classifying the developmental/training data). MaxEnt attempts to balance model fit and complexity through the use of regularization (see Elith *et al.* 2011). Elith *et al.* (2011) noted that MaxEnt fits a penalized maximum likelihood model, closely related to other penalties for complexity such as Akaike's Information Criterion (AIC, Akaike 1974). In order to evaluate whether any model region's model was over-fit we conducted rigorous cross-validation on each model (see below), and, when available we evaluated how well models classified independent data (see below).

Model discrimination

Once the best model was found for each region, we conducted a cross-validation of each model to evaluate how robust the model was. Each of 10 times we removed a random subset of 25% of the spotted owl locations, developed the model with the remaining 75% and classified using the withheld 25%. The area under the receiver operating characteristic curve (AUC) was evaluated for both training and test data within each region. AUC is a measure of a model's discrimination ability; in our case discrimination between spotted owl-presence locations and available locations (not discrimination of presence versus absence locations). AUC values, theoretically, range between 0 and 1.0, with values less than 0.5 having worse discriminatory ability than expected by chance, values closer to 0.5 suggesting no to poor discriminatory ability, and values closer to 1.0 suggesting excellent discriminatory ability.

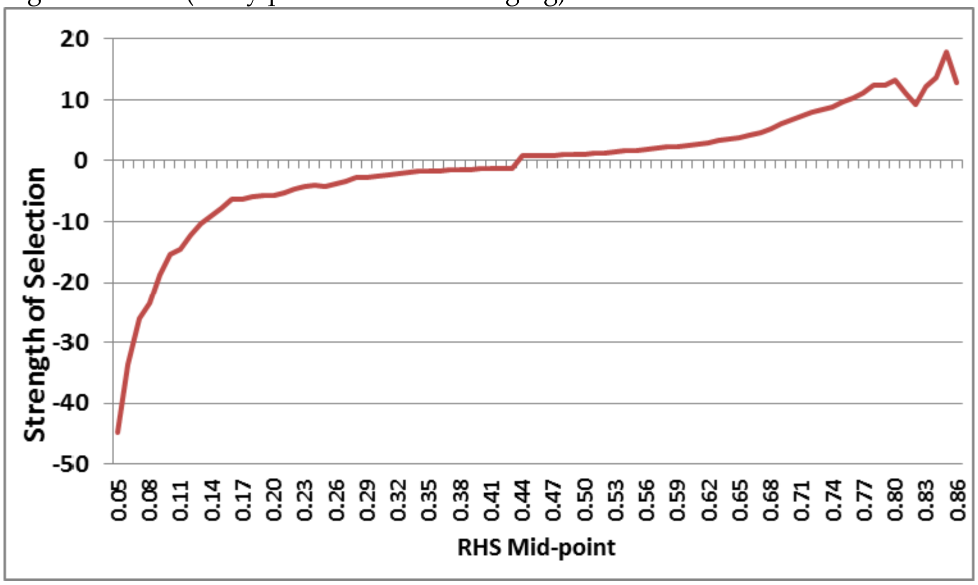
For these analyses, AUC values essentially describe the proportion of times one could expect a random selection of an actual spotted owl nest site location to have a larger relative habitat suitability value than a random selection from available locations. It is therefore a threshold-independent measure of model discriminatory ability. Because our evaluation represents use versus availability and not use versus non-use, AUC values have an upper limit somewhat less than 1.0 (because some of the available locations are actually used by spotted owls). Even for good (well-discriminating) models, AUC values should be lower in areas where the background areas contain larger amounts of suitable habitat. Two contrasting examples are provided to make this point: 1) a model estimating a riparian-dependent bird species' distribution in the Great Basin may have a very high AUC value because there is large contrast between riparian vegetation where the bird nests and the vast majority of background locations in sage-steppe, vs. 2) a model estimating the distribution of a generalist omnivore (like a black-bear) in a national forest may have a lower AUC because so much of the background habitat is suitable for the species. The point is that AUC is a measure of discrimination, but that a use-versus-availability model's ability to discriminate is a function of both the animal's habitat specificity and the abundance of the animal's habitat in the region of interest. To evaluate the degree to which AUC values from each modeling region's MaxEnt model were related to the abundance of suitable habitat we regressed AUC values against the proportion of each modeling region comprised of RHS values >30, >40, and >50 (the SOS values for all modeling regions showed selection for areas within this range – see Figure C-5 below). If the abundance of suitable habitat is high in areas with lower AUC values, and lower in areas with higher AUC values, the interpretation would be that the abundance of suitable habitat, not model discrimination ability, best explains this relationship.

In order to evaluate the degree to which AUC values were a function of the amount of suitable habitat in modeling regions, and thus help us interpret whether somewhat lower AUC values represented poor models versus a larger amount of suitable habitat in the modeling region, we evaluated the correlation between AUC values and the percentage of each modeling region with RHS scores above various thresholds corresponding to RHS values showing higher use than expected (see Model Calibration section below).

Model Calibration

To assess model calibration we evaluated the agreement between RHS and observed proportions of sites occupied. Phillips and Elith (2010) noted that model discrimination and model calibration are independent measures. Model calibration refers to the agreement between predicted probabilities of occurrence (habitat suitability for our study) and observed proportions of sites occupied (Pearce and Ferrier 2000, Phillips and Elith 2010). Phillips and Elith (2010) note that model discrimination and model calibration are independent measures. Hirzel *et al.* (2006) (whose work Phillips and Elith [2010] expand upon), developed "strength of selection" metrics for species distribution models using a moving-window approach. Strength of selection (SOS) evaluations allow for an understanding of the use that areas with various habitat suitability values receive (by nesting spotted owls in our case) relative to the abundance of such areas in the study area (see Figure C4 below). Essentially, a well-calibrated model will show the species to use higher suitability areas disproportionately more and lower suitability areas disproportionately less. The shape of the relationship provides insights into the degree to which the species avoids or is attracted to areas with particular habitat suitability values.

Figure C-4. This *example* of the strength of selection (SOS) evaluation shows a well-calibrated model. Areas with a mid-point RHS (*i.e.*, relative habitat suitability value) of 0.05 (the moving window size here was 0.1) were used ~45-times *less* than would be expected based on its extent in the study area. Similarly, areas with a mid-point RHS of 0.8 (window of 0.75-0.85) were used ~12-times *more* than expected based on its extent in the study area. This figure was developed from a model trained on >3,000 spotted owl night locations (many presumed to be foraging).



Habitat Modeling Results:

The following section provides summary descriptions of the final "best" models for each modeling region; including information on the relative contribution of each covariate to the model, model evaluation metrics, and the results of validation against independent data sets conducted to date. Because the primary objective of this habitat modeling step was to provide accurate prediction of relative habitat suitability and subsequent likelihood of spotted owl occupancy, we focus on presenting evaluation of model performance, rather than description of spotted owl habitat associations. Tables and table series C10 to C17 provide descriptions of the best nesting-roosting habitat model, foraging habitat model, and full model for each modeling region, as well as model evaluation metrics (AUC and Gain) and the relative contribution of each variable to the full model (a heuristic estimate provided in the standard output from MaxEnt). AUC values were highly correlated with the percentage of each modeling region comprised of RHS values >30, >40, and >50 (r^2 = 0.9685, 0.9649, 0.9574, respectively). Hence, variation in AUC values among modeling regions (which ranged from 0.76 – 0.93) has less to do with model discrimination ability (*i.e.*, the quality of the model) and more to do with the quantity of suitably habitat in each modeling region.

See Table C18 for codes and descriptions of variables used in the models.

Table Series C-10. Highest-ranking (best) Nesting/Roosting habitat (NR), foraging habitat (F), and full models for coastal Washington, Oregon and California modeling regions.

North Coast and Olympics Modeling Region (N= 196 training sites):

Model		**AUC**	**GAIN**
NR06	DDI (≥6) + TPH ≥ (>25/ha) + BAA GE3 (≥ 55 m²/ha)	0.8365	0.7667
F04	MNDBHBA_CON (≥40); TPH_GE75 (≥10)	0.8619	0.8817
Full Model	NR06 + NR06EDGE + F04 + SLOPE POSITION+ ELEVATION + CURVATURE + SUBALPINE FOREST+JULY MAX TEMP+JANUARY PRECIP + JULY PRECP + INSOLATION + JANUARY MIN TEMP + NORTHERN HARDWOODS	0.8989	1.057

Oregon Coast Ranges Modeling Region (N = 281training sites)

Model		**AUC**	**GAIN**
NR08	CANCOV_CON (≥55) + DDI (≥6) + TPH_GE75 (≥20)	0.7683	0.4498
F04	DDI (≥4) + TPH_GE50 (≥30)	0.7787	0.467
Full Model	NR08 + NR08 EDGE + SLOPE POSITION + JULY MAX TEMP + JANUARY MIN TEMP + F04 + CURVATURE + INSOLATION + JULY PRECIP + JANUARY PRECIP + ELEVATION + NR08 CORE + NORTHERN HARDWOODS + EVERGREEN HARDWOODS	0.864	0.811

Redwood Coast Modeling Region (N = 389 training sites)

Model		**AUC**	**GAIN**
NR03	CANCOV (≥70) + MNDBHBA_CON (≥44)	0.5928	0.0509
F05	CANCOV (≥65) + BAC_GE50 (≥3)	0.6256	0.0785
Full Model	SLOPE POSITION + CURVATURE + NR03 EDGE + F05 + NR03 + REDWOOD + ELEVATION + JANUARY PRECIP + OAK WOODLAND + JULY MAX TEMP + INSOLATION + JANUARY MIN TEMP + NR03 CORE + JULY PRECIP	0.760	0.335

Table C-11. Individual covariates and their contribution to full model.

North Coast / Olympics		Oregon Coast Ranges		Redwood Coast	
Full Model	**%**	**Full Model**	**%**	**Full Model**	**%**
NR 06	42.4	NR 08	29.4	Slope Position	48.2
NR06Edge	21.5	NR08 Edge	24.2	Curvature	11.2
NR06+F04	20.1	Slope position	11.9	NR03 Edge	10.3
Slope position	6.0	July Max Temp	10.1	NR03 + F05	6.1
Elevation	3.6	Jan Min Temp	8	NR 03	5.7
Curvature	1.8	NR08 + F04	5.5	Redwood (%BA)	4.8
Subalpine	1.1	Curvature	4.1	Elevation	4.1
July Max Temp.	0.9	Insolation	3.1	January Precip	3.2
Jan Precip.	0.9	July Precip	1.5	Oak Woodland	2.6
July Precip.	0.8	Jan Precip	1.3	July Max Temp	1.3
Insolation	0.6	Elevation	0.4	Insolation	0.9
Jan Min Temp	0.3	NR08 Core	0.2	Jan Min Temp	0.7
Northern Hdwd	0.1	Northern Hdwd	0.2	NR03 Core	0.7
		Evergreen Hdwd	0.1	July precip	0.4

Table Series C-12. Nesting/Roosting habitat, foraging habitat, and full models for Western Cascades modeling regions.

Western Cascades Modeling Region (Northern Section) (N = 76 training sites)

Model		AUC	GAIN
NR05	CANCOV (≥80) + MNDBHBA_CON (≥60) + TPHC_GE100 (≥7)	0.8377	0.7555
F01	CANCOV (≥70); DDI (≥5); TPH_GE50 (≥42); BAA_GE3 (≥40)	0.8417	0.7698
Full Model	NR05 EDGE + NR05 + SLOPE POSITION + CURVATURE + ELEVATION + JANUARY PRECIP + NORTHERN HARDWOODS + JULY MAX TEMP + SUBALPINE FOREST + INSOLATION + JULY PRECIP + F01 + JANUARY MIN TEMP + NR05 CORE	0.931	1.393

Western Cascades Modeling Region (Central Section) (N = 171 training sites)

Model		AUC	GAIN
NR09	TPH_GE50 (≥ 64) + TPH_GE75 (≥ 16) + TPHC_GE100 (≥ 4)	0.7965	0.5825
F01	CANCOV (≥70) + DDI (≥4) + TPH_GE50 (≥37) + BAA_GE3 (≥ 37)	0.816	0.6575
Full Model	NR09 EDGE + F01 + CURVATURE + ELEVATION + NORTHERN HARDWOODS + SUBALPINE + SLOPE POSITION + JANUARY MIN TEMP + NR09 + JULY PRECIP + JULY MAX TEMP + INSOLATION + NR09 CORE + JANUARY PRECIP	0.892	1.024

Western Cascades Modeling Region (Southern Section) (N = 470 training sites)

Model		AUC	GAIN
NR02	CANCOV (≥ 70) + MNDBHBA_CON (≥ 50) + TPH_GE75 (≥ 22)	**0.6877**	**0.2343**
F01	CANCOV (≥ 60) + DDI (≥ 4) + QMDC_DOM (≥ 37)	**0.6931**	**0.2385**
Full Model	NR02 + SLOPE POSITION + CURVATURE + F01 + JANUARY MIN TEMP + NORTHERN HARDWOODS + INSOLATION + JULY PRECIP + JANUARY PRECIP + JULY MAX TEMP + ELEVATION	**0.762**	**0.355**

Table C-13. Individual covariates and their contribution to full model.

Western Cascades North		**Western Cascades Mid**		**Western Cascades South**	
Full Model	%	**Full Model**	%	**Full Model**	%
NR05 Edge	34.4	NR09 Edge	44.8	NR 02	62.9
NR 05	17.2	NR09 + F01	13.9	Slope Position	17.8
Slope Position	13.0	Curvature	8.5	Curvature	4.7
Curvature	12.6	Elevation	7.6	NR02 + F01	3.9
Elevation	8.0	Northern Hdwd	7.4	Jan Min Temp	3.9
Jan Precip	4.3	Subalpine	4.2	Northern Hdwd	1.9
Northern Hdwd	3.7	Slope Position	4.1	Insolation	1.5
July Max Temp	2.2	Jan Min Temp	2.4	July Precip	1.5
Subalpine	1.4	NR 09	1.8	January Precip	0.9
Insolation	0.9	July Precip	1.5	July Max Temp	0.5
July Precip	0.9	July Max Temp	1.4	Elevation	0.5
NR05 + F01	0.8	Insolation	1.0		
Jan Min Temp	0.5	NR09 Core	0.7		
NR05 Core	0.2	Jan Precip	0.7		
NR05 Edge	34.4				

Table Series C-14: Nesting/Roosting habitat, foraging habitat, and full models for Eastern Cascades modeling regions.

Eastern Cascades Modeling Region (Northern Section) (n = 182 training sites)

Model		AUC	GAIN
NR06	CANCOV (≥ 70) + DDI (≥ 5) + MNDBHBA_CON (≥ 42)	0.685	0.2263
F03	CANCOV (≥52) + QMDC_DOM (≥30) + BAA_GE3 (≥23)	0.7347	0.3114
Full Model	NR06 + SLOPE POSITION + DOUGLAS-FIR + JANUARY MIN TEMP + ELEVATION + F03 + NR06 EDGE + JULY MAX TEMP + SUBALPINE FOREST + JANUARY PRECIP + CURVATURE + INSOLATION + JULY PRECIP + PINE	0.879	0.843

Eastern Cascades Modeling Region (Southern Section) (N = training sites)

Model		AUC	GAIN
NR07	CANCOV (≥ 70) + MNDBHBA_CON (≥ 45) + TPH_GE75 (≥ 9)	0.7263	0.2912
F03	MNDBHBA_CON(≥ 38) + DDI(≥ 4) + QMDC_DOM(≥ 32)	0.7868	0.4797
Full Model	(F03 + NR07) + NR07 + NR07 EDGE + PINE + DOUGLAS-FIR + JANUARY MIN TEMP + ELEVATION + SLOPE POSITION + NR07 CORE + JULY MAX TEMP + INSOLATION + JANUARY PRECIP + CURVATURE + SUBALPINE FOREST + JULY PRECIP	0.889	0.957

Table C-15. Individual covariates and their contribution to full model.

Eastern Cascades South		Eastern Cascades North	
Full Model	**%**	**Full Model**	**%**
NR07 + F03	18.4	NR06	20
NR 07	13.9	Slope Position	14.6
NR07 Edge	11.7	Douglas-fir	13.6
Pine	10.7	Jan Min Temp	10.6
Douglas-fir	10.7	Elevation	8.3
Jan Min Temp	9.5	NR06 + F03	6.8
Elevation	5.4	NR06 Edge	5.7
Slope Position	4.6	July Max Temp	4.1
NR07 Core	4.5	Subalpine	4.0
July Max Temp	3.3	January Precip	3.3
Insolation	3.2	Curvature	2.9
January Precip	1.6	Insolation	2.7
Curvature	1.5	July Precip	2.1
Subalpine	0.6	Pine	1.5
July Precip	0.4		

Table Series C-16. Nesting/Roosting habitat, foraging habitat, and full models for Klamath-Siskiyou Mountains and Interior California modeling regions.

Western Klamath Mountains (N = 357 training sites)

Model		AUC	GAIN
NR01	CANCOV (≥75) + DDI (≥6) + QMDC_DOM (≥50)	0.6608	0.1677
F03	DDI (≥4) + BAH_PROP (0.25 - 0.70) + BAC_GE3 (≥18)	0.6751	0.1886
Full Model	SLOPE POSITION + NR01 EDGE + NR01 + CURVATURE + JANUARY PRECIP + JULY PRECIP + NR01 CORE + JANUARY MIN TEMP + ELEVATION + INSOLATION + JULY MAX TEMP + F03 + OAK WOODLAND + EVERGREEN HARDWOODS	0.769	0.396

Eastern Klamath Mountains Modeling Region (N = 378 training sites)

Model		**AUC**	**GAIN**
NR01	CANCOV (≥65) + DDI (≥5.5) + QMDC_DOM (≥42)	0.7052	0.2601
F05	CANCOV_CON (≥45) + TPH_GE50 (≥23) + QMDC_DOM (≥30)	0.7075	0.2613
Full Model	NR01 + SLOPE POSITION+ DOUGLAS-FIR+ ELEVATION + NR01 EDGE + INSOLATION + JAN PRECIP+ F05 + CURVATURE + JULY MAX TEMP+ JAN MIN TEMP+ NR01 CORE + OAK WOODLAND+ PINE + SUBALPINE	0.830	0.605

Interior California Coast Ranges (N = 251 training sites)

Model		**AUC**	**GAIN**
NR02	CANCOV (≥65) + MNDBHBA_CON (≥46) + BAA_GE ≥75)	0.7136	0.2975
F04	DDI (≥3.5) + QMDC_DOM (≥30) + BAH_3_25 (≥5)	0.7296	0.3286
Full Model	NR02 + NR02 EDGE + SLOPE POSITION + JULY MAX TEMP + CURVATURE + F04 + NR02 CORE + JULY PRECIP + JAN PRECIP + INSOLATION + JAN MIN TEMP + EVERGRN HDWD + PINE +OAK WOODLAND + ELEVATION	0.820	0.540

Table C-17. Individual covariates and their contribution to full model.

Western Klamath		**Eastern Klamath**		**Interior CA Coast Ranges**	
Full Model	%	**Full Model**	%	**Full Model**	%
Slope Position	33.0	NR01	28.3	NR02	29.9
NR01 Edge	32.2	Slope Position	24.6	NR02 Edge	19.8
NR01	10.9	Douglas-fir	12.1	Slope Position	12.4
Curvature	6.6	Elevation	9.2	July Max Temp	11.1
January Precip	6.1	NR01 Edge	6.8	Curvature	5.6
July Precip	4.4	Insolation	5.4	NR02 + F04	4.9
NR01 Core	1.6	Jan Precip	4.9	NR02 Core	3.3
Jan Min Temp	1.3	NR01 + F05	3.3	July Precip	2.6
Elevation	1.1	Curvature	2.2	Jan. Precip	2.4
Insolation	1.0	July Max Temp	1.2	Insolation	2.0
July Max Temp	0.8	Jan Min Temp	0.8	Jan. Min Temp	1.8
NR01 + F03	0.5	NR01 Core	0.5	Evergrn Hdwd	1.7
Oak Woodland	0.2	Oak Woodland	0.2	Pine	1.3
Evergrn Hrdwd	0.2	Pine	0.2	Oak Woodland	0.7
		Subalpine	0.1	Elevation	0.5

Table C-18. Codes and descriptions of stand structural variables from GNN and compositional variables used in relative habitat suitability models.

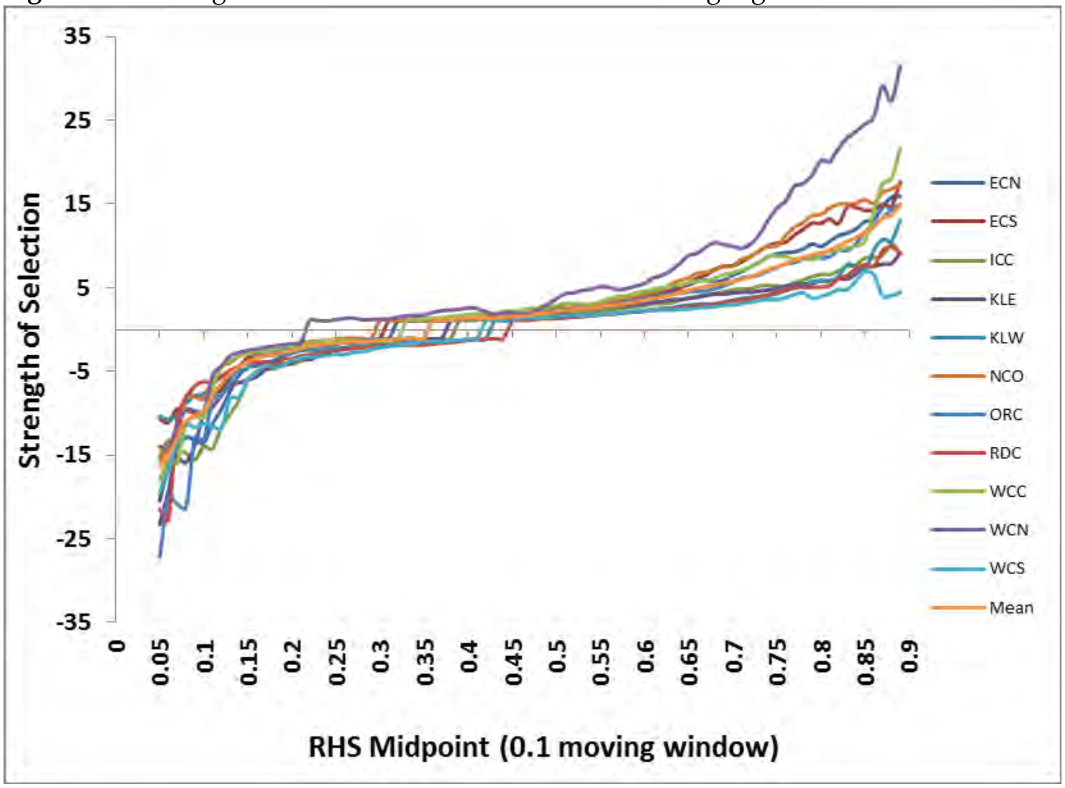
Variable	Definition
CANCOV	Canopy cover of all live trees
CANCOV_CON	Canopy cover of all conifers
DDI	Diameter diversity index (structural diversity within a stand, based on tree densities within different DBH classes)
SDDBH	Standard deviation of DBH of all live trees
MNDBHBA_CON	Basal area weighted mean diameter of all live conifers
TPH_GE_50	Live trees per hectare greater than or equal to 50 cm DBH
TPHC_GE_50	Conifers per hectare greater than or equal to 50 cm DBH
TPH_GE_75	Live trees per hectare greater than or equal to 75 cm DBH
TPHC_GE_75	Conifers per hectare greater than or equal to 75 cm DBH
TPHC_GE_100	Conifers per hectare greater than or equal to 100 cm DBH
QMDC_DOM	Quadratic mean diameter of all dominant and co-dominant conifers
BAA_GE_3	Basal area of all live trees greater than or equal to 2.5 cm DBH
BAA_3_25	Basal area of all live trees 2.5 to 25 cm DBH
BAA_GE_75	Basal area of all live trees greater than or equal to 75 cm DBH
BAC_GE_3	Basal area of conifers greater than or equal to 2.5 cm DBH
BAC_GE_50	Basal area of conifers greater than or equal to 50 cm DBH
BAH_PROP	Proportion of BAA_GE_3 that is hardwood
BAH_3_25	Basal area of all live hardwoods 2.5 to 25 cm DBH
Compositional Variables	
Evergreen Hardwoods	Basal area of tanoak, canyon, coast and interior live oaks, giant chinquapin, California bay and Pacific madrone
Subalpine	Basal area of silver fir, mountain hemlock, subalpine fir, red fir, Englemann spruce,
Pine	Basal area of ponderosa pine, Jeffrey pine, lodgepole pine, and Bishop pine
Northern Hardwoods	Basal area of red alder and bigleaf maple
Oak Woodland	Oregon white oak and blue oak

Results of Model Evaluation and Testing:

Strength of selection results

We plotted the observed use that areas with various RHS values receive (by nesting spotted owls in our case) relative to the abundance of such areas in each modeling region. Figure C5 shows the SOS curves for all 11 modeling regions. Although the degree of calibration varies among modeling regions, the RHS models are generally well-calibrated, with strong selection for areas of RHS > 0.6 to 0.7, and avoidance of RHS <0.15 to 0.25.

Figure C-5. Strength of Selection evaluation for all modeling regions.



Results of Model Cross-Validation

Overall, each modeling region's model proved to be fairly robust, and thus gave us confidence in the model's generality. When we evaluated the differences in the percentages of spotted owl sites classified among 10 equally-sized RHS bins between the full model (using all of the spotted owl locations – thinned by 3 km) and the cross-validated (CV) models (*i.e.*, the 25% of observations that were withheld from the developmental model, each of 10-times for each modeling region) there were generally very small differences (Table C19). The maximum percentage point difference (percentage of observations from the full model minus percentage of observations CV model) was 11.1 (see Table C19). The mean difference of the absolute values among modeling regions ranged from 1.6 (for the Klamath West) to 4.5 (for the West Cascades North). Absolute values were used for calculating means because without doing so, the positive and negative values within a modeling region will always have a mean of 0, and thus don't accurately represent overall differences between full and cross-validated models. There was an inverse (negative logarithmic) relationship between sample size of spotted owl sites and mean difference in absolute value ($r^2 = 0.537$, $P = 0.01$). Nonetheless, the magnitude of differences was generally quite low. For example, 39% of the differences were <2.0, 81% of the differences were <5.0, and only 7% of the differences were >7.0 (absolute value in each case). These findings suggest that none of the modeling region's full models were over-fit, and that all full models have good generality.

Table C-19. Results from cross-validation tests, showing absolute values of differences (% classified by full model - % classified in cross-validated model) among modeling regions.

	Absolute value of differences										
Po Bin	**ECN**	**ECS**	**ICC**	**KLE**	**KLW**	**NCO**	**ORC**	**RDC**	**WCC**	**WCN**	**WCS**
0-0.099	5.2	4.8	3.9	3.0	0.9	5.2	3.3	1.9	7.9	11.1	1.7
0.1-0.199	4.4	4.6	6.1	1.1	5.0	0.2	3.3	3.1	1.9	4.2	1.7
0.2-0.299	3.3	1.0	3.1	4.6	1.4	1.1	0.2	1.4	4.0	3.4	2.6
0.3-0.399	2.8	4.5	0.9	3.7	2.8	0.5	3.0	3.5	0.9	1.3	2.6
0.4-0.499	2.8	7.9	2.5	2.4	0.0	4.5	0.7	5.2	3.7	1.3	0.8
0.5-0.599	3.1	1.0	3.6	4.4	0.8	0.1	6.2	6.1	4.4	4.5	5.5
0.6-0.699	5.2	3.1	7.0	7.3	0.3	1.4	1.9	3.3	9.9	5.3	8.1
0.7-0.799	3.5	9.7	3.4	0.6	4.0	10.2	3.4	6.8	1.7	5.8	2.9
0.8-0.899	1.5	2.5	2.1	1.0	1.1	0.2	2.0	2.2	4.0	6.8	1.2
0.9-1.0	0.3	2.4	0.4	0.3	0.1	0.8	0.4	0.5	1.0	1.1	0.1
Mean	**3.2**	**4.1**	**3.3**	**2.8**	**1.6**	**2.4**	**2.4**	**3.4**	**3.9**	**4.5**	**2.7**

Results of comparisons with independent data sets

To further evaluate the reliability of the models' predictions, we obtained independent (*i.e.* not used in model development) samples of spotted owl territory locations that represented the period 1993 to 1999 (Test96) and 2003 to 2009 (Test06) and compared their associated RHS values to corresponding values for spotted owl sites used in model development. All test sites were greater than 0.8 km from a training site. Because the RHS models were developed using spotted owl territories from the 1996 time period, comparison with Test96 most directly addresses model accuracy. Comparison with independent spotted owl locations from 2006, however, enabled us to evaluate accuracy of the models when projected to a new time period (model transferability), and to investigate systematic shifts in RHS at spotted owl sites. These shifts may occur, for example, in areas where densities of barred owls have increased during the 1996 to 2006 period, and are displacing spotted owls from favorable habitat. If this is the case (as has been hypothesized), we might expect to see reduced use of RHS area at 2006 spotted owl sites, relative to 1996 values (see Methods: Spotted owl location data).

We obtained adequate (N ≥ 100) test samples for 2006 in four modeling regions. As data for additional modeling regions and Test96 become available, further evaluation of model accuracy should be conducted. Table C20 shows the proportions of spotted owl sites in each of five RHS "bins" for the training data (Train), and Test06. Because they allow comparison of RHS values across a gradient of relative habitat suitability, these comparisons are more informative than binary "correct classification" analyses.

Table C-20. Comparison of percentage of 1996 training sites versus test samples of 2006 spotted owl locations in 5 categories of Relative Habitat Suitability.

	Oregon Coast		**Western Klamath**		**Eastern Klamath**		**Redwood Coast**		**Rangewide**	
	Train	**Test**	**Train**	**Test**	**Train**	**Test**	**Train**	**Test**	**Train**	**Test**
N	247	169	358	136	375	108	392	284	2742	916
RHS bin										
0 – 0.2	7.3	7.1	8.7	2.2	6.1	4.6	4.8	3.2	6.1	4.6
0.2 – 0.4	19.0	23.1	18.2	19.8	14.1	20.4	13.8	12.7	16.5	17.8
0.4 – 0.6	35.6	35.5	38.5	46.3	38.4	39.8	42.1	44.7	36.7	41.8
0.6 – 0.8	32.8	30.2	33.5	30.8	38.7	35.2	37.2	37.7	36.7	33.8
0.8 – 1.0	5.3	4.1	1.1	0.74	2.7	0	2.0	1.8	4.0	1.2

Model evaluation summary:

All modeling regions' models were well calibrated and showed a quite similar pattern in terms of strength of selection (see Figure C5). Cross-validation results by modeling region showed that all models were relatively robust to the 25% iterative reduction in sample size (see Table C19). Lastly, comparison of model results with independent test data showed the models had good ability to predict spotted owl locations (Table C20), and performed well when projected to 2006 vegetation conditions. Overall, these evaluations suggest that our RHS models were robust and have good generality. Subsequently, we used the full dataset models.

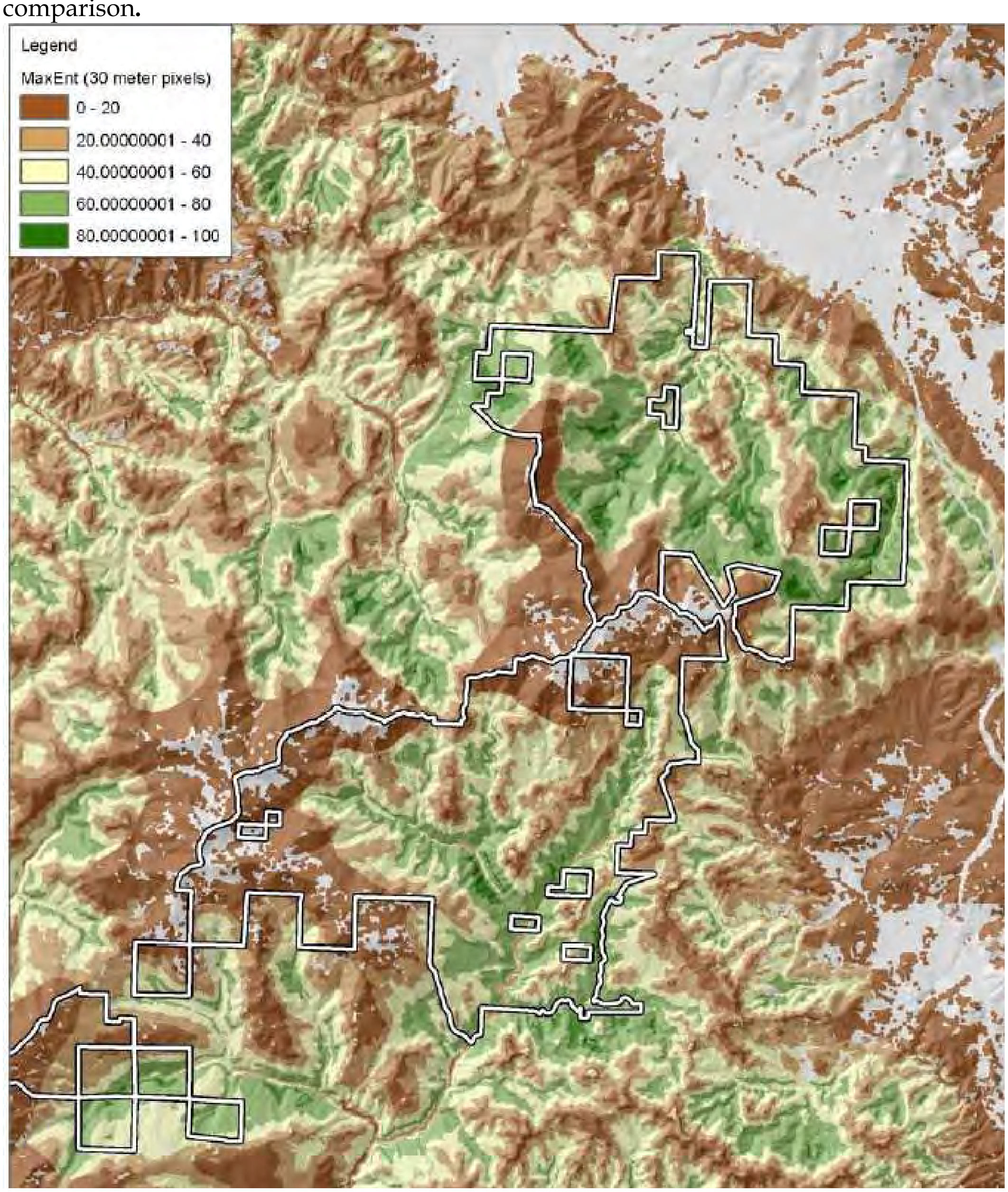
Interpretation of model output:

Elith *et al.* (2011) state that the MaxEnt logistic output is an attempt to estimate the probability that a species is present, given the environment (*i.e.*, the environmental conditions). For our purposes, we have taken a more conservative interpretation of the MaxEnt logistic output and interpret it to represent the relative habitat suitability (RHS) for nesting spotted owls within each modeling region. The map below (Figure C6) is the result of running each modeling region's best RHS model on each 30-m pixel within the region. That is, MaxEnt estimates a RHS value for each pixel based on the biotic and abiotic features within the 200-ha (~800 m radius) area around it (*i.e.*, based only on the variables in the best MaxEnt model for that modeling region). It is important to understand that a high RHS value is possible for a pixel that has little inherent value (*e.g.*, there are no trees in the 30x30 m focal pixel). It may, however, be that the surrounding 200-ha has many of the attributes associated with high RHS. Similarly, a focal pixel could have many of the positive characteristics that spotted owls generally select for, but it receives a low RHS value owing to the surrounding 200-ha having few or none of the attributes associated with high RHS values.

As noted above the RHS map is designed to facilitate and enable a wide variety of processes, discussions and analyses, including section 7 consultation, implementation and evaluation of the efficacy of spotted owl conservation measures such as Recovery Action 10 and management of barred owls. This model likely has utility for a wider variety of uses and processes than we currently envision, and it can be refined by future advances in the understanding of spotted owl habitat associations.

Maps depicting the RHS model outputs for the range of the spotted owl are available at:
http://www.fws.gov/oregonfwo/Species/Data/NorthernSpottedOwl/Recovery/Library/Default.aspx#Files
Once there, click on “maps” and “AppendixCMaps.pdf” The layers can be turned on and off using the “layers” button in the upper left-hand corner. The RHS values are the base layer on this map.

Figure C-6. Map depicting Relative Habitat Suitability from MaxEnt model. Higher suitability habitat conditions are indicated by darker green areas; brown colors denote lower suitability. Outline of the Mount Ashland Late-successional Reserve is shown for comparison**.**



Modeling Process Step 2 – Develop a spotted owl conservation planning model, based on the habitat suitability model developed in Step 1, and use it to design an array of habitat conservation network scenarios.

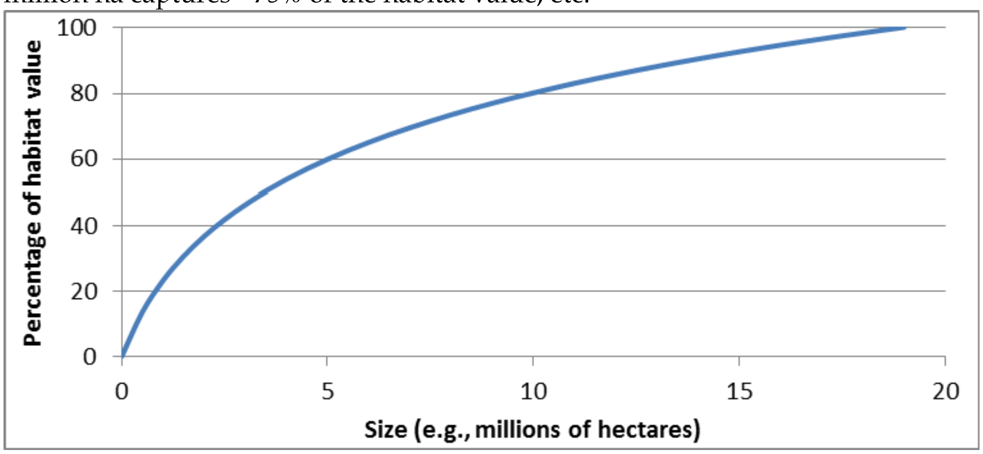
Because the RHS maps from Step 1 consisted of finely-distributed patterns of habitat suitability across the spotted owl's geographic range, we also wanted to provide a rigorous, repeatable method for aggregating habitat value into habitat conservation networks. We used the conservation planning model "Zonation" (Moilanen and Kujala 2008) to develop a spotted owl conservation planning model which can be used to design an array of habitat conservation network scenarios. To test this model we mapped a series of alternative spotted owl conservation network scenarios based on a series of rule-sets (*e.g.*, varying land ownership categories, the inclusion of existing reserves, identifying a specific amount of "habitat value" to include). The primary output of a Zonation analysis of the landscape is a "hierarchical ranking" of conservation priority of all cells or pixels in the landscape. Zonation allows analysts to incorporate species-specific factors such as dispersal capabilities and response to habitat fragmentation into the ranking of cells, and also allows the inclusion of factors such as land ownership and status into various evaluations. It is important to recognize that the maps produced by Zonation represent user-defined scenarios that were evaluated and compared in subsequent population modeling to test this modeling process; they do not represent decisions about the size or distribution of habitat conservation areas. While Zonation uses the term "reserve" to describe the conservation areas it identifies, this term does not dictate the types of management actions that could occur in those areas.

Zonation produces a hierarchical prioritization of the landscape based on the conservation value or "habitat value" of cells. A cell's habitat value is a function of its "base" value (*i.e.*, its RHS value) as well as the value of cells surrounding it. Thus, two cells of identical RHS may have different habitat value depending on how many other high, medium, and low value cells are nearby. The term habitat value therefore incorporates a larger spatial context than does RHS. Hierarchical, in this case, means that the most valuable five percent is also within the most valuable 10 percent; the top two percent is within the top five percent, and so on. Zonation uses minimization of marginal loss as the criterion to decide which cell is removed, and iteratively removes the least valuable cells from the landscape until no cells remain. The order of cell removal and its proportion of the total habitat value are recorded and can later be used to select any top fraction of cells or habitat value, the best 10 percent of cells or the top 10 percent of habitat value, for example, of the landscape.

To ensure that spotted owls and their habitat would be well-distributed throughout their range (one of the goals for recovery), Zonation analyses were conducted separately for each modeling region. This modeling region decision also had the impact of ensuring that conservation areas would be better distributed across the range of the species.

Zonation allows analysts to identify specific areas of the landscape that represent a particular percentage of the total estimated habitat value to the species. An important attribute of the Zonation algorithm is that it attempts to produce "efficient" solutions. That is, it prioritizes cells into units that maximize the habitat value per unit area within the solution (Figure C7). For example, in one Zonation scenario, 70% of the habitat value existed on ~40% of the landscape.

Figure C-7. *Hypothetical* relationship between total size of habitat conservation system (x-axis) and percentage of habitat value "captured" (y-axis). Theoretically, the only way to capture 100% of the habitat value is to have the entire area to be considered reserve (or all areas with value >0). For this example, the entire area is ~ 19 million ha. In this example, a reserve system that is ~4 million ha "captures" ~50% of the habitat value, one that is ~9 million ha captures ~75% of the habitat value, etc.



Because Zonation is spatially explicit, in a GIS environment the user can control several aspects of how the program evaluates the distribution of habitat value. This enables the program to emulate important aspects of the species' life history, landscape pattern of habitat, and desired attributes of a habitat conservation network.

Zonation's **Distribution Smoothing** function is a species-specific aggregation method that retains high-value areas (pixels) that are better-connected to others, resulting in a more compact solution. The user specifies the area or "smoothing kernel" within which Zonation averages or smooths habitat values, based on a two-dimensional habitat density calculation, in accordance with attributes of an organism's movement patterns or abilities, such as home range area. We compared kernel sizes corresponding to the core use area (800 m radius), median home range (2100 m), and median dispersal distance (27.7 km; Forsman *et al.* 2002). The main difference in the resulting solutions from these three different settings is that the results from the kernel estimated from dispersal distance or home range were less fine-grained than the results from the kernel value estimated from a core area. Given that we are estimating habitat conservation network scenarios at relatively large scales, the coarser-grained (home range-derived kernel values) maps provided more discrete areas as estimated networks, and thus we used the home range scale kernel size.

Zonation's **Cell Removal Method** function allows users to control the spatial pattern or "grain" of priority areas by specifying whether cell removal begins around the edges of the analysis area or at cells scattered across the analysis area. The idea behind the "Edge Removal" setting is that it is more likely to result in connectivity of higher-value areas within the more central areas of the landscape. However, because cell removal is limited to the perimeters of large landscapes, the Edge Removal option can result in large blocks containing extensive areas of unsuitable habitat such as interior valleys and high mountain peaks. The "Edge Removal with Add Edge Points" option allows the user to randomly distribute a specified number of edge points where cell removal occurs within large landscapes. This setting allows more flexibility than edge removal and provides a greater chance that interior areas of poor-suitability habitat will be removed from the solution, and results in more finely-grained pattern of priority areas. The "No Edge Removal" option does not predispose Zonation to start cell removal from any particular area or region, but removes the lowest value cells in the landscape first, then the next lowest, and so on. This results in very finely-grained prioritized areas (and very long computer run times). We conducted side-by-side comparisons and found that Add Edge Points and No Edge Removal end up with nearly identical solutions (~95% overlap in identifying the top 25% habitat value areas in the landscape). To develop a series of alternative habitat conservation networks, we selected Add Edge Points, distributing 2,000 edge points into each modeling region.

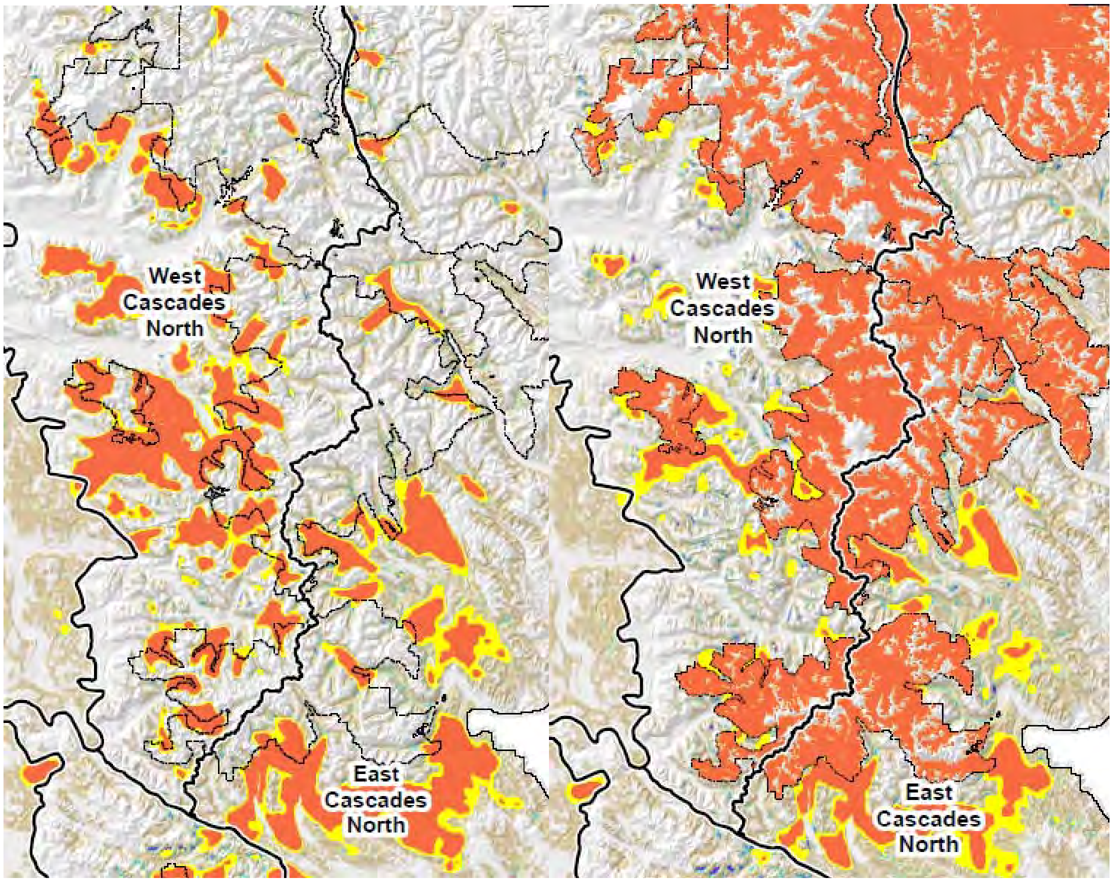
Exclusion Areas are areas that were excluded from the habitat suitability base maps prior to running Zonation. Examples are areas such as high elevation alpine areas as well as generally low elevation valley areas (*e.g.*, the Willamette Valley) that are considered incapable of supporting spotted owls. Including these areas in Zonation runs would give a false impression of habitat conservation block efficiency. That is, the algorithm would be able to remove large amounts of area (high elevation and valley areas) with no impact on the loss of spotted owl habitat value. Thus, we believed these areas should be masked out from the start. The GIS layer used to represent exclusion areas is the same one (mask) developed for the NWFP Monitoring Group (Davis and Dugger in press) and used in our MaxEnt modeling.

Selection of values for conservation value ranking: Zonation enables the user to specify the proportion of habitat value to display as maps of habitat conservation networks. Selection of the quantity of habitat value has a large influence on the size and distribution of habitat conservation networks. Because there is a near-infinite number of values that could be selected for evaluation, we compared results across a broad gradient of habitat values (20%, 30% 40%, 50%, 60%, 70%, and 80%), with the objective of identifying a smaller subset of reasonably diverse habitat conservation network scenarios for testing with the population model (see below). In addition, we compared habitat conservation networks from the above habitat values to the habitat values contained in existing networks such as spotted owl critical habitat (1992 and 2008) and the NWFP reserve network.

Precedence Masking allows the analyst to identify areas that must be or must not be included in the habitat conservation network. For example, existing protected areas such as Wilderness Areas and National Parks can be "forced" into the priority areas, regardless of their habitat value. Similarly, various land ownership categories can be "forced" out of priority areas. To accomplish this, the user identifies zones (land ownership, existing reserves, etc.) and ranks them by conservation priority (Zone 1, Zone 2, and so on) into a 'precedence mask'. In processing, Zonation removes the lowest value cells in Zone 1 first, , and continues by removing the next lowest value cell until all cells are removed in Zone 1 before moving on to Zone 2 and any potentially subsequent zones. Because the cells in Zone 2 are assigned a higher ranking, in terms of removal order, than those in Zone 1, they are disproportionately included in the solution. This process is repeated until all zones defined by the precedence mask have been fully evaluated. Zonation does not re-calculate or otherwise change the habitat value of a cell according to which zone it is in. Instead, identifying zones identifies discrete areas of the landscape that are to be given higher or lower priority of consideration for reasons other than the cells' habitat value.

The basis for precedence masking in Zonation is to allow factors such as land status to be incorporated into the landscape prioritization. For example, forcing existing National Parks and Wilderness Areas into habitat conservation networks would recognize that these areas exist as protected areas, and thus should be included in a habitat conservation networks regardless of their value to spotted owls. However, because we used Zonation to *help identify* areas estimated to provide the most conservation value for the spotted owl, we proceeded by first conducting an evaluation based purely on habitat value (unforced), and *then* evaluated how much overlap the resulting habitat conservation networks had with existing protected areas and other land designations or ownerships. Forcing existing reserves into priority areas will likely predispose Zonation to not find optimal solutions (*i.e.*, because some non-optimal areas are forced into the solution). For example, in areas such as the northern Cascades where high-value spotted owl habitat is relatively sparsely distributed, forcing Congressionally Reserved land allocations into priority areas resulted in an extremely inefficient network design (Figure C8).

Figure C-8. Comparison of Zonation 40% (orange) and 50% (yellow) solutions on all land ownerships (left) and with Congressional Reserves prioritized (right). Outlines of habitat conservation network solutions in the right frame correspond largely to National Park and National Forest boundaries.



After evaluating Zonation results employing a range of values for distributional smoothing, cell removal methods, ranking values, and land status and ownership prioritization, we selected habitat conservation network scenarios comprised of 30 percent, 50 percent, and 70 percent of habitat value as reference points. These scenarios sample along a gradient from somewhat smaller than the current habitat conservation network (NWFP) to a habitat conservation network approximately twice as large as the LSR network (Table C21). We recognize that the results of population modeling may indicate other Zonation scenarios that should or could be developed and tested (feedback loop in Figure C1). ***Also, it is important to recognize these scenarios are not recommendations for the specific size or location of habitat conservation blocks – they are only scenarios for the purpose of comparing to other scenarios to evaluate how they influence spotted owl population performance in the population simulation model.***

Settings and Values Used in Zonation

Distribution Smoothing: Home range area (2100 m radius)
Cell Removal Method: Add Edge points (2000 points/modeling region)
Exclusion Areas: Used NWFP non-capable habitat mask from NWFP Monitoring
Ranking Values: Used 30%, 50%, and 70% of habitat value
Precedence Masking: Land ownership scenarios evaluated include:

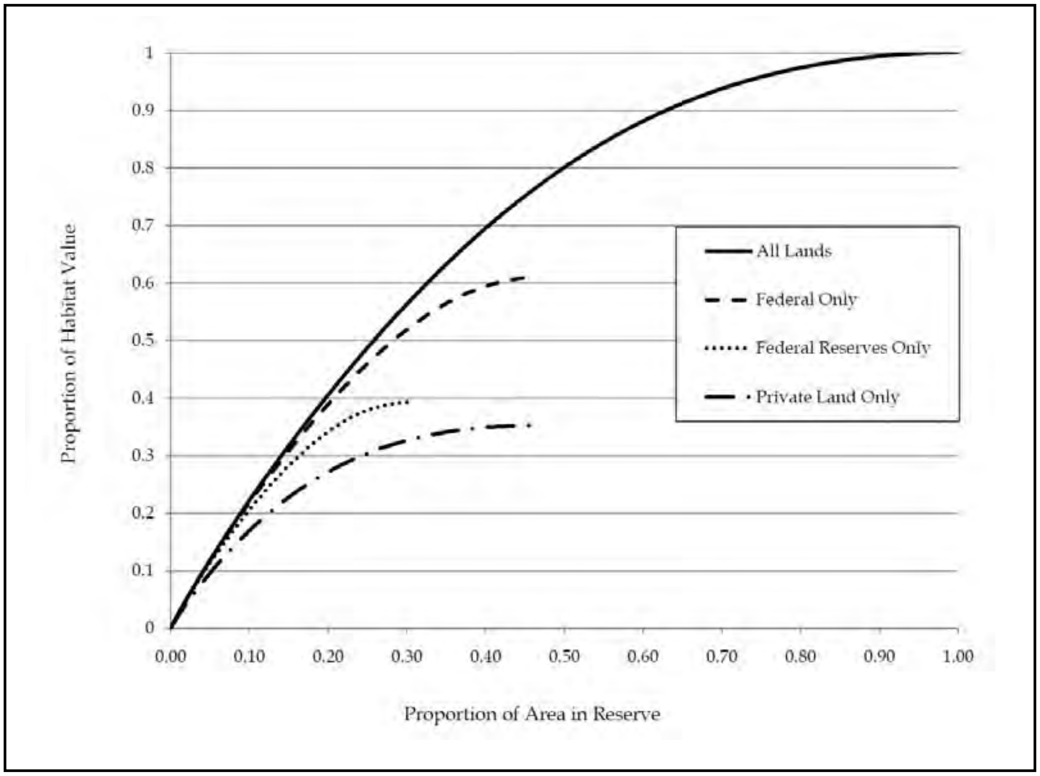
1) **No limit on inclusion** – No hierarchical masking - all land ownerships were allowed to be included and existing reserves were not forced into the priority areas. This scenario was chosen to represent the potential of the entire area to provide for spotted owls.

2) **Public lands only** – precedence masking was done such that non-public lands were removed first, and public lands were removed last. This had the effect of emphasizing reserves on public lands, but if the total amount of habitat value specified (*e.g.*, 50% or 70%) could not be acquired from cells in public lands, other lands could be included in the solution.

Maps depicting all of the initial Zonation scenarios are available at: http://www.fws.gov/oregonfwo/Species/Data/NorthernSpottedOwl/Recovery/Library/Default.aspx#Files
Once there, click on "maps" and "AppendixCMaps.pdf" The layers can be turned on and off using the "layers" button in the upper left-hand corner.

Zonation outputs can be used to compare the contributions of different land classes (ownership, reserve status, etc.) based on the area and proportion of habitat value of each land class. Figure C9 depicts the relationship between area (proportion of the spotted owl's range) that could, hypothetically, be included in a habitat conservation network and the amount of spotted owl habitat value that various habitat conservation networks would contain among four categories: 1) all lands, which represents no limits on ownerships in the habitat conservation network; 2) Federal lands only, with no priority for currently existing reserves; 3) Federal reserves only, this scenario includes only NWFP reserves (Congressional Reserves and LSRs); and 4) private lands only; no reserves on Federal lands. These depictions are for demonstrative purposes only, not recommendations. They are essentially asking what would be the conservation value to spotted owls if habitat conservation areas were restricted to various land ownership categories. For example, private lands constitute about 45 percent of the spotted owl's range and provide roughly 35 percent of the rangewide habitat value (RHS), whereas the NWFP reserve network provides 40 percent of rangewide habitat value on 30 percent of the area (Figure C9).

Figure C-9. Relationship between proportion of various land ownerships/categories (no restriction, Federal lands only, Federal reserves only, or private lands only) included in a habitat conservation network and proportion of spotted owl habitat value included in the habitat conservation network.



While Zonation outputs do not evaluate or predict potential spotted owl population sizes associated with different habitat conservation network scenarios, they nonetheless permit comparison of the sizes of existing reserve or conservation networks to possible habitat conservation areas, and enable additional comparisons to be made in a GIS environment. For example, Table C21 shows a comparison of network size, percent of spotted owl training locations from the habitat modeling that falls within various habitat conservation network scenarios, and percent of the top two Zonation habitat value ranks among 10 habitat conservation network scenarios. Table C22 shows the relationship the proportion of RHS bins within each of 20 Zonation and 4 non-Zonation habitat conservation network scenarios. The results show the efficiency with which Zonation selects high RHS areas.

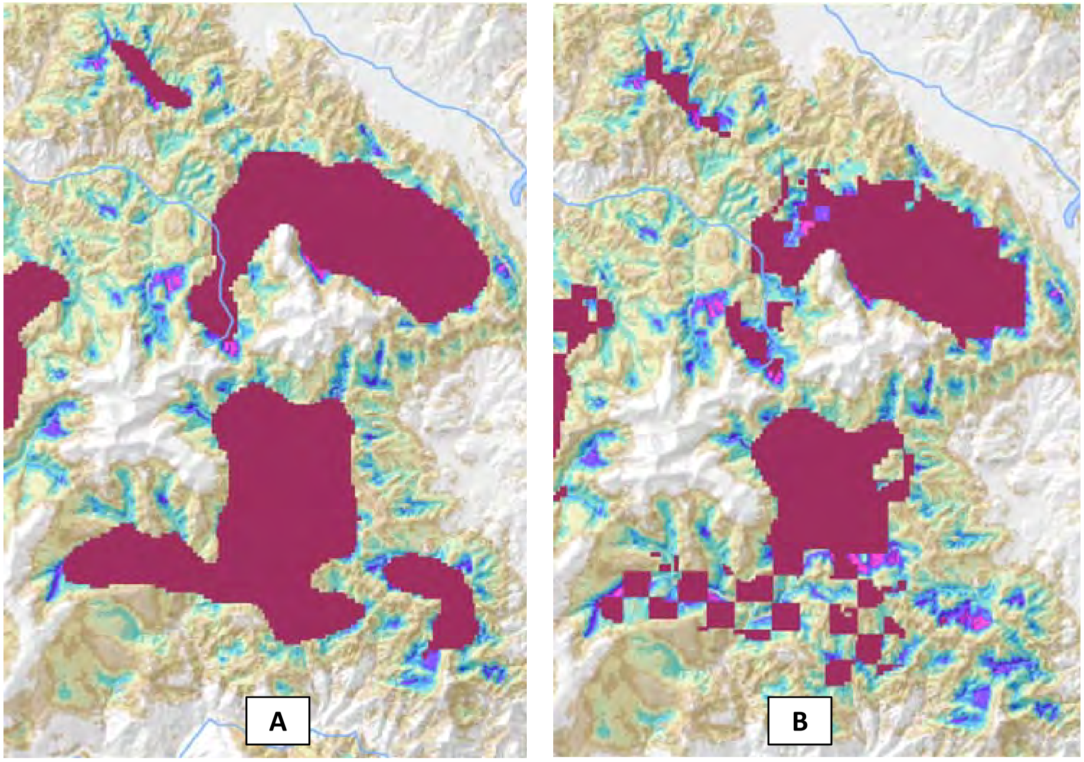
Table C-21. Comparison of area, percent of 1996 spotted owl sites used in model development, and percent of top 10% and 20% Zonation ranked habitat value for 10 spotted owl reserve scenarios.

Network scenario	Network scenario size (million hectares)	Percent of 1996 spotted owl sites	Percent of top 10% Zonation-ranked	Percent of top 25% Zonation-ranked
NWFP	6.63	46	56.7	55.2
MOCA	4.77	33	46.3	43.8
1992 Critical Habitat	5.75	44	57.3	55.4
2008 Critical Habitat	5.17	37	49.6	47.7
Z30 All lands	5.61	50	100	100
Z50 All lands	7.80	71	100	100
Z70 All lands	10.55	87	100	100
Z30 Public lands	5.57	51	94.9	91.3
Z50 Public lands	7.82	73	95.0	93.0
Z70 Public lands	11.24	88	98.9	98.0

Table C-22. Proportion of relative habitat suitability (RHS) bins represented among various habitat conservation network scenarios. Many more Zonation (Zall and Zpub) scenarios are presented in this table than in the remainder of the document. Zall = all lands available; public = Zpub lands prioritized in Zonation.

	Relative Habitat Suitability Bin									
Habitat Conservation Network Scenario	**0 - 10**	**10 - 20**	**20 - 30**	**30 - 40**	**40 - 50**	**50 - 60**	**60 - 70**	**70 - 80**	**80 - 90**	**90 - 100**
NWFP	0.22	0.26	0.31	0.36	0.41	0.46	0.51	0.57	0.63	0.58
MOCA	0.16	0.18	0.22	0.25	0.30	0.34	0.40	0.46	0.49	0.31
1992 Critical Habitat	0.17	0.22	0.28	0.33	0.38	0.44	0.50	0.57	0.66	0.57
2008 Critical Habitat	0.16	0.20	0.24	0.28	0.32	0.37	0.43	0.51	0.60	0.51
Z10all	0.00	0.00	0.02	0.03	0.07	0.16	0.33	0.54	0.70	0.89
Z10pub	0.00	0.01	0.02	0.04	0.08	0.16	0.30	0.51	0.68	0.83
Z20all	0.00	0.02	0.05	0.10	0.19	0.35	0.57	0.77	0.89	0.99
Z20pub	0.00	0.03	0.06	0.11	0.20	0.34	0.54	0.73	0.85	0.90
Z30all	0.01	0.05	0.11	0.20	0.33	0.53	0.74	0.89	0.95	1.00
Z30pub	0.01	0.06	0.13	0.21	0.34	0.51	0.70	0.83	0.90	0.91
Z40all	0.01	0.09	0.19	0.32	0.49	0.69	0.85	0.94	0.98	1.00
Z40pub	0.02	0.11	0.22	0.34	0.48	0.66	0.80	0.88	0.92	0.91
Z50all	0.02	0.15	0.30	0.46	0.63	0.81	0.92	0.98	0.99	1.00
Z50pub	0.04	0.21	0.35	0.47	0.61	0.75	0.85	0.90	0.92	0.91
Z60all	0.04	0.24	0.43	0.61	0.77	0.90	0.96	0.99	1.00	1.00
Z60pub	0.12	0.37	0.48	0.58	0.70	0.82	0.89	0.92	0.93	0.92
Z70all	0.08	0.38	0.59	0.75	0.87	0.95	0.99	1.00	1.00	1.00
Z70pub	0.25	0.47	0.59	0.70	0.81	0.90	0.94	0.97	0.98	1.00
Z80all	0.15	0.57	0.75	0.87	0.95	0.99	1.00	1.00	1.00	1.00
Z80pub	0.32	0.61	0.73	0.83	0.91	0.96	0.98	0.99	1.00	1.00
Z90all	0.31	0.80	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00
Z90pub	0.47	0.79	0.88	0.95	0.98	1.00	1.00	1.00	1.00	1.00
Z100all	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Z100pub	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Figure C-10. Example Zonation output map of the Mount Ashland, OR, area, depicting 30 percent of habitat value in red on all lands (A) and on Federal lands only (B).



Modeling Process Step 3 - Develop a spatially explicit spotted owl population model that reliably predicts relative responses of spotted owls to environmental conditions, and use it to test the effectiveness of habitat conservation network scenarios designed in step 2 in recovering the spotted owl. The simulations from this spotted owl population model are not meant to be precise estimates of what will occur in the future, but provide information on comparative trends predicted to occur under differing habitat conservation scenarios.

To meet this objective, the modeling team elected to use a spatially explicit, individual-based modeling approach. While other approaches such as population level population viability analysis (PVA) and metapopulation models have been used for evaluating spotted owl populations, we required an approach that enabled comparison of a wide range of spatially explicit conditions such as variation in habitat conservation networks. Dunning *et al.* (1995) wrote the following regarding spatially explicit population models:

> *"Spatial models, structured and parameterized according to a species' life history, allow one to explore the efficiency of various reserve designs. The models can be*

> *used to estimate the potential effects on a species' persistence by systematically varying factors such as the percentage of the landscape that is suitable habitat, and the size, shape, and spacing of habitat patches. The addition of marginal (i.e., sink) habitat to a reserve can be assessed for negative effects on a managed population (Pulliam and Danielson 1991). These exercises can be done on artificial landscape maps to explore general reserve design principles (Lamberson et al. 1992, 1994) or on GIS-based maps that incorporate land-use and ownership constraints (Murphy and Noon 1992, Noon and McKelvey 1992)."*

Individual-based models (IBMs) allow for the representation of ecological systems in a manner consistent with the way ecologists view such systems as operating. That is, emergent properties such as population increases or declines are the result of a series of effects and interactions operating at the scale of individuals. Individuals select habitat based on what is available to them, disperse as a function of their individual circumstance (age), compete for resources, etc.

Grimm and Railsback (2005) noted that IBMs need to be simple enough to be practical, but have enough resolution to capture essential structures and processes. The spotted owl is perhaps the most studied raptor in the world, and thus there exists a tremendous quantity and quality of data (*e.g.*, vital rates are evaluated in a meta-analysis for several long-term demographic study areas every 5 years; *e.g.*, Anthony *et al.* 2006, Forsman *et al.* (2011)); habitat selection (see review by Blakesley 2004) has been thoroughly evaluated; large numbers of individuals have been followed during dispersal (Forsman *et al.* 2002); among many other aspects of the species' ecology. The spotted owl is therefore ideally suited for spatially explicit IBM. Bart (1995), however, noted that the question "Does the model improve our ability to make decisions?" needs to be explicitly considered. The modeling team believes that the spatially explicit IBM HexSim, which is parameterized largely with empirically-derived values from spotted owl studies, improves our ability to make land management decisions, and therefore we have decided to use this approach.

The HexSim Model:

HexSim (Schumaker 2011) was designed to simulate a population's response to changing on-the-ground conditions by considering how those conditions influence an organism's survival, reproduction, and ability to move around a landscape. The modeling team developed a HexSim spotted owl scenario based on the most up-to-date demographic data available on spotted owls (Forsman *et al.* 2011), published information on spotted owl dispersal, and home range size as well as on parameters for which less empirical information was available (see below). Initially, the HexSim spotted owl model allows users to evaluate the efficacy of existing conservation strategies, under currently-estimated barred owl impacts and with currently-estimated habitat conditions, to meet recovery goals. Subsequently, the model serves as a consistent framework into which variation in spatial data layers (*e.g.*, reserve or conservation block boundaries, different assumptions about habitat conditions (RHS) inside and outside of reserves or blocks, different assumptions about RHS change on public versus private lands, and different assumptions about the impact of barred owls among modeling regions) can be introduced. Comparison of estimates of simulated spotted owl population performance estimates across the range of scenarios incorporating variation in habitat conservation network sizes, habitat trends, and barred owl influence, can inform evaluations of habitat conservation networks and other conservation measures designed to lead to spotted owl recovery.

In very general terms, we tried to design the model to answer the following questions: (1) Given current circumstances (reserves, habitat, barred owls, spotted owl demographic rates, etc.), is recovery of the spotted owl likely in the foreseeable future?; (2) Given current estimates of habitat, barred owls, and spotted owl demographics, is recovery of the spotted owl likely in the foreseeable future under different habitat conservation network scenarios?; and (3) To what degree would management of habitat and barred owls contribute to or detract from reaching spotted owl recovery goals under a range of habitat conservation networks and management scenarios? Evaluation and ranking of the population simulation results from the model obtained across a range of habitat conditions, barred owl effects, and conservation network scenarios, and comparison with established recovery criteria, should provide important insight into these questions. **The HexSim model is available at: www.epa.gov/hexsim.**

HexSim Overview:

HexSim is a spatially explicit, individual-based computer model designed for simulating terrestrial wildlife population dynamics and interactions. HexSim is a generic life history simulator; it is not specifically a spotted owl model. HexSim was designed to quantify the cumulative impacts to wildlife populations of multiple interacting stressors.

HexSim simulations are built around a user-defined life cycle. This life cycle is the principal mechanism driving all other model processing and data needs. Users develop the life cycle when initially setting up a simulation. The life cycle consists of a sequence of life history events that are selected from a list. This event list includes survival, reproduction, movement, resource acquisition, species interactions, and many other actions. Users can impose yearly, seasonal, daily, or other time cycles on the simulated population. Each event can work with all, or just a segment of a population, and events can be linked to static or dynamic spatial data layers. Each life cycle event has its own data requirements. Simple scenarios may use few events with minimal parameterization and little spatial data. When more complexity is warranted, HexSim allows a great deal of data and behavior to be added to its simulations.

HexSim scenarios include descriptions of one or more populations, spatial data needs, life cycle definitions, event data, and basic simulation criteria such as the number of replicates and time steps. Each population is composed of individuals, and individuals have traits that can change probabilistically, or based on age, resource availability, disturbance, competition, etc. HexSim also includes optional genetics and heritable traits (though these were not used for the spotted owl model). The use of traits allows members of the simulated population to have unique properties that change in time and space. Traits also allow populations to be segregated into classes, such as males and females, fitness categories, disease categories, etc. Combinations of trait values can be used to stratify events such as survival, reproduction, movement, etc.

Traits are a fundamental part of HexSim scenarios. Traits can be used to control most life cycle events because events can be stratified by trait combinations. For example, a movement event might be set up to operate only on a fledgling stage class. Or a survival event might assign mortalities based on the values of a trait that reflects resource acquisition. In addition, one trait's values can also be influenced by multiple other traits, which makes it possible to set up stressor interactions and complex feedback loops. Traits can also be used to capture interactions such as parasitism, competition, mutualism, breeding, etc.

Overview of the Spotted Owl Scenario

Because females are the most influential sex in terms of population dynamics, the HexSim spotted owl scenario is a females-only model. The life cycle is simple except that the acquisition of resources by individual spotted owls is spatially stratified, and thus somewhat complex. The scenario depends on two static spatial data layers; one representing the distribution and relative suitability of habitat, and an "exclusion layer" to prevent spotted owls from moving out into the Pacific Ocean, or into areas outside of their geographic range .

An additional layer comprised of the boundaries of both the modeling regions and demographic study areas (DSAs were used to generate HexSim reports (*i.e.*, we extracted information about spotted owls in DSAs as well as within modeling regions and for all modeling regions overall), had no effect on the simulated population. All spatial data layers are converted to grids consisting of 86.6- ha hexagons. To the extent possible, simulation parameter values were estimated based on published empirical data.

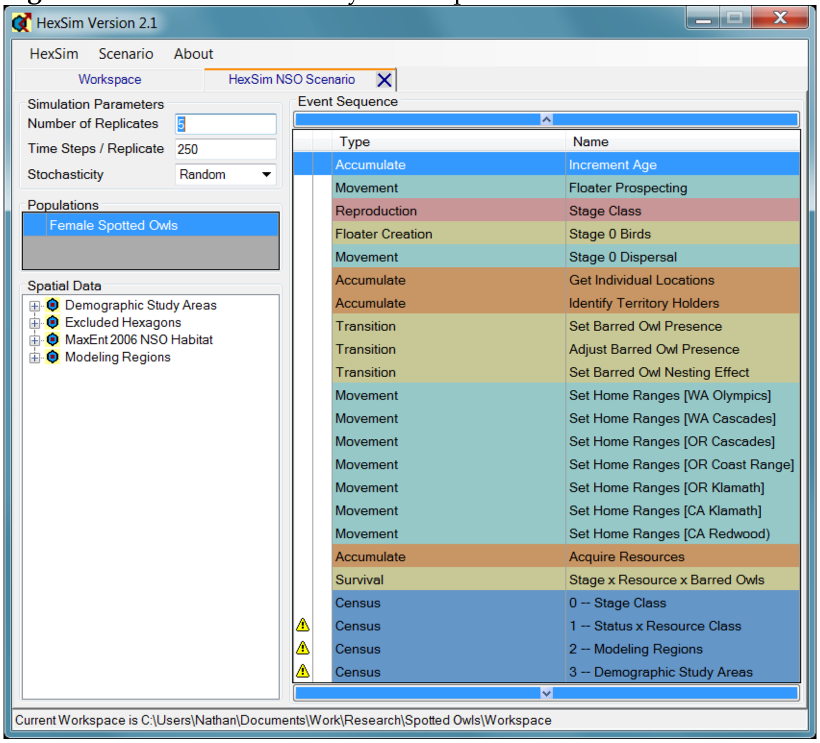
The HexSim simulations began with 10,000 spotted owls being virtually introduced into the study landscape. The initial population's ages were randomly distributed, and they were placed preferentially into areas of high RHS. Once initialization was complete, individual spotted owls were subjected to the event cycle shown in Figure C11. The year begins with each individual becoming a year older. Next, floaters (spotted owls without a territory) prospect for a territory. This is followed by reproduction and fledgling dispersal. Dispersing fledglings do not prospect for a territory.

We assumed that the RHS map developed in MaxEnt was a proxy for the amount of resources available to spotted owls within each hexagon. Because nesting spotted owls showed relatively strong selection for some RHS categories and against others (see Figure C5), we reasoned that this selection was based on a combination of factors (including, but not limited to, those we included as covariates in our models) that influence spotted owl natural selection. That is, spotted owls select some areas and avoid other areas in order to maximize their survival and reproductive success. Spatially-explicit data on competitors, prey, predators and other factors influencing spotted owls were unavailable, and thus we were unable to incorporate more direct measures of resource quantity and quality.

In the HexSim Spotted Owl Scenario, a primary influence of RHS on simulated spotted owl populations occurs in territory acquisition (occupancy). To the extent that some areas aren't selected by spotted owls (or disproportionately selected against), habitat suitability acts to limit survival and reproduction (*i.e.*, spotted owls don't survive or reproduce in areas that they don't occupy). Subsequent to territory establishment, resource acquisition (RHS values) determines the resource class a spotted owl is placed in, which influences survival rates. Reproduction was not influenced by resource acquisition, and thus was not influenced by habitat quality. Individual studies (*e.g.*, Franklin *et al*. 2000) and meta-analyses have reported influences of habitat on survival and in some cases fecundity (see Forsman *et al*. 2011).

We recognized the importance of dispersal and habitats used by dispersing spotted owls in developing habitat conservation planning models. However, relatively little is known about the characteristics of areas used by dispersing spotted owls. In the spotted owl modeling effort, the modeling team therefore elected not to define or attempt to model dispersal habitat, but instead to rely on reasonable assumptions about the influence of relative habitat suitability (for nesting) on successful dispersal. Success (survival) of spotted owls dispersing through variable landscapes may be influenced by factors similar to those affecting territorial spotted owls (*e.g.* availability of prey, cover from predation, thermal stress) albeit at a different scale. Because the RHS values generated by MaxEnt retain the full gradient of habitat suitability (*i.e.* not 'thresholded' or categorized), it is reasonable to assume that relative habitat suitability is correlated with relative success of dispersal occurring in those areas (pixels). In HexSim, dispersing spotted owls are allowed to disperse through the full range of RHS values, with some degree of repulsion to the lowest RHS values.

Figure C-11. HexSim event cycle for spotted owls.



After floater spotted owls finish prospecting for territories, the modeling region they are in is recorded. Then the determination of whether each territorial spotted owl is in the presence of a barred owl is made probabilistically, with the probability of being in the presence of a barred owl dependent on the modeling region (Table C25). The region-specific probabilities for spotted owl exposure to barred owls were based on the proportion of spotted owl territories where barred owls were detected each year on the 11 DSAs (see Appendix B; Forsman *et al*. 2011). This decision is only made once per "bird-territory" (*i.e.*, once the decision is made for an individual spotted owl at a territory, the barred owl presence/absence is fixed for that territory until another spotted owl takes over the territory). All non-territorial spotted owls are placed in an 'undetermined status' category until they obtain a territory. A newly territorial spotted owl that has this undetermined status is assigned a "barred owl present" or "barred owl absent" status, based on the barred owl encounter probability for that modeling region.

Next, spotted owls that have the "barred owl present" status are placed in either a "*nesting normal*" or "*nesting halted*" class. At present, every spotted owl is placed into the *nesting normal* class. If spotted owls were assigned to the *nesting halted* class, they would not reproduce. Unlike the barred owl presence/absence trait described above, the *nesting normal* vs. *nesting halted* decision could be revisited every year, for every territorial spotted owl. Spotted owl floaters do not reproduce, so although they are always assigned to the *nesting normal* category, this has no impact on the simulation results. We mention these features (even when they aren't used) that were built into the HexSim Spotted Owl Scenario model to show how the model can adapt to and incorporate new information when it becomes available.

In the HexSim simulation, barred owls affect spotted owls through survival only. However, the simulation has been developed to facilitate a barred owl impact on spotted owl reproduction. This feature has not yet been used. It would also be possible to have barred owls impact habitat selection by spotted owls, or site fidelity. Neither of these processes has been implemented. Reproductive rates were obtained from Table 3 of Forsman *et al*. (2011). Those estimates were for time periods as long as 1985 to 2008 and as short as 1992 to 2008. It is generally agreed that barred owl populations have increased in most areas of the spotted owl's range over that time. Thus, to the degree that barred owls have an influence on fecundity, that influence is incorporated into these estimates.

Spotted owl reproduction is stratified by both stage class and nesting status (see above). Spotted owls that are in the *nesting halted* class have 100% probability of producing a clutch of size 0. Otherwise, the reproductive rates vary by stage class.

Spotted owl survival is stratified by barred owl presence, stage class, and resource class. Spotted owls in the barred owl present class have lower survival rates. Those in the barred owl absent, or undetermined classes, have higher survival rates.

At present, barred owls are not explicitly simulated, but are instead captured probabilistically. Accounting for barred owl impacts on spotted owl habitat selection or site fidelity would require that barred owls be actually located on the simulated landscape, and possibly even fully simulated within HexSim. The modeling team felt that sufficient data did not exist range-wide to permit either option to be incorporated into the current simulations. When such data become available, they can be integrated into the framework we have developed.

Next, each spotted owl establishes a home range. The simulated spotted owls have small defended territories, but large overlapping home ranges. Home range size varies with modeling region. The spotted owls extract resources from their home ranges, and thus they experience competition for resources from conspecifics. Finally, resource acquisition and survival are simulated. Survival varies based on stage class, resource acquisition class, and exposure to barred owls.

Home range sizes were set to the mean of the available regional-specific estimates (see summary in Schilling 2009). Spotted owl survival rates were based on study area-specific estimates from Forsman *et al*. (2011), with adjustment for the impact of barred owls across all study areas as calculated from the survival meta-analysis model containing an additive barred owl effect, also from Forsman *et al.* (2011).

The Population Parameters

Three distinct component groups were involved in the specification of the HexSim spotted owl population. These involved a set of basic properties, the definition of several different population traits, and finally the establishment of rules for the spotted owl's use of space and resource needs. The basic properties were used to establish an initial population size of 10,000 spotted owls, and to define an exclusion layer. Individuals were initially placed into the best hexagons in the simulation landscape, but only one spotted owl was allowed per hexagon.

Seven traits were created as part of the spotted owl population definition. These traits track stage class, location (modeling region and possibly DSA), resource class, territory status (territorial vs. floater), exposure to barred owls, and barred owl impacts on spotted owl nesting. Table C23 shows each possible trait value.

The simulated spotted owls produced each year begin life at age zero, and stage class zero. Each year they transition into the next stage class. At age 3 they reach stage class three, which is the terminal stage class. The spotted owls always belong to one of three resource classes, depending on the amount of resources they are able to acquire from their home range. Resources are a function of the mean RHS of hexagons, derived from the MaxEnt models (see above). Spotted owls that acquire 2/3 or more of their resource target are placed in the high resource class. Those that attain less than 1/3 of their resource target are placed into the low resource class. All other spotted owls are placed into the medium resource class. Resource targets vary by modeling region, and are described below.

The territory status trait is used to record whether individual spotted owls own a territory, or are floaters. The barred owl presence trait categorizes individual spotted owls as being exposed, or unexposed, to a barred owl. This decision is made once for each territorial spotted owl. The barred owl nesting effect trait is used to assign a probability that exposure to a barred owl will cause a spotted owl to avoid nesting. This evaluation is repeated every year for every spotted owl.

Table C-23. Spotted owl scenario traits and value categories.

Trait	Values
Stage Class	Stage 0
	Stage 1
	Stage 2
	Stage 3
Resource Class	Low
	Medium
	High
Territory Status	Floater
	Territorial
Barred Owl Presence	Pending
	Absent
	Present
Barred Owl Nesting Effect	Normal
	Halted

Trait	Values
Modeling Region	North Coast Olympics
	Oregon Coast
	East Cascades South
	East Cascades North
	West Cascades North
	West Cascades Central
	West Cascades South
	Klamath East
	Klamath West
	Inner-California Coast Range
	Redwood Coast

Trait	Values
DSA	Cle Elum
	Coast Ranges
	HJ Andrews
	Klamath
	Olympic
	Rainier
	South Cascades
	Tyee
	Warm Springs
	Wenatchee
	Hoopa
	Marin
	NW California
	Simpson

The modeling region and demographic study area traits are used to track individual spotted owl locations. The 11 modeling regions are space-filling and non-overlapping. Each individual spotted owl occupies one modeling region at any one time. If a spotted owl territory spanned multiple modeling regions, it was assigned to the region in which the majority of its territory hexagons fell. The demographic study areas (DSAs) take up just a fraction of the landscape. So at any moment most spotted owls will not be in a DSA. Resource targets (explained below) and home range size vary by modeling region.

The population parameters also control individual's use of space. The simulated spotted owls had territory sizes of no more than three 86.6-hectare hexagons. This territory size represents a reasonable approximation of a spotted owl core area (see discussion of spatial scale above). Hexagons had to have at least a score of 35 (out of 90 possible) to be usable in forming a territory. We decided on a minimum score of 35 after evaluating the scores of hexagons overlaid on 3,790 spotted owl nest sites. We evaluated the score for the focal hexagon (the one in which the nest resided), the second, and third closest hexagons, as well as the mean scores of the first, second, and third hexagons. More than 75% of the nest sites were in hexagons with scores >35. Similarly, 73% of the spotted owl sites had a mean score >35 for the focal, second, and third closest hexagons. Although other scores might be reasonable, we reasoned that increasing the score would unreasonably inhibit settlement on suitable areas, whereas decreasing the score would result in unrealistic densities in areas with relatively low RHS. Territory size had little significance for the simulated population dynamics, as the spotted owls derive resources from their home ranges. The territories served as a core area around which home ranges could be constructed. Territories, in the HexSim simulations, were exclusively used areas, whereas the remainder of the home range area could overlap with that of neighboring spotted owls.

Each simulated spotted owl has a resource target, which controlled how much resource it must have access to in order to be placed into the highest resource class. The resource targets vary by modeling region. Spotted owls that acquire 2/3 or more of their resource target are placed into the high resource acquisition class. Those that attain less than 1/3 of their resource acquisition target are placed into the low resource acquisition class. All other spotted owls end up in the medium resource acquisition class. The resource targets are listed in Table C24.

Table C-24. Estimated resource targets based on RHS values at 3,790 spotted owl locations.

Modeling Region	Home Range Size ha (# hexagons)	Resource Target
North Coast Olympics	11,052 (128)	1250
East Cascades North	7,258 (84)	1000
West Cascades North	7,258 (84)	1250
West Cascades Central	7,258 (84)	1250
Oregon Coast	4,123 (48)	375
West Cascades South	3,949 (46)	375
Inner CA Coast Range	3,165 (37)	375
East Cascades South	3,033 (35)	750
Klamath East	3,033 (35)	375
Klamath West	3,033 (35)	375
Redwood Coast	1,173 (14)	250

The Event Sequence

There are 23 events in the HexSim spotted owl scenario. Not all of these events modify the population, and some have similar or related functions. These events are described in turn below. Each event is listed by type (*e.g.*, movement) and specific name (in square brackets).

Accumulate [Increment Age]

This event makes each individual one year older. As a result, stage 0 individuals will move into stage 1, stage 1 individuals will move into stage 2, and stage 2 individuals will move into stage 3.

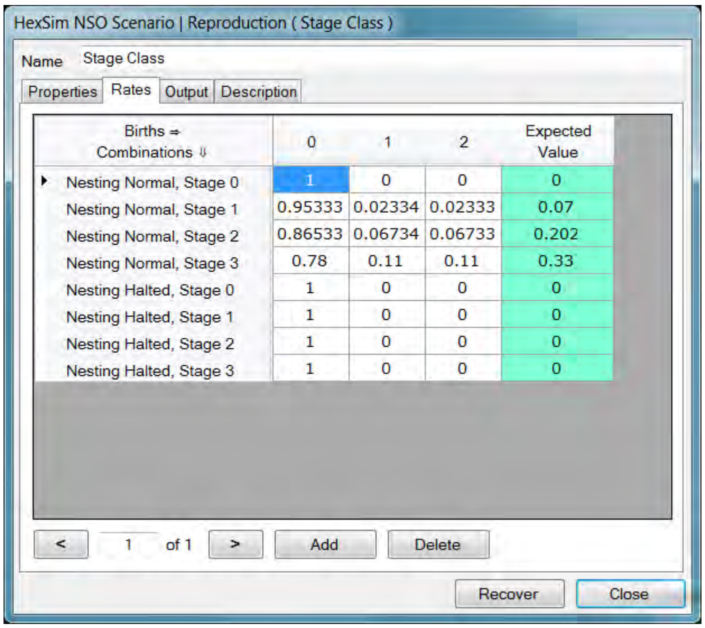
Movement [Floater Prospecting]

HexSim's movement event controls dispersal and prospecting behavior. But any one event may do either or both. This event only performs prospecting, but it does so for all spotted owls that are floaters (*i.e.*, those who do not own a territory). Individual floaters are allowed to search an area of up to 500 86.6 - hectare hexagons in search of a vacant area from which a territory could be constructed. The search strategy is imperfectly informed by resource availability. That is, spotted owls tended to construct home ranges from high RHS hexagons, but they did not select the best sites with certainty.

Reproduction [Stage Class]

HexSim's reproduction module is parameterized by assigning probabilities to each possible clutch size. Reproduction is also stratified by traits. In this case, the maximum clutch size was set to 2, and reproduction rates were varied by stage class, and based on the Barred Owl Nesting Effect trait values. The reproductive rates used in the event are shown in Figure C12. The unperturbed (by barred owls) reproductive rates were obtained from Table 3 of Forsman *et al.* (2011).

Figure C-12. Estimated spotted owl reproductive rates by stage class.



Births ⇒ Combinations ⇓	0	1	2	Expected Value
Nesting Normal, Stage 0	1	0	0	0
Nesting Normal, Stage 1	0.95333	0.02334	0.02333	0.07
Nesting Normal, Stage 2	0.86533	0.06734	0.06733	0.202
Nesting Normal, Stage 3	0.78	0.11	0.11	0.33
Nesting Halted, Stage 0	1	0	0	0
Nesting Halted, Stage 1	1	0	0	0
Nesting Halted, Stage 2	1	0	0	0
Nesting Halted, Stage 3	1	0	0	0

The column headings in Figure C12 correspond to clutch sizes. The rows contain all of the permutations of the two trait values. The right-most column shows the expected values, which, in a females-only model, equal fecundities. Individuals whose nesting has been halted by a barred owl are assigned a 100% probability of having a clutch size of zero. The same is true for stage class 0 individuals. Otherwise, the probabilities of having clutches of size 1 and 2 were set as equal as possible, to whatever value was necessary to produce the fecundity values reported in Forsman *et al.* (2011). Finally, the probability of having a clutch of size zero was set so that each row summed to exactly 1.0.

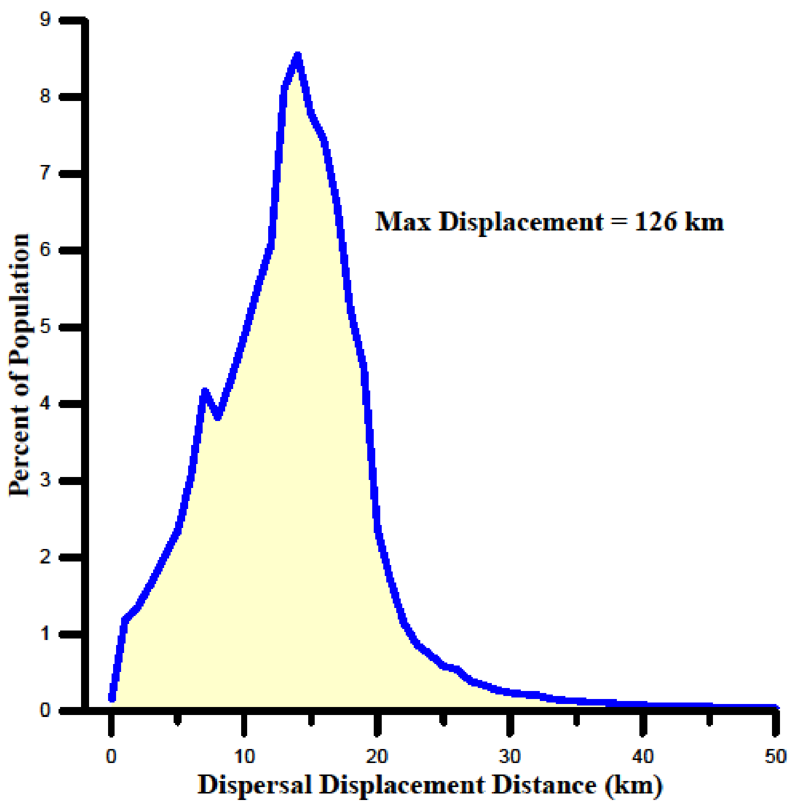
Floater Creation [Stage 0 Birds]

In HexSim, recruits become a co-owner of their mother's territory. They will disperse from their natal territory when forced to by a floater creation event at the end of Year 1. This floater creation event removes all stage 0 birds from their natal groups. These animals disperse in the next event.

Movement [Stage 0 Dispersal]

HexSim's movement event controls dispersal and prospecting behavior. Any one movement event may do either or both. This event strictly performs dispersal for stage class 0 spotted owls. The dispersing birds move with moderate auto-correlation until they encounter enough resource that a territory may be constructed (see above). Territory construction does not actually take place at this time. The dispersers are limited to moving 250 km total distance. The birds have a slight repulsion to lower RHS areas of the landscape, but are not prevented from moving into zero-valued hexagons. Figure C13 shows an example of the distribution of simulated dispersal displacement distances produced by this movement event. These data were gathered from five replicate simulations, for years 100-250. The total number of dispersal events in this period was approximately 852,000. The shape of this frequency distribution will change if either the rules for stopping (3 territory-quality hexagons encountered in succession) or the degree of autocorrelation (50%) are modified.

Figure C-13. Distribution of 852,000 simulated Year 1 dispersal distances.



Accumulate [Get Individual Locations]

This event records which modeling region each spotted owl is in. If an individual falls within a demographic study area then this event will captures that information, as well.

Accumulate [Identify Territory Holders]

This event updates a trait that segregates into two classes: floaters and territory-holders.

Transition [Set Barred Owl Presence]

This transition event assigns values to the Barred Owl Presence trait. Each modeling region was assigned a separate barred owl encounter probability, based on field data illustrating the proportion of spotted owl territories on DSAs where a barred owl was documented each year (Appendix B; Forsman *et al.* 2011). Using these probabilities, this event places each territorial spotted owl into one of two classes. The classes indicate whether the spotted owl is exposed to a barred owl or not. Once this determination is made for a specific spotted owl, it is not changed until that spotted owl dies or otherwise leaves the territory. The probabilities that were used are shown in Table C25.

Table C-25. Barred owl encounter probabilities estimated from Forsman *et al.* (2011).

Region	Encounter Probability
North Coast Olympics	0.505
East Cascades North	0.296
West Cascades North	0.320
West Cascades Central	0.320
Oregon Coast	0.710
West Cascades South	0.364
Inner CA Coast Range	0.213
East Cascades South	0.180
Klamath East	0.245
Klamath West	0.315
Redwood Coast	0.205

Transition [Adjust Barred Owl Presence]

This transition event simply removes the barred owl presence designation from floater spotted owls. This way, if a spotted owl was to give up its territory and leave, it would not retain its barred owl presence / absence designation. In the present scenario territorial spotted owls have perfect site fidelity, so this event has no impact.

Transition [Set Barred Owl Nesting Effect]

This transition event uses the barred owl presence trait to set the value of a barred owl nesting effect trait. This allows spotted owls that are exposed to a barred owl to be placed into a non-nesting category with some probability. As this probability increases from zero, barred owls have an increasingly strong influence over spotted owl nesting rates, and hence reproductive output. In these simulations, the barred owl effect on spotted owl nesting was set to zero.

Movement [Set Home Ranges]

Eight different movement events are used to set home range sizes differently based on modeling region. These movement events only establish home ranges for territorial spotted owls. The home range sizes used are listed in Table C26. Spotted owls acquire resources from their home ranges, and the home ranges for different birds may overlap; territories however, cannot overlap. This results in competition among spotted owls for resources. Spotted owl home ranges were always contiguous, but their shapes were not constrained. The home range sizes used were developed from the published results of many field studies, and were compiled by the modeling team.

Table C-26. Spotted owl home range sizes used in population modeling.

Region	Home Range Size (in hexagons)
North Coast Olympics	128
East Cascades North	84
West Cascades North	84
West Cascades Central	84
Oregon Coast	48
West Cascades South	46
Inner CA Coast Range	37
East Cascades South	35
Klamath East	35
Klamath West	35
Redwood Coast	14

Accumulate [Acquire Resources]

This "accumulate event" assigns individual spotted owls to a resource class, based on how much resource they acquire from their home ranges. Habitat suitability and quantity, plus competition with conspecifics will dictate what resource class individual spotted owls end up in.

Survival [Stage x Resource x Barred Owls]

The survival event is stratified by stage class, resource class, and exposure to barred owls (which is binary). The survival rates that were used are shown in Table C27. The derivation of these values is discussed in a separate section below.

Census [x 4]

Four census events are used to track the number of spotted owls by stage class, resource class, modeling region, and demographic study area.

Table C-27. Estimated survival rates of spotted owl based on stage class, resource class, and barred owl effect.

Without Barred Owls			With Barred Owls		
Stage Class	**Resource Class**	**Survival Rate**	**Stage Class**	**Resource Class**	**Survival Rate**
Stage 0	Low	0.366	Stage 0	Low	0.28
	Medium	0.499		Medium	0.413
	High	0.632		High	0.546
Stage 1	Low	0.544	Stage 1	Low	0.458
	Medium	0.718		Medium	0.632
	High	0.795		High	0.709
Stage 2	Low	0.676	Stage 2	Low	0.590
	Medium	0.811		Medium	0.725
	High	0.866		High	0.780
Stage 3	Low	0.819	Stage 3	Low	0.733
	Medium	0.849		Medium	0.763
	High	0.865		High	0.779

Spatial Data

The Baseline HexSim spotted owl scenario uses four different map files. All four maps are static (they do not change with time), and each is made up from 538,395 hexagons arranged in 1430 rows and 377 columns. Individual hexagons are 1000 meters in diameter, and 86.6 hectares in area. The spatial data were developed by sampling raster imagery, using a tool that is built into the HexSim model. The sampling process involves intersecting a grid of hexagonal cells with a raster image, and then computing a per-hexagon mean from a series of weights assigned to the land cover classes present in the raster data.

The habitat map (*MaxEnt 2006 NSO Habitat)* depicts spotted owl RHS values developed using MaxEnt in Step 1 (see above). In HexSim, each pixel was assigned a weight equal to its RHS score. Pixel scores ranged between zero and 97. Thus when the HexSim RHS map was constructed from this raster file, the largest possible hexagon score was 97.00; this upper limit was never realized because each hexagon’s value represented an average of the pixels underneath it. The hexagons in the HexSim RHS map vary between 0.00 and 90.37. Hexagon scores were assumed to be proxies for the value of resources available to NSOs within the hexagon.

The habitat map (*MaxEnt 2006 NSO Habitat)* captures spotted owl resource quality, and was derived from RHS values developed using MaxEnt in Step 1 (see above). In HexSim, each land cover class was assigned a weight equal to its category ID. The category IDs ranged between zero and 97. Thus when the HexSim resource quality map was constructed from this raster file, the best possible hexagon score was 97.00; this upper limit was never realized because each hexagon's value represented an average of the pixels underneath it. The hexagons in the HexSim resource quality map vary between 0.00 and 90.37.

A map delineating the study area (*Excluded Hexagons)* was binary, with ones being assigned to each hexagon within the range of the spotted owl, and zeros elsewhere. Simulated spotted owls were not allowed to move into hexagons that were zero-valued in this map. This map included boundaries to the study area, such as the Pacific Ocean and other areas outside of spotted owl's range, or outside our area of inquiry (*e.g.*, the spotted owl's range in British Columbia).

The final two maps depict the locations of the modeling regions and DSAs. The map called *Modeling Regions* breaks the range of the spotted owl up into 11 different regions. This map was used to identify which region individual spotted owls occupied, because each modeling region had different resource requirements and home range sizes. Similarly, a map called D*emographic Study Areas* indicates the locations of 14 different DSAs.

Survival Rates

The survival event is stratified by stage class, resource class, and exposure to barred owls. To begin with, 9 survival rates (estimated apparent survival) were derived from Table 12 in Forsman *et al.* (2011). Because true adult survival is unknown we made the assumption that apparent adult survival is equal to, or a reliable surrogate for, true adult survival. These rates corresponded to the three oldest stage classes x 3 resource classes. Forsman *et al.* (2011) provided stage class-specific survival estimates for each of 11 DSAs. For each study area and stage class, mean apparent survival values for males and females were provided. We computed the mean of each pair and identified the smallest and largest of these mean values. For any given stage class, the smallest mean value was assigned to individuals in the low resource class. Likewise, the largest stage-specific mean value was assigned to individuals in the high resource class. The stage-specific survival rates for individuals in the medium resource class were set equal to the mean taken over all of the survival estimates present in Table 12 of Forsman *et. al* (2011) for that stage class. Through this process survival rates were obtained for stage 1-3 spotted owls in all three resource classes.

Stage class 0 survival estimates were taken from Franklin *et al.* (1999: 27-28). This is the final report titled "Range-wide status and trends in northern spotted owl populations" that was written after a major workshop held in Corvallis, Oregon, in 1999 to estimate demographic rates of the subspecies. The estimates of juvenile survival rates for three study areas from banding studies were adjusted to compensate for emigration rates, based on radio telemetry studies conducted by Eric Forsman (unpublished data). Mean, minimum and maximum juvenile survival rates were taken from this reference and used in the model. The mean value for Stage class zero was set to the midpoint between the minimum and maximum value.

Finally, survival rates were varied based on the presence or absence of barred owls, and the magnitude of their effect was based on the best meta-analysis model for survival with an additive barred owl covariate across all DSAs from Forsman *et al.* (2011). These values were stratified by both stage class and resource class.

Evaluation of Model Calibration

The HexSim model simulated a females-only population of spotted owls throughout their range. The principal metric used to evaluate the model was the simulated population size. The numbers of female spotted owls were tracked range-wide, per modeling region, and also per DSA. The model's performance was assessed by comparing all three measures of simulated population size to field data. We compared simulation year 50 HexSim estimates to field data for 8 DSAs. For this comparison, we used the HexSim simulations during which barred owl impacts were inserted during year (or time-step) 40. After barred owl impacts were incorporated at time-step 40, they remained constant for the remaining 210 time-steps. For these simulations we did not attempt to back-cast barred owl "invasion" dynamics. Our "scenario", therefore, predisposed barred owl impacts to occur all at once, not incremented. We determined by inspection that simulation year 50 most closely represented the present day.

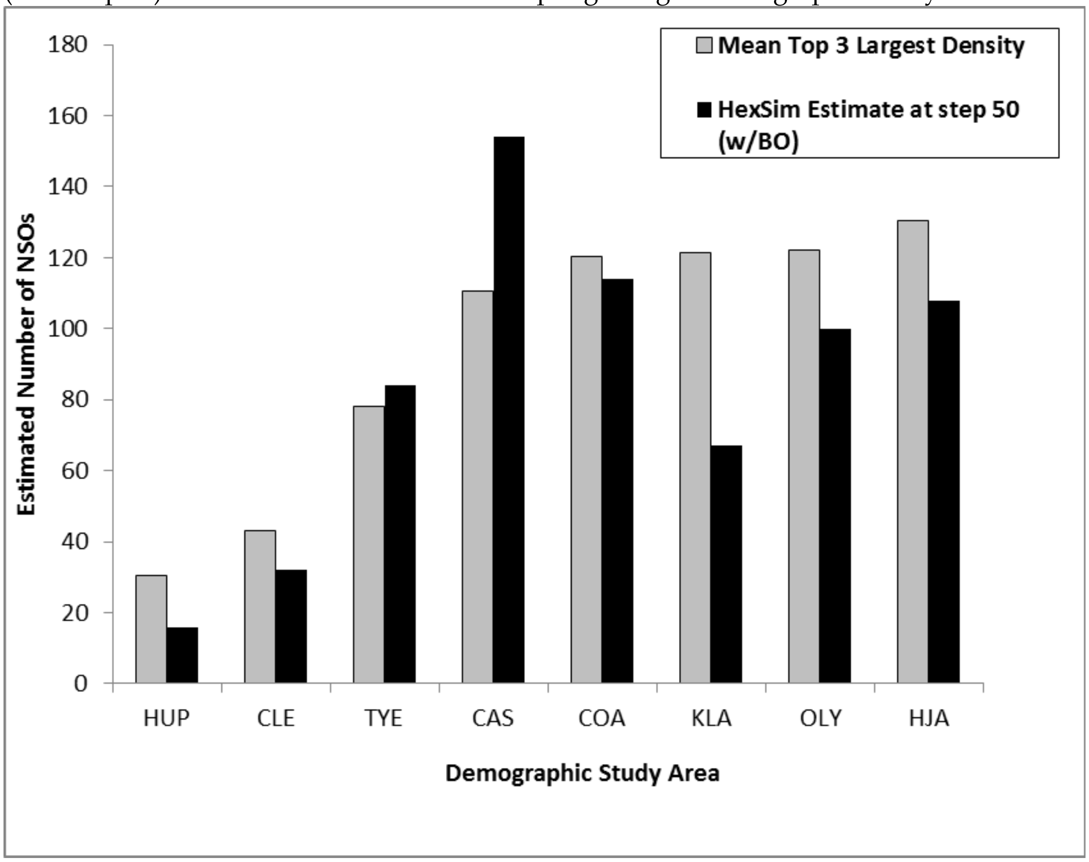
HexSim simulations are stochastic, and to quantify population size, the mean was taken from 5 replicate simulations. Each simulation was 250 time-steps (years) in duration. This does not suggest that spotted owl population sizes were forecasted 250 years into the future. Doing so would at minimum require performing the simulations with a series of maps illustrating habitat changes through time. In contrast, these initial simulations were performed with static data from year 0 to year 40, then (if changes were introduced) changes in barred owl or RHS were introduced and remained static until year 250. The length of the simulations (250 years) simply allowed a steady-state population size and trend to be estimated.

Most, but not all DSAs had data that could be used to approximate density of female spotted owls. Additionally, not all DSAs functioned as "density study areas", and they did not always sample spotted owls identically, nor present data consistently (among DSAs at least). Nonetheless, most DSA annual reports contained tables of historic data which revealed trends. For calibration purposes data from the following DSAs were used: Cle-Elum, Olympic, Oregon Coast, HJ Andrews, Tyee, Klamath, Cascades, and Hoopa. Several calibration iterations were performed by varying resource requirements one modeling region at a time.

Discrepancies in the fit between simulated and observed population size were addressed by varying the resource targets (described above). The resource targets were specified on a modeling-region basis, and they indicated how much resource an individual spotted owl living in a specific region would attempt to acquire. The resource targets were a proxy for resource availability, which varied from region to region and was not fully captured in the RHS maps. As the resource targets increased, individual spotted owl's needs for resources increased. An inability to acquire sufficient resources could cause spotted owls to drop into the lower resource acquisition classes, which would then lower their survival rates.

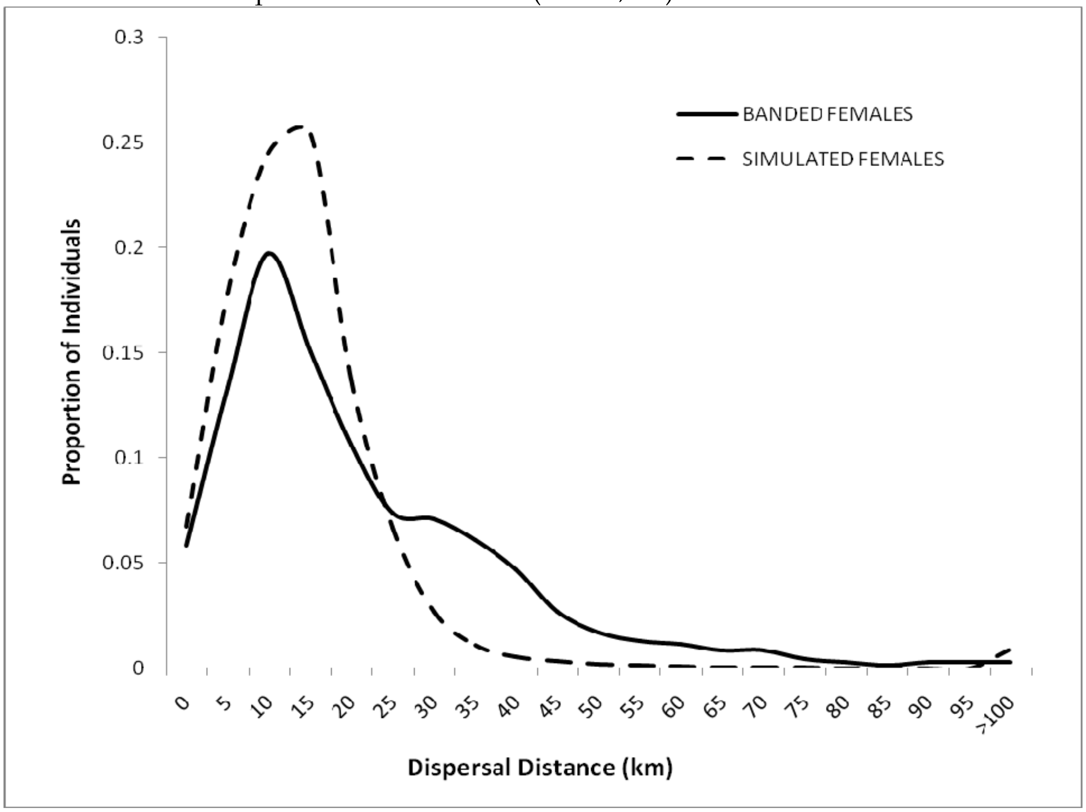
The Baseline HexSim simulations, in which barred owl impacts were introduced at time-step 40, then held static, produced an estimated total female spotted owl population size within the eight DSAs of 675. From field sampling, the total estimated female spotted owls in those DSAs based on the largest number recorded between 1996 and 2006 was 778. The average of the three highest density years from the annual reports (using only data from 1996-2006) for total estimated spotted owl females was 756. The mean of the highest three years (1996-2006) was selected instead of the highest single year in order to reduce the chance that a single year was uncharacteristic of the DSA (Figure C14). Differences in number of female spotted owls on the eight DSAs between those estimated from field sampling and those estimated from our HexSim runs ranged from 5% to 47%, with a mean absolute percentage difference of 26%. Subsequent changes to HexSim did not eliminate these differences.

Figure C-14. Model calibration: Comparison of simulated spotted owl population size (time step 50) to estimates based on field sampling in eight Demographic Study Areas.



Dispersal is a critical process through which landscape structure impacts spotted owl population size and meta-population structure, and is a primary concern in habitat conservation network design (Murphy and Noon 1992). Of particular importance is natal dispersal; the movements of juvenile spotted owls between their natal site and the site where they eventually establish breeding territories. We evaluated the performance of HexSim relative to natal dispersal by comparing graphs of simulated versus observed natal dispersal displacement distances (Figure C15). HexSim generates reports of annual dispersal events by non-territorial (juvenile and floater) spotted owls. The dispersal behavior of the simulated spotted owls was affected principally by landscape structure, the dispersal stopping criteria, and the amount of autocorrelation (both discussed above). Observed natal dispersal distances were estimated from movements of banded spotted owls (Forsman *et al.* 2002).

Figure C-15. Model calibration: Comparison of natal dispersal distances of banded female spotted owls (N= 328) from Forsman *et al.* (2002) to simulated natal dispersal distances for female spotted owls in HexSim (N=850,000).



Because our HexSim spotted owl scenario consists solely of females, we limited the comparison to banded female spotted owls. The distributions of natal dispersal distances for 328 banded female spotted owls were generally similar to 850,000 natal dispersal events recorded during a 250 time-step (years) HexSim simulation. The majority of both observed and simulated dispersal distances were between one and 25 km, however, about 10 % fewer simulated dispersal distances were greater than 10 km and 20% fewer were greater than 25 km.

Uncertainties and Limitations

An important goal of the spatial population modeling effort is to provide a tool to evaluate and compare the suitability of suites of habitat conservation network scenarios. Each scenario represents a unique ensemble of conditions that could affect future spotted owl population size and trends. The overall amounts of spotted owl habitat, the arrangement of habitat conservation networks, and barred owl influences will vary from scenario to scenario.

Several conclusions about each scenario could be drawn from the HexSim spotted owl simulations. Very specific results, such as estimates of absolute population size, will be the most sensitive to parameter uncertainties. Less specific conclusions, such as the relative differences between scenarios, will be increasingly robust. The HexSim simulations provide, at a minimum, a repeatable methodology for qualitatively ranking the efficacy of the habitat conservation scenarios. This analysis might also extend further, to include a quantification of individual reserve or block carrying capacities, and attendant probabilities of extinction. The conclusions that are drawn from a simulation model must balance concern over uncertainties with the desire to preserve a threatened species.

The HexSim spotted owl simulation model resulted from an attempt to construct the simplest model that could do a credible job of ranking habitat conservation network scenarios. HexSim makes adding realism relatively simple. But more life history detail does not automatically translate into more accurate forecasts. Realism comes at a cost since complex models have larger numbers of parameters, and thus greater data requirements.

There are many details that could be added to the existing HexSim simulation model. Examples include environmental stochasticity, the explicit modeling of spotted owl males (including mate-finding and pairing) and barred owl populations, genetics, disturbance regimes such as fire, etc. Some of these "enhancements" might provide more accurate forecasts of future spotted owl population sizes and probabilities of extinction, and decisions whether to incorporate some of them can be made in the future by model users depending on their specific needs. These enhancements, however, are not necessary in order to reliably rank habitat conservation network scenarios based on their likelihood of facilitating recovery of the spotted owl.

The modeling team considered several enhancements that could be added to the current HexSim spotted owl model. Some enhancements that might be made to the HexSim model are listed below.

Environmental Stochasticity

Incorporation of environmental stochasticity into HexSim scenarios will be necessary when estimates of population size or extinction probability need to be made. However, the addition of environmental stochasticity is unlikely to change the order in which habitat conservation network scenarios rank (*i.e.*, from least to most likely to recover the spotted owl). Developing a modeling process to determine the rank-ordering of scenarios was the modeling team's primary goal, and environmental stochasticity was left out of these simulations in order to limit the computational burden associated with that analysis. Environmental stochasticity should be added to the HexSim model before it is used to estimate population sizes or extinction rates. At that time, the more variable model could be used to test a subset of the rank-ordering results obtained without environmental stochasticity. Recent research into the effects of variability in climate on spotted owl demographic rates (Glenn *et al.* 2010) suggested adding realistic variation in annual temperature and precipitation would provide an important element of environmental stochasticity into HexSim simulations.

Effect of relative habitat suitability on reproductive rates

The HexSim spotted owl model links habitat to survival rates through resource acquisition. Individual spotted owls acquire resources from their simulated home ranges, and home ranges with higher RHS values provide greater resources. But home ranges overlap, and competition between spotted owls will lower resource availability. Resource acquisition, because it links landscape structure and intra-specific competition, is a more realistic driver of survival rates than habitat would be on its own. Resource acquisition could easily influence reproduction in exactly the same way that it influences survival. Unfortunately, the most recent meta-analysis (Forsman *et al.* 2011) was inconclusive regarding the role that habitat played in determining reproductive rates. For this reason, the modeling team elected to not vary spotted owl reproductive rates as a function of resource acquisition.

Effect of barred owls on reproductive rates

The HexSim spotted owl model includes the machinery necessary for barred owl influences to include a lowering of spotted owl reproductive rates. This is done by setting a probability that a spotted owl in the presence of a barred owl will nest. Each year, every affected territorial spotted owl will make an independent nesting decision, based on this probability. However, in the current model, the probability that a spotted owl in the presence of a barred owl will forgo nesting entirely is set to zero.

Modeling team members determined that range-wide empirical estimates were not sufficient to assign region-by-region probabilities for barred owl impacts on spotted owl reproduction. Such impacts could come in several forms. For example, the presence of a barred owl could cause a spotted owl to abandon its territory, to keep the territory but forgo nesting (or calling for a mate), or a barred owl could lower effective spotted owl reproductive rates by interfering with nest-tending or preying on spotted owl offspring.

In order to simulate territory abandonment, it would be necessary to explicitly model barred owl locations across the landscape. But sufficient data on barred owl locations and habitat associations were not available range-wide to permit doing more than setting region-by-region probabilities of barred owl occurrence. Simulating barred owl predation on spotted owl offspring runs the risk of double-counting this impact, since barred owl presence does lower survival rates in the HexSim spotted owl model. As described above, the model is able to simulate a lowering of spotted owl nesting rates (when in the presence of a barred owl). But sufficient data was not available range-wide to do more than speculate on the associated parameter values.

Interaction between habitat and barred owl effect

By incorporating the barred owl into the spotted owl scenario as a dynamic spatially explicit stressor, the influence of habitat on barred owl presence and barred owls effects to spotted owl occupancy (extinction rates), recruitment and survival could be more realistically simulated. While there is new information suggesting that habitat and barred owl effects may interact, the data necessary to develop reliable models of barred owl habitat suitability (and subsequently, distribution) are not available. For this reason, the modeling team elected not to attempt this. Moreover, outcomes of modeling region-specific simulations suggest that the current barred owl parameterization is realistic; low to intermediate barred owl encounter probabilities act to depress spotted owl populations but do not result in extinction.

Sensitivity analyses

When the HexSim spotted owl model is used to make estimates of population size, or probabilities of extinction, it will be necessary to also conduct a sensitivity analysis. The modeling team has conducted some work on a traditional sensitivity analysis. Whereas a traditional sensitivity analysis is focused on making small changes to individual parameter values, it would be instructive to complement this work with an assessment of the consequences of varying elements of the model structure itself. Examples of model design elements that might be varied include the lack of direct effects of resource acquisition on reproductive rates, the number of resource acquisition levels being simulated, and some of the behavioral features associated with dispersal and prospecting.

The most important parameters in any model of the spotted owl are going to be the survival and reproductive rates. The rates used in the HexSim survival and reproduction events have been derived from the most recent compendium of spotted owl field data (Forsman *et al.* 2011). Still, some uncertainty is introduced when these survival data are used to assign rates to spotted owls in three different resource acquisition classes, as that process involves extrapolation. We therefore elected not to use a larger number of resource acquisition classes. Likewise, the impact of barred owls on spotted owl reproduction is not perfectly understood, and certainly varies from region to region (as we represent in the HexSim scenarios).

One element of realism that the modeling team deemed necessary for this analysis was ensuring that the simulated spotted owls' home ranges and resource requirements varied by modeling region. The variation in home range size is supported by much published information (see review in Schilling 2009). The variation in resource requirements was used to account for regional differences in resource availability that were not captured in the MaxEnt resource map. In areas where the resource availability was known to be lower, spotted owls were assigned a higher resource requirement. The resource requirements were used as a fitting parameter that made it possible to adjust regional population sizes independently.

The HexSim spotted owl model described here is simple, but not overly so. It is likely the most realistic spatially-explicit individual-based spotted owl simulation that has been developed to-date. Its design and complexity mirror what is being asked of it. Additional complexity may be added at a future time as needed to meet the goals that accompany other planning exercises.

Testing Modeling Process Applications – Using the HexSim Spotted Owl Scenario model to compare the demographic effectiveness of various habitat conservation network scenarios and other recovery strategies:

For the Revised Recovery Plan, the modeling team's objective was to develop and test a modeling framework (Steps 1-3) that would support a wide variety of recovery actions, including evaluation of habitat conservation network scenarios. To facilitate the implementation of recovery actions contained in the Revised Recovery Plan, the modeling team established a process for developing scenarios and conducted preliminary population simulations to compare a sample of habitat conservation network scenarios in order to test the modeling framework's reliability. The results from these preliminary comparisons were necessary in order to obtain feedback on the overall framework and provided the basis for revisions to the HexSim model. This objective was completed as part of the recovery planning process. The following evaluation consists of the actual comparison of simulated spotted owl population responses among many alternative scenarios representing various recovery strategies and habitat conservation networks.

Development of Scenarios for Evaluation and Comparison in HexSim

An important use of the modeling framework is to simulate spotted owl population performance relative to three primary sources of variation: size (area) and distribution of habitat conservation networks; trends in habitat conditions inside and outside of the habitat conservation networks; and trends in the influence of barred owls. Considering the many possible variations in network designs, land ownership limitations, future habitat trends, and barred owl effects that could be evaluated, it is clear the number of scenarios needed to evaluate all of the possibilities could increase rapidly and become unfeasible. Instead, the modeling team developed an iterative process for evaluation of scenarios; establishing broad sideboards in earlier comparisons, then testing the models' sensitivity to habitat conditions and barred owl effects. The HexSim spotted owl model can also be used to evaluate the response of spotted owl populations to future climate scenarios.

To test the modeling framework's ability to evaluate the influence of habitat conservation network size (area) and spatial distribution on spotted owl population performance, we analyzed a subset of 10 habitat conservation network scenarios from Step 2 representing a wide range of sizes (proportions of "habitat value"), as well as existing habitat conservation networks (Table C28).

Table C-28. Initial set of habitat conservation networks evaluated in population modeling Rounds 1-3.

Network **scenario**	**Code**
Northwest Forest Plan Reserve Network	**NWFP**
Managed Owl Conservation Areas	**MOCA**
1992 Critical Habitat	**1992CH**
2008 Critical Habitat	**2008CH**
30% Zonation (All Lands Available)	**Z30all**
50% Zonation (All Lands Available)	**Z50all**
70% Zonation (All Lands Available)	**Z70all**
30% Zonation (Public Lands Only)	**Z30pub**
50% Zonation (Public Lands Only)	**Z50pub**
70% Zonation (Public Lands Only)	**Z70pub**

Maps depicting each of the network scenarios listed above are available at:
http://www.fws.gov/oregonfwo/Species/Data/NorthernSpottedOwl/Recovery/Library/Default.aspx#Files
Once there, click on "maps" and "AppendixCMaps.pdf" The layers can be turned on and off using the "layers" button in the upper left-hand corner.

The habitat conservation networks listed in Table C28 form the basis for a series of comparisons in the population modeling environment (called Rounds) wherein different environmental conditions such as barred owl effects and habitat conditions are manipulated both spatially and temporally (scenarios). Each habitat conservation network that is subjected to different conditions is termed a habitat conservation network scenario. Rounds simply articulate the specific modifications that are made. The following paragraphs provide descriptions of the scenarios developed by the modeling team, and the results of HexSim runs for the scenarios in Rounds 1-3.

Interpreting HexSim results:

Each HexSim simulation run provides estimates of population size at any chosen time period as well as population trend over any range of time steps. Estimates are reported at both range-wide and regional scales. It is important to recognize that the results are intended to allow comparison of *relative population performance* among alternative habitat conservation network scenarios, not predictions of actual population size or trend in the future.

When a HexSim simulation starts, the number of individuals, age class distribution, spatial arrangement of territories, and other population attributes will have values that reflect the model's initial conditions. It takes many years for these artifacts to subside, and thus for the population's stable-state dynamics to become evident. Simulations were started with 10,000 female spotted owls, thus this initial period of transitory dynamics involved a period of rapid (apparent) population decline for the first 25 or 30 time-steps; typically subsiding by approximately time step 50. It is important not to confuse this decline with an observed or predicted loss in spotted owl numbers that has resulted from changing environmental conditions. We could have chosen to begin simulations with many fewer spotted owls than are known to currently exist in the landscape (say 250), and waited many time-steps for them to increase and reach some sort of equilibrium with their simulated landscape. That would have resulted in a rapid (apparent) population *increase*, but again would simply be the transitory dynamics involved with the starting population conditions. The point is that the first 25-30 time steps are not meant to be interpreted, but can be thought of as a "burn-in" period for the simulation whereby the simulated spotted owls equilibrate with the simulated environment.

Round 1: Baseline (2006) conditions

This was the simple "Baseline" scenario that was used to evaluate parameterization of the HexSim spotted owl scenario. This scenario assumes no change in habitat through time (2006 RHS map); therefore the 10 habitat conservation networks listed above are not compared (because nothing different happens inside and outside of habitat blocks in this scenario). Also, barred owl effects remain constant over time (either at zero or constant at their currently-estimated impacts, beginning at time step 40).

Figures C16 through C18 highlight differences in the relative influence of barred owls among modeling regions. Rangewide, barred owls act to depress spotted owl populations to roughly 50 percent of potential population size without barred owls (Figure C16). However, spotted owl populations in modeling regions with high barred owl encounter rates such as the Oregon Coast Ranges (P_{BO} = 0.710; figure C17) decline rapidly in comparison to modeling regions with low to intermediate barred owl encounter rates such as the Western Klamath (P_{BO} = 0.315; figure C18).

Figure C-16. Results of HexSim Round 1 model runs with five replicates each for "Without STVA" (barred owl) impacts and "With STVA" impacts for the spotted owl's entire geographic range in the U.S. The apparent within-year variation that appears in the figure is a function of an "even-odd" year effect on reproduction that was included in this version of the HexSim model.

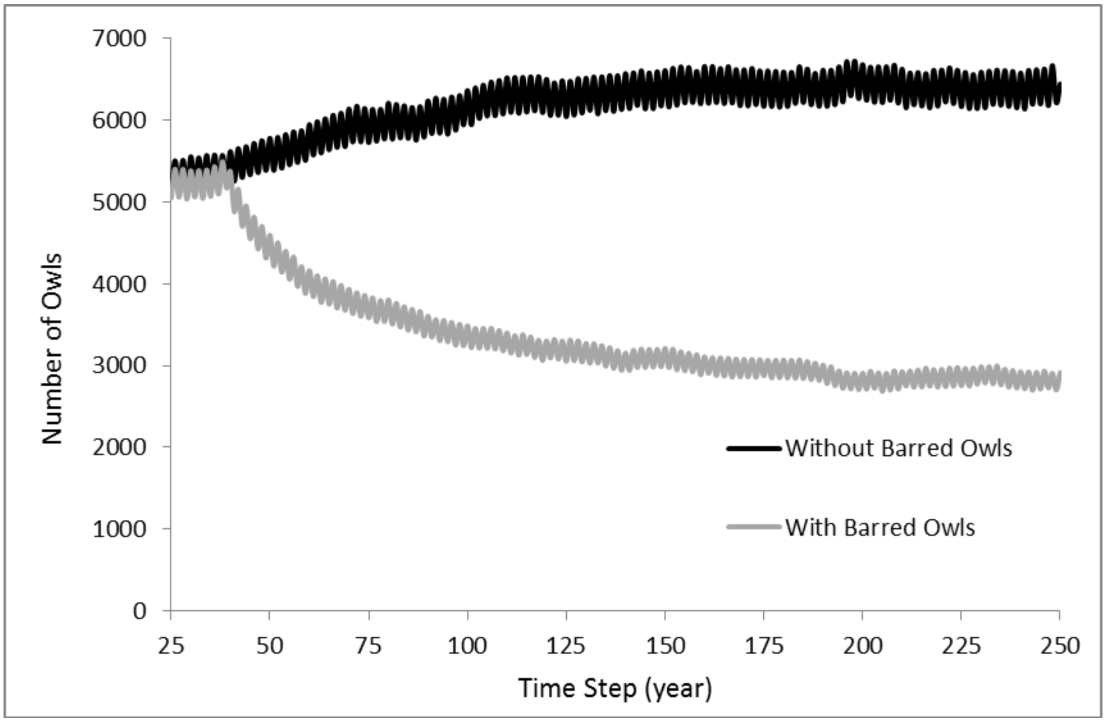


Figure C-17. Simulated Round 1 spotted owl population sizes in the Oregon Coast Ranges modeling region showing 1) current barred owl influence and 2) barred owl influence removed.

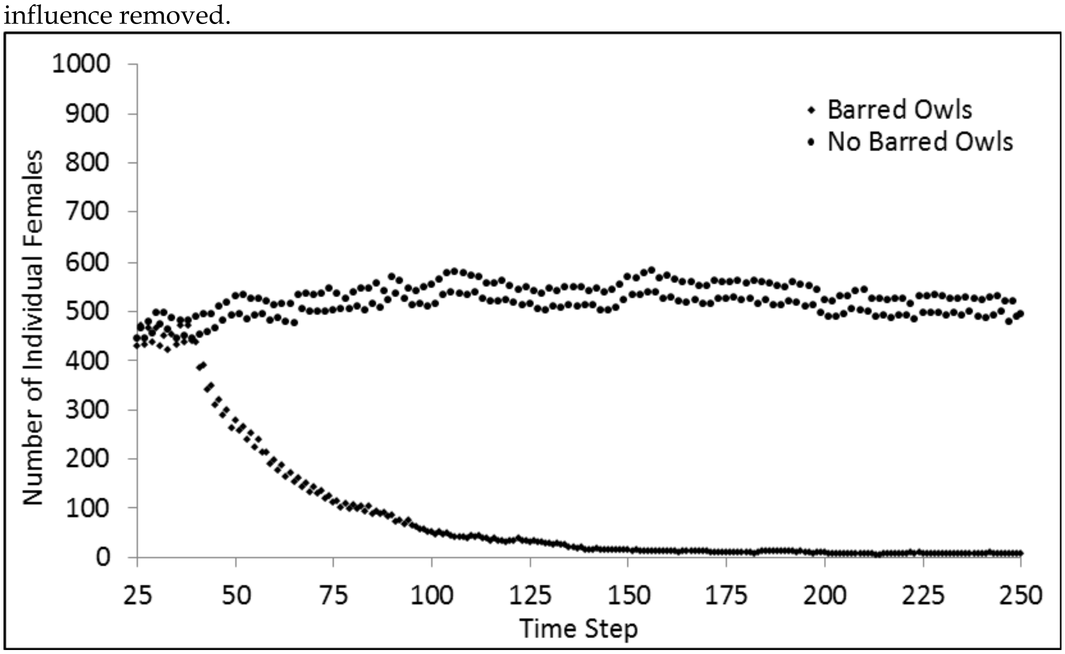
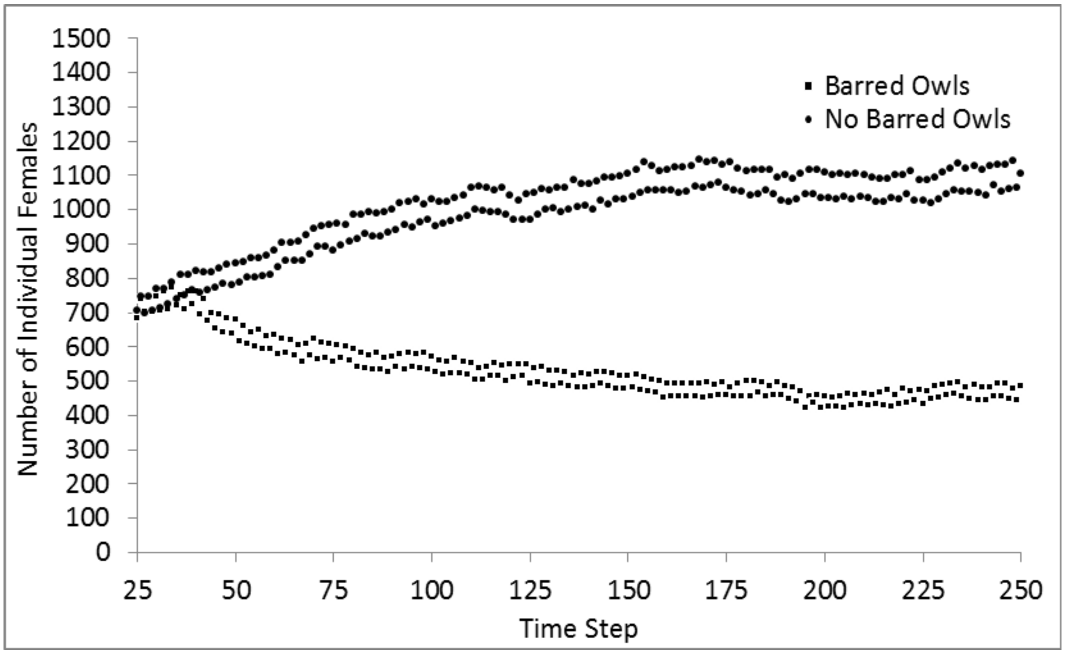


Figure C-18. Simulated Round 1 spotted owl population sizes in the Western Klamath modeling region showing 1) current barred owl influence, and 2) barred owl influence removed.



Round 2: Simulating a high degree of reliance on habitat conservation networks

Because the primary objective in this evaluation is to compare estimated spotted owl population performance across a range of habitat conservation network, the goal of Round 2 was to "isolate" the habitat conservation networks by devaluing non-network habitat suitability and holding habitat in networks at its 2006 estimated level throughout the simulation. In this scenario, we reduced relative habitat suitability (RHS) *outside* of habitat conservation networks to 34 (RHS=0.34); *just below* that needed for territory establishment; RHS within networks remained unchanged. The influence of barred owls was held to the currently-estimated encounter rates calculated from Forsman *et al.* (2011); the barred owl influence was slotted in at year 40. We repeated Round 2 with *No barred owl effect*, to evaluate the relative contribution of habitat and barred owl effects on simulated spotted owl population performance. The results of the Round 2 simulations allow for an evaluation of the relative influence of habitat conservation network size and distribution (relying primarily on public versus both public and private lands) and barred owls on spotted owl population performance – when the habitat conservation network provides nearly all nesting and roosting habitat.

Round 3: Simulating RA10 - retention of high-value habitat outside of habitat blocks

The goal of Round 3 was to evaluate the relative contribution of habitat conditions ***outside*** of habitat conservation networks to spotted owl populations; Scenarios R3S1 through R3S10 are intended to emulate the management approach of maintaining occupied spotted owl territories outside of network areas . RHS within habitat conservation networks was held constant, and areas of high RHS (>50) *outside* of networks (on public lands) were retained through time. Areas of RHS between 35 and 49 (outside of networks) were decremented to RHS 34. Scenarios R3S11 through R3S20 were similar but apply to *all* non-network lands (public and private). We repeated Round 3 with *No barred owl effect*, to evaluate the relative contribution of habitat and barred owl effects on simulated spotted owl population performance.

Figures C19 and C20 provide examples of different metrics that can be used to compare estimated spotted owl population outcomes among habitat conservation network scenarios, in this case Rounds 2 and 3 described above. Initial results using a wide range of population metrics can provide insights for meeting the recovery criteria established in the Revised Recovery Plan. Comparison of these estimates of spotted owl population performance across the range of scenarios can inform evaluation of habitat conservation networks designed to lead to spotted owl recovery.

Figure C19 provides results for the entire range of the spotted owl, but as described in Round 1 and evidenced in Figure C20, it is important to recognize that population outcomes may differ markedly among modeling regions.

Figure C-19. Comparison of percent population change (rangewide) between year 25 and year 250 under the scenarios in Rounds 2 and 3, with and without barred owl influence. MOCAs and critical habitat were not compared for Round 3.

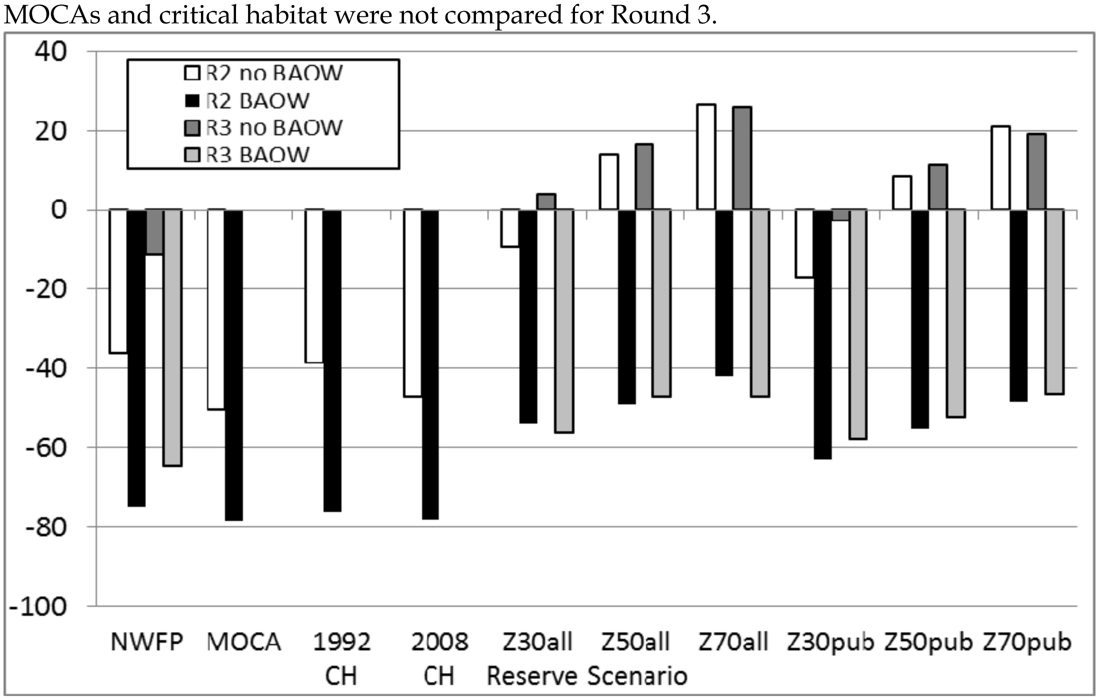
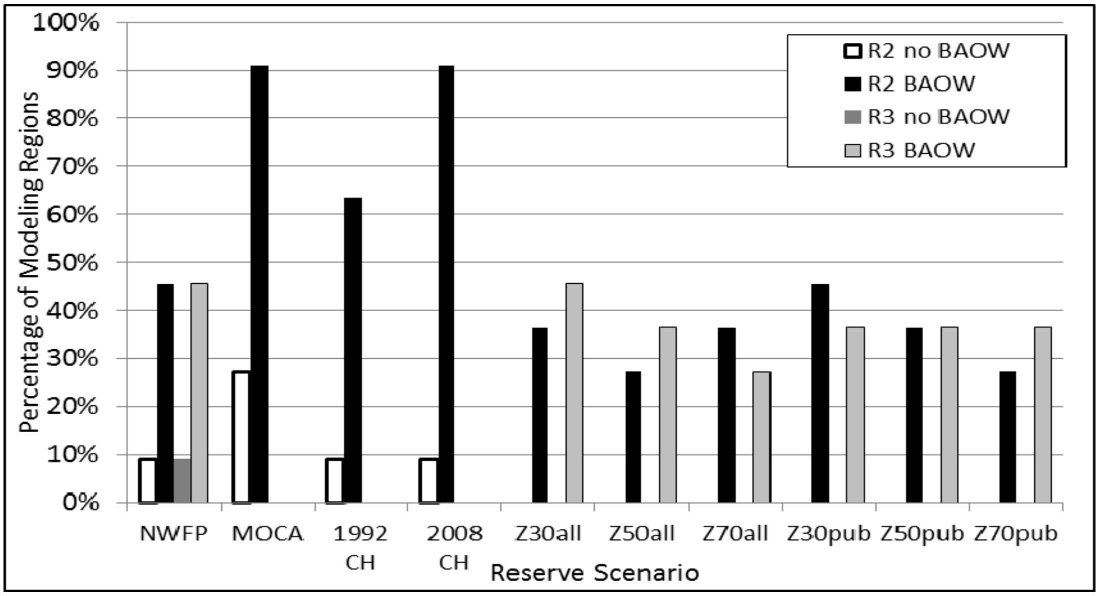


Figure C-20. Percentage of modeling regions whose simulated populations declined by more than 75% between years 25 and 250 (indication of extinction risk) under the scenarios in Rounds 2 and 3, with and without barred owl influence.



The interaction of network size with other conservation measures is highlighted in Figures C19 and C20. In Round 3 (simulated RA10 - retention of likely occupied, high-value habitat with RHS>50 in non-network areas), the amount of habitat "retained" is inversely proportional to the size of area within habitat conservation networks Subsequently, RA 10's benefit to simulated spotted owl populations is relatively less for larger habitat conservation network scenarios such as Z50 and Z70.

Conclusions:

The analysis presented in this appendix is intended to demonstrate how the three-part modeling framework can be used to evaluate spotted owl population response to a variety of environmental conditions such as habitat variation and barred owls. Although this initial analysis is intended to evaluate the modeling framework, it provides insight into factors influencing spotted owl populations and conservation planning for recovery of the spotted owl.

HexSim population simulations can be completed for the entire range of the spotted owl as well as for subsets of the species' range, such as individual modeling regions or DSAs. This capability enables evaluation of varying environmental conditions and subsequent population effects occurring in different parts of the species' range. For example, the relative effect of barred owls on spotted owl survival and subsequent population size varies among modeling regions, in accordance with different barred owl encounter rates (Table C29). Comparison of the relative differences between simulated spotted owl populations without barred owls and those resulting from different barred owl encounter rates among modeling regions (Figures C17 and C18) suggests there may be barred owl population levels (encounter rates) below which spotted owl populations remain stable (albeit at lower population sizes). Further evaluation of these relationships may inform planning of barred owl management scenarios.

Table C-29. Barred owl encounter probabilities estimated from Forsman *et al.* (2011).

Region	Encounter Probability
North Coast Olympics	0.505
East Cascades North	0.296
West Cascades North	0.320
West Cascades Central	0.320
Oregon Coast	0.710
West Cascades South	0.364
Inner CA Coast Range	0.213
East Cascades South	0.180
Klamath East	0.245
Klamath West	0.315
Redwood Coast	0.205

As shown in Figure C1, the modeling framework contains feedback loops that facilitate an iterative process, with each iteration informed by the results of previous scenarios and simulated population outcomes. This process enables an adaptive approach to developing and testing conservation measures. As new information from monitoring or other research becomes available, its influence on spotted owl conservation can be incorporated into subsequent evaluations in a consistent manner.

In sum, our goal was to develop a modeling framework that can be applied by interested parties to make better informed decisions concerning spotted owl management and recovery. The analyses described in this appendix represent a small subset of possible scenarios and are presented to test the framework and to give potential users of this approach some preliminary exposure to the models' potential utility. Future conservation planning for spotted owls will require development and evaluation of additional scenarios that are relevant to the management questions of particular interest to various stakeholders. These future planning efforts will likely address temporal factors such as changing barred owl populations, climate change, and future habitat change. They might also apply to private land managers who are evaluating different options within a Habitat Conservation Planning scenario, or Federal land managers who are considering recommendations for amending long-term forest management plans. Whatever the use to which this framework is applied, our goal was to provide managers with tools that will ultimately result in better informed decisions for spotted owl conservation.