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

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INTRODUCTION

This document provides 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*). 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, 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 MODELING PROCESS

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

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; USFWS 2011) was used to help develop, refine and evaluate alternative possible critical habitat networks. The modeling process consisted of three principal steps:

Step 1: At the outset, 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-- were identified based on the habitat selection exhibited by nearly 4,000 known owl pairs (USFWS 2011, pp. C-20 to C-28). We then used these physical and biological features of nesting, roosting, and foraging habitats to create a range-wide map of (relative) habitat suitability (MaxEnt) (Phillips *et al.* 2006, entire; Phillips and Dudik 2008, entire). In addition to providing a map of relative habitat suitability, this process allowed us to evaluate an area's suitability and determine whether the presence of the species was likely based on an assessment of known species-habitat relationships.

Step 2: We developed potential northern spotted owl 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 region 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.

Step 3: In this last step, we determined where the physical and biological features, as well as unoccupied areas, are essential to the conservation of the species. To do this we used a spatially-explicit northern spotted owl population model (HexSim) (Schumaker 2008, entire) to predict relative responses of northern spotted owl populations to different habitat network designs, different assumptions of barred owl (*Strix varia*) impacts, and competing scenarios describing trends in habitat suitability. Results from the HexSim model were used to develop rank-orderings of 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 scenarios.

Relative Habitat Suitability Model

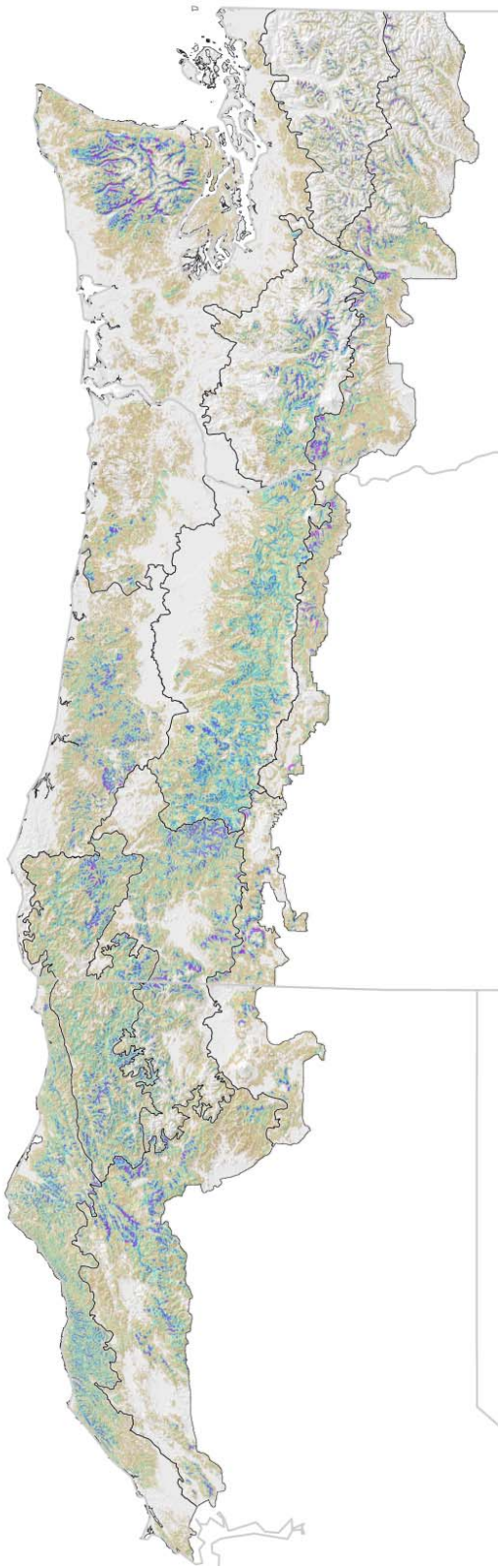
We used spatially explicit relative habitat suitability (RHS) models to identify potential critical habitat networks, and to gauge the responses of owl populations to differing scenarios of changing habitat suitability. Our RHS model performed very well (USFWS 2011) at distinguishing northern spotted owl territories from the conditions available in the landscape. The model's predictions were similar to those reported by Davis et al. (2011). 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 (USFWS 2011), and conducted modeling within each region separately. 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).

Habitat Network Scenarios: Approaches to Refining a Critical Habitat Network

The potential habitat network scenarios described here were taken from the ten habitat conservation network scenarios described in Appendix C of the Revised Recovery Plan. The six Zonation scenarios (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 (RHS) to include in a given scenario. These six scenarios were comprised 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 prioritizing habitat 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. The Northwest Forest Plan (NWFP) was also evaluated 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 (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 this "wall-to-wall" 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 assumptions 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 scenario and set of assumptions 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, and the transient behaviors due to the initial conditions typically subsided over the first 25-50 time steps.

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). But 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 ranking the potential critical habitat networks. Such relative rankings 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 scenarios. In our stochastic HexSim simulations, steady-state was generally achieved after time step 150, but because this varied considerably between scenarios, we also recorded how long it took to achieve steady-state under the various potential critical habitat networks.

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: 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.

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. 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 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 1). 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 1. 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 2.

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. The primary objective of Phase 2 modeling was to develop and evaluate a single potential critical habitat network design for subsequent refinement.

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 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."

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 habitat 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 they were plausible, not that they were the most extreme case we could imagine. The team 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 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 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 habitat networks by increasing contrast between network and non-network areas. The pessimistic scenario used in Phase 2 modeling was identical to 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.

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, the team 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 2). 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 identify those specific areas that provide the physical or biological features essential for the conservation of the northern spotted owl, by segregating the negative effects of barred owls from the positive 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 was deemed unreasonable and unrealistic. Therefore, we chose a middle ground between the extremes of no barred owl management (barred owl encounter rates at present levels or greater in the future) and complete theoretical eradication (no barred owl influence), and did so on a modeling region by modeling region basis, because the current barred owl encounter rate varies among modeling 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 2 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.

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 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.

Table 2. 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.

Environmental Stochasticity

The HexSim spotted owl model described in Appendix C of the Recovery Strategy (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 (e.g. 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 3. 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 3. 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 4. If the collection of fecundities shown in Table 4 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 4. 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 the team believed to represent overall risk thresholds (Table 5). 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 5). We used these risk metrics to establish criteria for comparing range-wide population results among reserve designs.

Table 5. 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. 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 6-8). 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 6-8).

Table 6. 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 2.

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 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	2364

Table 7. 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 2.

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 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	3543

Table 8. 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 2.

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 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	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 9).

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 9). 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 9).

Table 9. 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 (ISC 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 ISC's (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 iif 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 continue to 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 and, given the Endangered Species Act's direction to focus first on occupied habitat when identifying critical habitat, represents 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:

<u>Efficiency</u> – 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.

<u>Connectivity and Isolation</u> – 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.

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.

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 was 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

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

Model Region	Network Design	Area within Networks (acres)				
		MR 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 11. 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 2.

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 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	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 11). 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 12. 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 13. 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 2.

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 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	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 Bureau of Land Management 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 Forest Service. 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 14. 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, WCC) exhibited higher extinction risk.

Table 15. 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 2.

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 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	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 with 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 removal 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 16. 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.

Table 17. 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 2.

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 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	3533

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.

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

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 18. 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	Non-public/3
NCO	Composite 6, WA state/private lands refined	1,595,821	734,119	723,445	137,318	939
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	58,911	135,067
ECS	Composite 6,	526,810	417,770	109,040	0	0
WCN	Composite 6, WA state/private lands refined	820,832	543,615	165,407	111,222	588
WCC	Composite 6, WA state/private lands refined	1,353,045	923,742	324,966	57,400	46,937
WCS	Composite 6, modified	1,624,836	1,371,170	253,666	0	0
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	0
ICC	Composite 6, modified, refined Napa unit	1,276,450	978,599	250,575	12,123	35,153
RDC	Composite 6, refined Sonoma unit	1,550,747	114,523	185,025	203,102	1,048,097
	Rangewide Total	13,962,449		2,646,671		

/1 USFS and BLM lands, excluding Congressional Reserves (Wilderness, National Parks)
/2 Congressional Reserves (Wilderness, National Parks)
/3 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 20). 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 2 and 3).

Table 19. 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 2.

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 population size at time-step 350	Grand mean population size time steps 150-350
NCO	100	99	21	52	74
OCR	99	58	0	173	212
ECN	100	95	3	66	97
ECS	100	95	0	112	120
WCN	100	100	80	4	8
WCC	100	100	28	25	38
WCS	59	14	0	375	501
KLE	38	0	0	473	522
KLW	9	0	0	732	776
ICC	12	0	0	596	641
RDC	46	2	0	442	475
Total				3051	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 20; Figures 2 and 3).

Table 20. 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 2.

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 was one of the Service's goals. One method of evaluating efficiency is to compare habitat scenario area to owl population size. Figure 2 shows this relationship for each of the seven Composite network scenarios and the NWFP.

Figure 2. 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.

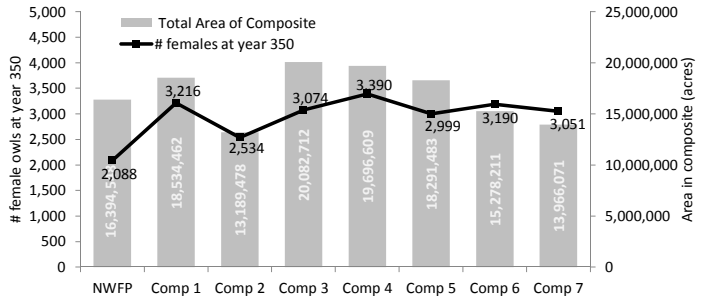
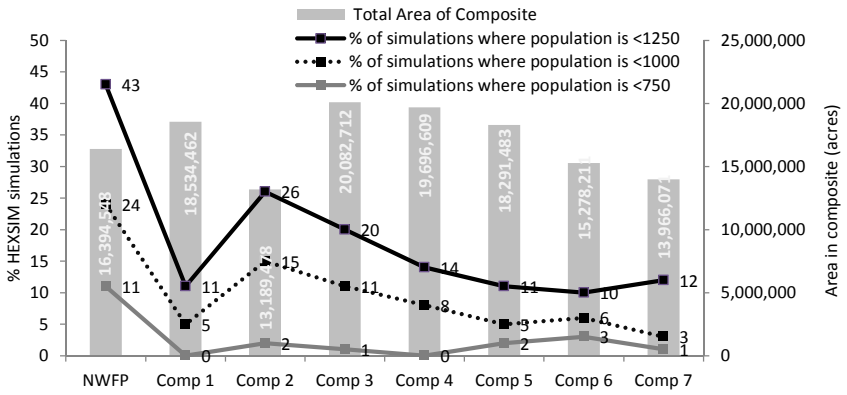


Figure 3. Total area and percent of HexSim simulations (pessimistic habitat scenario) where spotted owl populations fell below 1250, 1000, and 750 total owls for Composites 1-7 and the Northwest Forest Plan (NWFP).



Levels of population risk (Figure 3) followed a pattern similar to that shown in Figure 2; with Composite 7 as the most efficient of the scenarios we evaluated.

SUMMARY AND CONCLUSION

The Service employed a 3-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 network, habitat 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. Each composite scenario represented the Service's effort to maximize efficiency and realism by reducing the potential critical habitat designation, focusing on well-connected high quality habitat while maintaining the best possible population performance. The last scenario in this process (Composite 7) performed substantially better than the NWFP and other composites nearly twice its size (area), and represents a robust potential critical habitat network that conforms with the statutory definition of critical habitat.

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