Chapter 3: Habitat Status and Trend

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Introduction

The primary contribution of the Northwest Forest Plan (the Plan) to conserving the northern spotted owl (the owl) was the federal network of reserved land use allocations designed to support clusters of reproducing owl pairs across the species' range. These "reserves" include late-successional reserves, adaptive management reserves, congressionally reserved lands, managed late-successional areas, and larger blocks of administratively withdrawn lands (fig. 3-1). Federal lands between these reserves were designed to provide habitat to allow movement, or dispersal, of owls from one reserve to another. The "between" lands are a combination of matrix, riparian reserves, smaller tracts of administratively withdrawn lands and other smaller reserved areas such as 100-acre owl core areas. Individually, these areas may not support clusters of reproducing owls, but in combination provide population connectivity between the clusters. Monitoring the condition and trend of owl habitat on federal land—larger, reserved blocks as well as the land between them—are keys to assessing the success of maintaining and restoring owl habitat under the Plan.

Owl habitat is the term we use for forest stands used by territorial owls. It is commonly described in discrete terms as nesting, roosting, and foraging habitat (Lint et al. 1999), but it is more ambiguous. Thomas et al. (1990: 164) stated:

> Structural components that distinguish superior owl habitat from less suitable habitat in Washington, Oregon and northwestern California include a multi-layered, multispecies canopy dominated by large (>30 inches d.b.h.) conifer overstory trees, and an understory of shade-tolerant conifers or hardwoods; a moderate to high (60 to 80%) canopy closure; substantial decadence in the form of large, live coniferous trees with deformities—such as cavities, broken tops, and dwarf mistletoe infections; numerous large snags; ground-cover characterized by large accumulations of logs and other woody debris; and a canopy that is open enough to allow owls to fly within and beneath it.

The term dispersal habitat is commonly used to describe forest stands used by juvenile owls during movement away from natal areas or by subadult and adult owls moving from one territory to another (Forsman et al. 2002). Forest stands with average tree diameters >11 in and conifer overstory trees with closed canopies (>40 percent canopy closure) with open space beneath the canopy to allow for the owls to fly are considered owl dispersal habitat (Thomas et al. 1990). As such, all owl habitat meets the definition of dispersal habitat, but not all dispersal habitat meets the definition of owl habitat as it may be lacking the necessary structure for nesting or roosting.

Owl habitat monitoring addresses the central question about both owl habitat and dispersal habitat: Is owl habitat and dispersal habitat being maintained and restored as prescribed under the Plan? Additional questions were aimed at providing information to address the central question:

- What proportions of the total landscape on federal lands are capable of developing into owl habitat?
- What proportions of the total landscape on federal lands are owl habitat and dispersal habitat?
- What are the trends in amount and changes in distribution of owl habitat, particularly in the large, reserved blocks?
- What are the trends in amount and distribution of dispersal habitat outside of the large, reserved blocks?
- What are the sizes and distribution of owl habitat patches?
- What primary factors are leading to loss and fragmentation of both owl habitat and dispersal habitat, that is, the change agents and amount of loss, and what are the trends associated with these changes?

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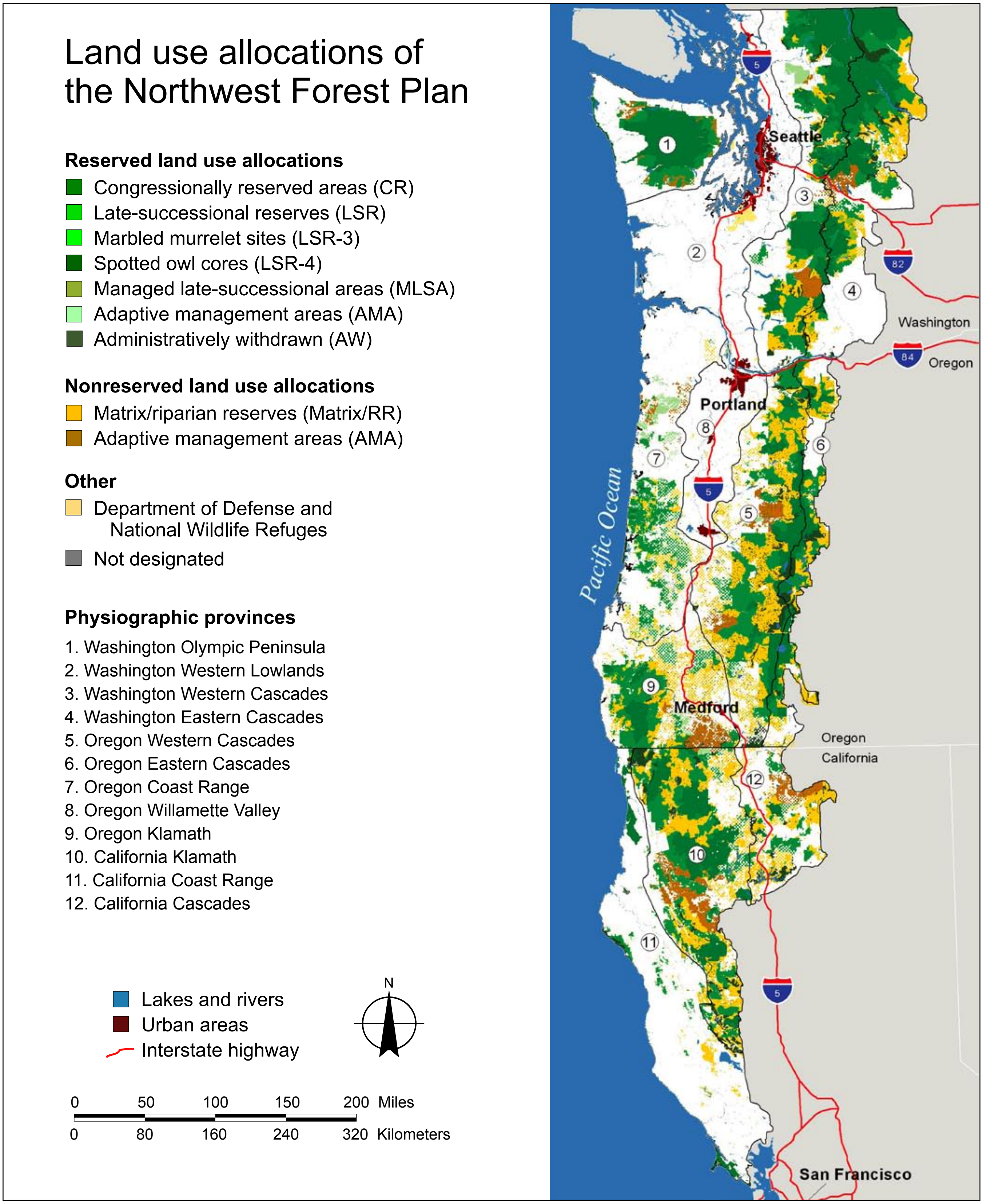

Figure 3-1—Northwest Forest Plan land use allocations.

To address these questions, we used both spatial and nonspatial analysis methods. Lint et al. (1999) explained the basis for spatial monitoring of habitat under the spotted owl effectiveness monitoring plan, as follows:

> The basic information needed for range-wide monitoring of spotted owl habitat is a set of map layers that collectively characterize spotted owl habitat and dispersal habitat. An overlay of map layers will allow the development of a GIS-compatible database used to describe amount and distribution of habitat in relation to land allocations or other geographic areas of interest. Once developed, the map would be updated periodically to track habitat change. Periodic updates of the map layers in the near term will allow the estimation of changes in amount and distribution of habitat over time resulting primarily from timber harvest and wildfires. Changes in vegetation due to forest succession are not expected to provide any significant changes in habitat condition for several decades.

Nonspatial habitat monitoring was based on the same premises as the spatial monitoring, but it assessed habitat conditions independent of the spatial analysis. This approach estimated forest attributes important to owl habitat through plot measurement data. The nonspatial assessment used grid-plot data from the current vegetation survey inventory program on USDA Forest Service (FS) and USDI Bureau of Land Management (BLM) lands in Oregon and Washington. Forest Inventory Analysis Program data were used for FS lands in California. Plot data were not available for the USDI National Park Service (NPS) lands or for BLM lands in Washington or California.

The condition of owl habitat was reported at three broad geographical scales: (1) the physiographic province, (2) the state, and (3) the range of the owl. For the spatial analysis only, owl habitat conditions were also reported by land use allocation. An additional province-scale assessment examined owl habitat condition, both spatially and nonspatially, inside and outside of the large, reserved habitat blocks (reserved blocks).

We used a step-wise approach to analyzing and reporting habitat conditions. First we estimated the federal land area covered by the Plan. We further refined this area by estimating the percentage capable of growing forests and the subset of the forest-capable area that was capable of producing owl habitat. The habitat-capable area was the basis for model application and analyses of model outputs.

Habitat, Habitat Suitability, and Habitat Modeling

Habitat models frequently address the potential of a given location to serve as habitat (Hill and Binford 2002). Habitat, in the strictest sense, implies not only species occupancy, but also incorporates elements of survival and reproduction (Block and Brennan 1993, Hall et al. 1997, Morrison et al. 1992). Hall et al. (1997) provided the following definition and discussion of habitat:

> We therefore define "habitat" as the resources and conditions present in an area that produce occupancy—including survival and reproduction—by a given organism. Habitat is organism-specific; it relates the presence of a species, population, or individual (animal or plant) to an area's physical and biological characteristics. Habitat implies more than vegetation or vegetation structure; it is the sum of the specific resources that are needed by organisms. Wherever an organism is provided with resources that allow it to survive, that is habitat.

Hall et al. (1997) also noted that it is possible to have "used" and "unused" habitats (occupied and unoccupied). They suggested that unoccupied habitat can occur for species that use patchy habitats where some of the patches are unused, at least temporarily. In the case of the owl, habitat patches may be unused (temporarily) perhaps owing to the patch size or distance from other used habitat. It was not the purpose of our analysis to identify occupied versus unoccupied habitat or predict the likelihood of owl occupancy on the landscape. That prediction is part of another element of the monitoring program that is attempting to develop models to predict the likelihood of occupancy for a given landscape habitat mosaic (refer to the "Predictive Model

Development" section in chapter 5 of this report). Our objective was to produce maps of forest stands (regardless of patch size and spatial configuration) that showed their level of similarity to stand conditions known to be used by spotted owls.

Habitat suitability indices are often used for assessing the suitability of an area as a function of several environmental variables that most affect species presence, abundance, and distribution (Morrison et al. 1992). However, habitat suitability is a term that Hall et al. (1997) advised against using because (by definition) all habitat is suitable and there is no such thing as unsuitable habitat. Instead, they suggested using the term "habitat quality," which they defined as a continuous variable, ranging from low to medium to high, based on the ability of the environment to provide conditions appropriate for survival and reproduction (including demographic features). Thomas et al. (1990) used the terms "habitat suitability" and "habitat quality" interchangeably (Thomas et al. 1990: app. F):

> Discussions of an organism's habitat usually include assessments of its relative "value" or "suitability." For any species, habitat suitability for various life functions—breeding, feeding, and cover—is not identical in all possible habitats. Suitability of different types of habitat can be graded from excellent to poor, which means that habitat suitability values tend to be continuous as opposed to discrete. Partitioning of habitats into categories, however, facilitates discussion.

We used the term "habitat suitability" in our report because it is the descriptor used by Hirzel et al. (2002) for the output of their habitat model, which we used in our analyses. We did not consider it appropriate to change the nomenclature of the model output, but thought it was important to briefly discuss "habitat" and habitat-related terms to avoid confusion or misunderstanding of the use of the term "habitat suitability" in this report. It might be more helpful to view "habitat suitability" in terms of "habitat similarity." The "suitability" statistic calculated by the model we used is based on the similarity of the biotic and abiotic characteristics of a habitat-capable map unit to the characteristics of sites inhabited by territorial owls. Habitat "similarity" ranges on a continuous scale from 0 to 100, where a value close to zero signifies that an individual map unit (pixel) has little in common with the conditions found where territorial owls are present, and those with values close to 100 have much in common with sites having territorial owl presence.

Although use of habitat suitability indices prohibits exact population estimates, they can be used to compare one area to another (Dettki et al. 2003), or (as in the case of monitoring) the same area at different times. We used a set of histograms to profile habitat suitability for the three spatial scales previously described, and for individual land use allocations. Finally, we examined changes to the habitat suitability profiles caused by stand-replacing timber harvest and wildfire during the monitoring period (1994–2003).

Data Sources

Vegetation Map Data

The sources of vegetation data for habitat monitoring were the database from the classification and assessment via Landsat Thematic Mapper (TM) of visible ecological groupings (CALVEG) in California and the interagency vegetation mapping project (IVMP) in Oregon and Washington. Data from both sources were from the 1992–96 period, about the time of Plan implementation. We did not have spatial vegetation data from 2002 or 2003 for comparison of vegetation conditions (growth or loss) after 10 years of Plan implementation. The only vegetation change agents we were able to analyze were stand-replacing timber harvest and wildfire that occurred during the monitoring period. This was done by using the change-detection layer described later in this section.

The CALVEG data set comprises polygon data derived from 1994 satellite images. The minimum mapping unit was 2.5 ac. Qualitative categories or classes of vegetation type, tree cover, and overstory tree size were the polygon attributes we used. The average polygon was about 10 to 15 ac, but some were hundreds to thousands of acres. Tree-size maps were slightly less accurate than tree-cover maps. Traditional (right or wrong) accuracy for size was about 42 to 60 percent, but it improved to 68 to 78 percent with fuzzy (see "Glossary") accuracy standards (± one class). User's and producer's accuracy[3] for specific tree-size classes ranged from about 10 to 40 percent (traditional), improving to 80-plus percent for some map classes under fuzzy accuracy standards. Cover accuracies were 49 to 68 percent (traditional) and increased to 75 to 83 percent based on fuzzy accuracy assessments (http://www.fs.fed.us/r5/rsl/projects/mapping/accuracy.shtml). Refer to Moeur et al. (2005) for additional discussion of accuracy assessments.

Satellite imagery information from the 1992–96 period was used to map vegetation conditions in Oregon and Washington. The IVMP products were 25-m-resolution (82-ft), raster-based data (0.15-ac pixel) of continuous (a numerical scale that can be subdivided into an infinite number of intervals—Schreuder et al. 2004), quantitative, or qualitative classes of vegetation cover, conifer canopy cover, tree size, and cover type. Traditional (right or wrong) accuracy for size was about 33 to 44 percent, which improved to 61 to 87 percent with collapsed classes. User's and producer's accuracy for specific tree-size classes ranged from about 13 to 71 percent (traditional). Traditional cover-class accuracies ranged from 10 to 86 percent, and map accuracies for cover classes ranged from 44 to 68 percent (traditional) and increased to 57 to 80 percent based on fuzzy accuracy assessments (http://www.or.blm.gov/gis/projects/ivmp.asp). Refer to Moeur et al. (2005) for additional discussion on IVMP and CALVEG.

These two vegetation data sources required slightly different habitat-map modeling strategies. To the extent possible, vegetation map attributes for modeling were made as consistent as possible between the two data sources. The final map products from California, however are not directly comparable to the maps from Oregon and Washington. In general, the finer resolution of the Oregon-Washington data and its division into specific vegetation attributes with continuous values was better suited for habitat modeling. The coarser nature of the California polygons may have affected model output. Engler et al. (2004) found that fine-resolution habitat predictors were superior to coarse-resolution data (25-m [82-ft] versus 500-m [1,640-ft] raster data). The lower model performances they observed at the 500-m resolution (roughly 62-ac pixel size) were probably caused by the unavoidable loss of information when environmental map units are aggregated. This aggregation of information may sometimes hide important combinations of habitat predictors that would otherwise be detectable with finer resolution data. This fine- versus coarse-scale dilemma might also apply to the "resolution" of habitat predictor attributes. When map pixels are assigned a unique continuous value from 0 to some maximum (for example, 0 to 75-in diameter), a finer resolution of measure is obtained than with coarse categorical "class" attributes (for example, 0 to 4.9 in, 5 to 9.9 in, …etc.). Although nonspatial in nature, attribute classification aggregates information and may also cause loss of important data. This attributing problem (lack of continuous data) occurred in all attributes of the CALVEG data and may have reduced model performance in the eastern Cascades physiographic provinces of Oregon and Washington, because of a lack of continuous tree-size data.

Land Use Allocation Data

An updated map of the Plan's land use allocations was produced under the direction of the Regional Interagency Executive Committee in 2004. The new version of the map updated the original 1994 coarse-scale land use map (40-ac resolution) to correct inconsistencies for certain land use allocations among administrative units and to incorporate land use allocation changes since the Plan was implemented. Although improvements were made in the accuracy of land use allocation mapping, including representing the allocations at a finer resolution, the map product still had some limitations (fig. 3-1). The most significant limitation was its inability to show the riparian reserves. Lands outside of reserves, that might be mapped as riparian reserve, were combined with lands in matrix so that neither allocation was individually identifiable. Also, the variation in the size and classification criteria for administratively withdrawn areas resulted in inconsistent mapping across the range of the owl. Other mapping-related problems included inconsistent edge matching of allocations between some

[3] User's accuracy is associated with errors of inclusion that include an element in one class when it belongs in another. Producer's accuracy is associated with errors of exclusion that exclude an element when it does belong in a class or category.

adjacent administrative units (for example, national parks[4] and national forests) creating "sliver-sized gaps" in the map, and inconsistent attributing of large bodies of water. These problems, with the exception of the riparian reserve limitation, were dealt with case by case and either corrected or considered minor, in light of the analysis scale, and let stand. The allocation classes in the map were as follows:

- **CR**, congressionally reserved
- **LSR**, late-successional reserves
- **AMR**, adaptive management areas in reserves (an allocation designed to display the areas' acres in late-successional reserves)
- **MLSA**, managed late-successional areas
- **AW**, administratively withdrawn
- **LSR-3**, marbled murrelet reserved areas
- **LSR-4**, 100-ac spotted owl cores
- **AMA**, adaptive management areas
- **MATRIX/RR**, matrix (which contains riparian reserves that were not mapped)
- **ND**, not designated (lands with no assigned land use allocation)

Spotted Owl Presence Data

Owl presence data were compiled from various FS, BLM, NPS and nonfederal cooperators' databases. These data were collected by wildlife biologists using standardized survey protocols to determine spotted owl occupancy and reproductive status in defined geographical locations (USDA FS 1988) for project clearance and demographic monitoring (Forsman 1995, USDI FWS 1992). Results of these surveys were recorded in [digital] databases and displayed in a geographic information system (GIS) format. The GIS data were linked to vegetation data to identify forest stands where owls were repeatedly detected, many of which were confirmed nest groves and, sometimes, the nest trees. From this rangewide (range of the owl) set of data, only points representing the presence of owl pairs (male and female) were used (n = 8,967). Each point represented an actual historical location of concentrated territorial owl activity from the late 1980s through the 1990s (fig. 3-2). Sometimes, especially for demographic study areas, more than one point signified the same owl pair. The separate locations denoted distinct nesting or roosting locations pairs used in different years. The locations were usually within the same general geographic location or forest stand.

An assessment of the spatial accuracy of each owl location was performed by overlaying the GIS points on digital orthophotos (1- to 3-m [3- to 9-ft] resolution) or satellite images (10-m [33-ft] resolution) in ArcView GIS. Sometimes, wildlife biologists familiar with the data were consulted and asked to conduct an independent quality control of a location's spatial accuracy by using original data sources, maps, or orthographic photos. Many points were dropped from the original data set because they were in nonforested areas, (for example, clearcuts), which may have been owl habitat when the surveys were done, but subsequently harvested and thus no longer owl habitat and without value as training information for the model. Owl locations used for habitat modeling were always accurate to the forest stand in which the owl pair was recorded, and usually accurate to within 100 m (328 ft) of the actual location where the owls were observed in that stand. Prior to habitat modeling, the owl location data were converted into Boolean (values of 0 or 1) species maps matching the pixel resolution of the underlying vegetation data. Map values of "1" represented proof of territorial owl presence, and values of "0" represented a lack of proof of presence.

Change Detection Data

Three data sets were used to estimate the amount of habitat change during the monitoring period (1994 to 2002–03). For Oregon and Washington, a change-detection grid (officially titled *Stand-Replacing Harvests and Fires in Oregon, 1972 through 2002*), was developed by using multiple Landsat TM images dating from 1972 through 2002. Data for 2003 were not available. Change pixels were smoothed, and filtered to a minimum mapping unit of 2 ha (5 ac). Disturbance by fire was separated from disturbance owing to harvest by visual inspection and expert knowledge. Refer to Cohen et al. (1998) for a description of their analysis methods.

[4] National Park Service lands in the redwood region of California also included acres of state park lands that were not split out from the federal lands in the map update.

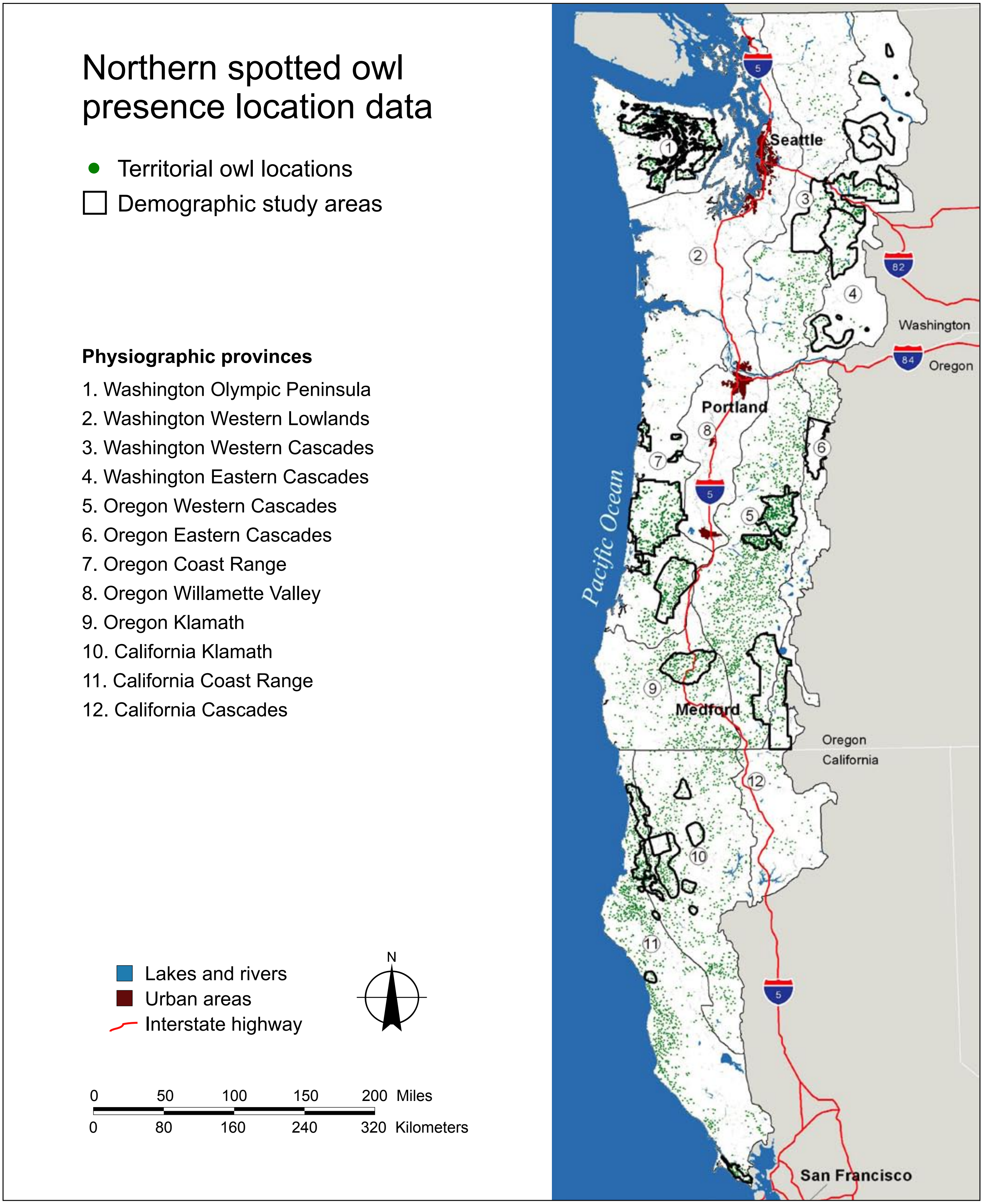

Figure 3-2—Northern spotted owl range and owl pair-presence point locations.

For California, change-detection data were generated in two parts by the USDA Forest Service and California Department of Forestry and Fire Protection. The first part was developed in 1998 (Levien et al. 1998) by using Landsat TM data from 1990 through 1998 to identify and map areas of vegetation change and to determine the cause of the change by using ancillary data and fieldwork. This part was then supplemented by using six additional Landsat TM scenes to create a map of stand-replacing disturbance during 1998–2003. Processing decisions about the degree of change were conservative so that possible change events meeting the "stand-replacing" criterion (Maurizi 2004) would not be excluded. Figure 3-3 displays the stand-replacing timber harvest and wildfire events that compose the change-detection layer. Refer to Moeur et al. (2005) for additional discussion of the change-detection map.

Wildfire Occurrence Data

Spatial wildfire occurrence data were used to analyze the densities of wildfire across the owl's range during the monitoring period as a complement to the change-detection data. The data set was developed by the Climate, Ecosystem, and Fire Applications (CEFA) Program of the Desert Research Institute (Brown et al. 2002). These data are a coarse assessment of historical federal wildfire occurrence records from the National Interagency Fire Management Integrated Database (NIFMID). In it, wildfire occurrence points were "flagged" as to their suitability for subsequent analyses (Brown et al. 2002). We used the portion of this data set from 1994 to 2002 for the FS-, BLM-, and NPS-managed lands within the range of the spotted owl (n = 13,159). Only points with a "flagged" value of "0" (acceptable for reporting) were used. A few minor corrections were made for large fires >10,000 ac in Oregon and Washington, based on cross-referencing this data set with an updated (1994–2003) NIFMID query.

Historical Forest Maps

Maps created from the first large-scale forest survey of the Pacific Northwest in the early 1930s (Andrews and Cowlin 1940, Harrington 2003) and from 1945 forest surveys by the California Forest and Range Experiment Station (Wieslander and Jensen 1946) were used to compare baseline (Plan implementation, 1994) and current owl habitat conditions with historical conditions. These historical forest maps were created by using intensive field reconnaissance methods and aerial photographs (Harrington 2003, Wieslander and Jensen 1946). Timberland types from the Pacific Northwest map and age classes from the California map were used to create a proxy map of historical owl habitat (table 3-1). We also assumed that all cutover areas represented harvest of large timber, and they were included in our estimate of historical owl habitat.

Current Vegetation Survey Data

The current vegetation survey (CVS) inventory is comprehensive information on vegetative resources on FS lands in Oregon and Washington and BLM lands in the Plan area in Oregon. There are no data for NPS lands or BLM lands in California. The CVS consists of four, 3.4-mi grids of field plots that are offset from one another to produce one 1.7-mi grid across BLM lands and all FS lands except in wilderness areas where the grid intensity is 3.4-mi panels. The forest inventory analysis (FIA) provided data for FS lands in California. The FIA plots are on a 3.4 mi grid.

Table 3-1—Timberland types from the 1930s Pacific Northwest forest resources inventory mapping used to estimate historical owl habitat across the owl's range

Timberland types and age classes	Diameter at breast height
Douglas-fir old growth	22–40, 40+ inches
Douglas-fir large second growth	22–40 inches
Spruce hemlock, large	20+ inches
Cedar redwood, large	24+ inches
Balsam firs, mountain hemlock upper-slope types, large	16+ inches
Pine mixture, large	22+ inches
Recent cutovers	Clearcut since the 1920s
Nonstocked cutovers	Clearcut before 1920s
Old growth (California map)	Not defined
Young growth–old growth (California map)	Not defined

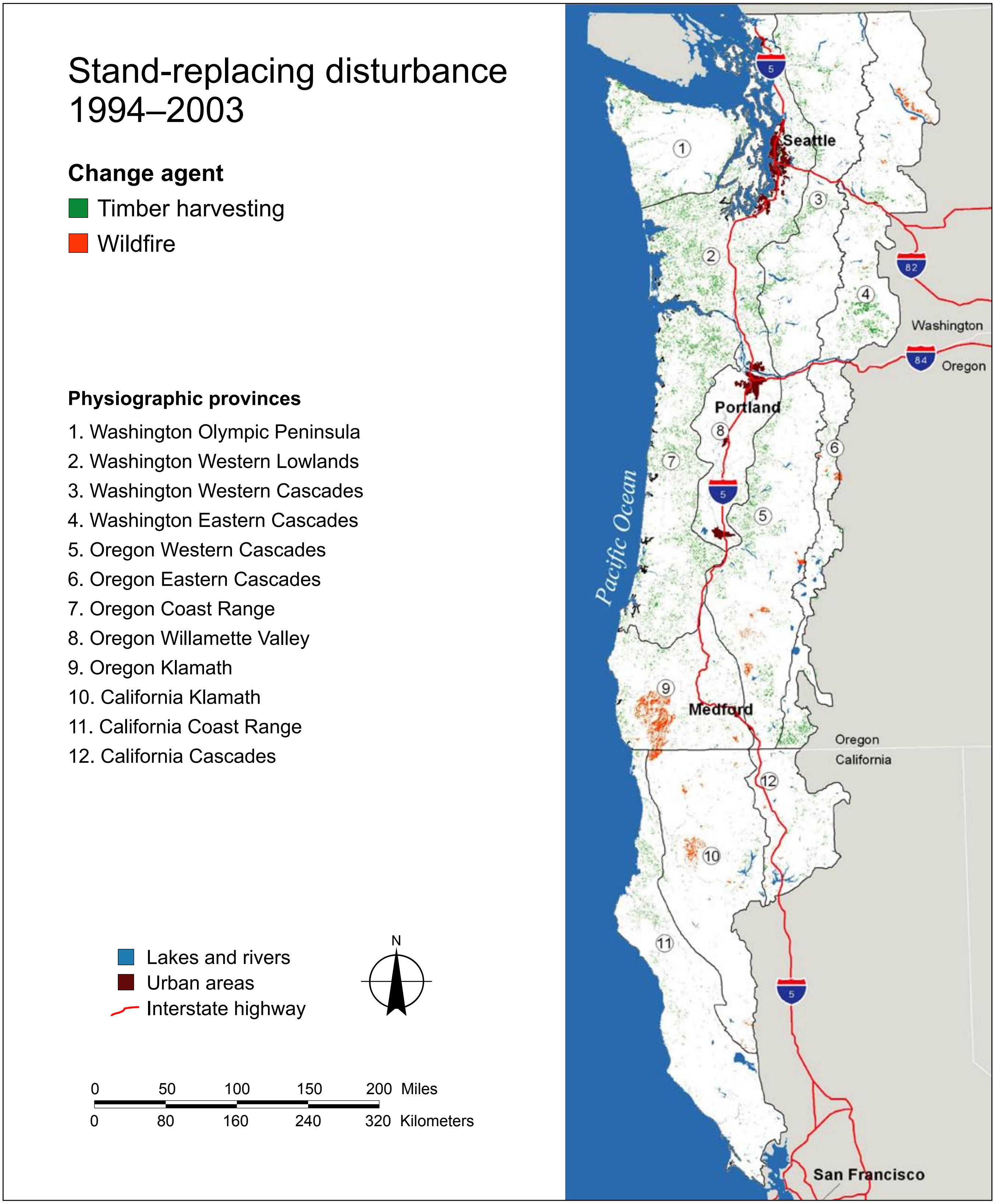

Figure 3-3—Stand-replacing timber harvest and wildfires during the first 10 years of Plan implementation.

The primary sampling unit is 1 ha (2.47 ac) with five fixed-radius subplots in a nested design. There is one subplot located at the plot center and four subplots each in a cardinal direction and 133.9 ft from the center of the plot (Max et al. 1996). For specific information on the attributes that are collected on FS lands, refer to the Web site: http://www.fs.fed.us/r6/survey/. Refer to Moeur et al. (2005) for additional discussion of the current vegetation survey and forest inventory analysis.

Other Ancillary Data Sources

We used several other data sources to support our habitat modeling effort. These included USDI Geological Survey (USGS) digital elevation models (DEMs) at 10-m (33-ft) resolution for Oregon and Washington and resampled to match IVMP data resolution of 25 m (82 ft). In California, USGS 30-m (100-ft) elevation models were used in California, and CALVEG data were resampled to match its resolution. Other sources were the Environmental Protection Agency's (EPA) level III ecoregion map units (Omernik 1987), EPA level IV ecoregion subdivisions (Woods et al. 2003), forest-level soils maps, potential natural vegetation maps (Eyre 1980), and the geologic map of California (Jennings 1977).

Analysis Methods

Estimating Federal Land Area

Our analysis of spotted owl habitat focused only on federal (public-owned) land in each physiographic province; privately owned land was not included. National wildlife refuges (Fish and Wildlife Service) and military reservations (Department of Defense) were also omitted from the analyses because they make up a very small proportion (<1 percent) of federal land in the owl's range (Refer to Moeur et al. (2005) for data on these lands).

The federal land in our analysis is land administered by the FS, BLM, and NPS. In the analysis, the combined lands for all three agencies are referred to as "federal land," unless otherwise specified.

A GIS layer of federal land was created by using the land use allocation map layer and GIS techniques (fig. 3-1). Large water bodies, (lakes and reservoirs), wildlife refuges, and military reservations were omitted. The federal land layer was queried by physiographic province to produce estimates of federal land area in each province. Province estimates were summed to obtain state and rangewide estimates.

Estimating "Forest-Capable" Federal Area

Not all federal land in the range of the owl can grow forests. Unproductive areas include rock outcrops, barren lands, alpine meadows, and snow-covered mountain peaks. GIS methods were used to subtract nonforested areas delineated on the IVMP and CALVEG layers to estimate the federal forest-capable area. Forest-capable federal land was estimated for each physiographic province and summed to obtain estimates for each state and the range.

Estimating "Habitat-Capable" Federal Area

Not all of the forest-capable federal land can develop owl habitat. Examples of nonhabitat are forested land higher in elevation than where territorial owls are found and forests on serpentine soils, which do not attain the necessary tree size and canopy closure to provide habitat for territorial owls. The federal forest land omitted was identified by using a rangewide elevation isopleth and geologic maps identifying serpentine soils.

The elevation isopleth was developed by using a linear regression analysis on the relation between the elevation of the owl-pair activity center and latitude as defined by Universal Transverse Mercator (UTM) northings. Because of the extreme north-to-south extent of the owl range (about 770 mi), it was subdivided into 10 latitudinal bands of equal width (77 mi north to south). The range was further divided into ecologically similar areas by using the EPA level III ecoregion map units (Omernik 1987). Physiographic province boundaries were not used because they contain nonecological divisions based on state boundaries (fig. 1-1). Because of the extreme north-to-south range of the Coast and Cascades ecoregions, these two level III ecoregions were split into northern and southern portions based on EPA level IV ecoregion subdivisions (Woods et al. 2003). The Washington Coast ecoregion was further subdivided for the Olympic Peninsula, based on an existing elevation isopleth used by Holthausen et al. (1995). An isopleth of 1219 m (4,000 ft) was used in the northeastern portion of the Olympic Peninsula, and an elevation limit of 914 m (3,000 ft) (Holthausen et al. 1995) was used for the remaining coastal areas of Washington and Oregon.

No elevation limit was used in four of the ecoregions or subdivisions (fig. 3-4) that were primarily low-elevation valleys and foothills (for example, the Willamette Valley), especially in the southern coastal areas where marine influences override latitudinal and altitudinal influences. The linear regression was applied in the remaining ecoregions by using the five owl-pair activity centers at the highest elevations in each latitudinal band. The derived equation from this linear relation (R^2 = 0.73 to 0.88) was used to develop the isopleth for that ecoregion, and a rangewide isopleth map was created by aggregating the regional isopleths (fig. 3-5).

Almost 99 percent of the 8,967 owl-pair-presence points used in our analysis are below the rangewide elevation isopleth. Given the variation of conditions across the range and the need to create a consistent, repeatable process for habitat monitoring purposes, the small number of owl- pair points above the isopleth was considered acceptable.

Areas of serpentine soils are primarily within the Klamath Mountains provinces in Oregon and California and to a lesser extent in the Coast and Cascade provinces of California (fig. 3-6). These soils are characterized by low available soil moisture and nutrients, which limit tree growth and produce forests with low canopy closure because of the scattered (parklike) distribution of the trees. These soils cannot grow forests suited for territorial owl nesting and roosting. Maps of these soil areas were assembled from soil maps for the Siskiyou National Forest

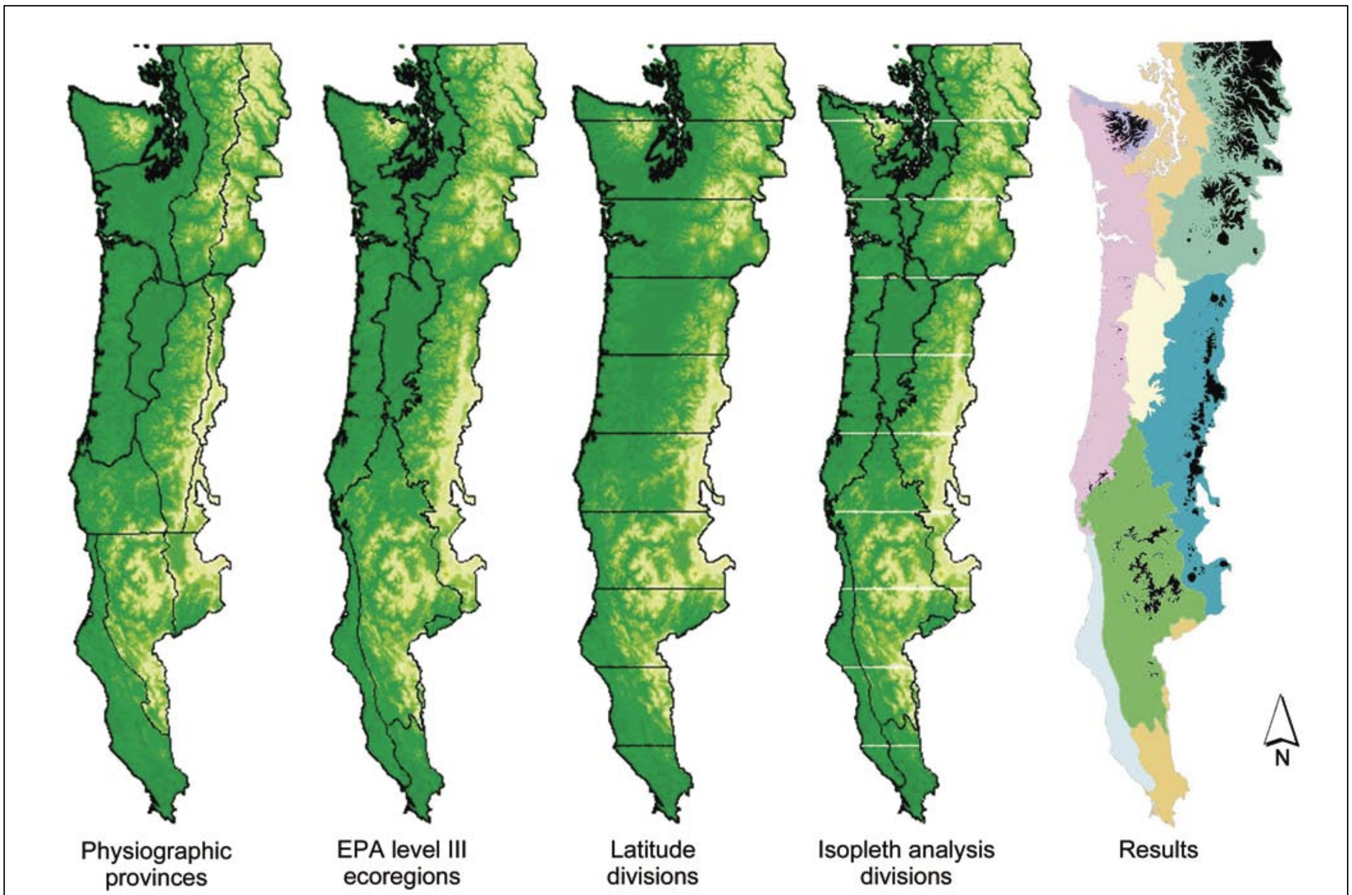

Figure 3-4—Step-wise progression of delineations used to develop a rangewide elevation isopleth denoting areas above which owls commonly do not nest (shown as black areas in the “results” map).

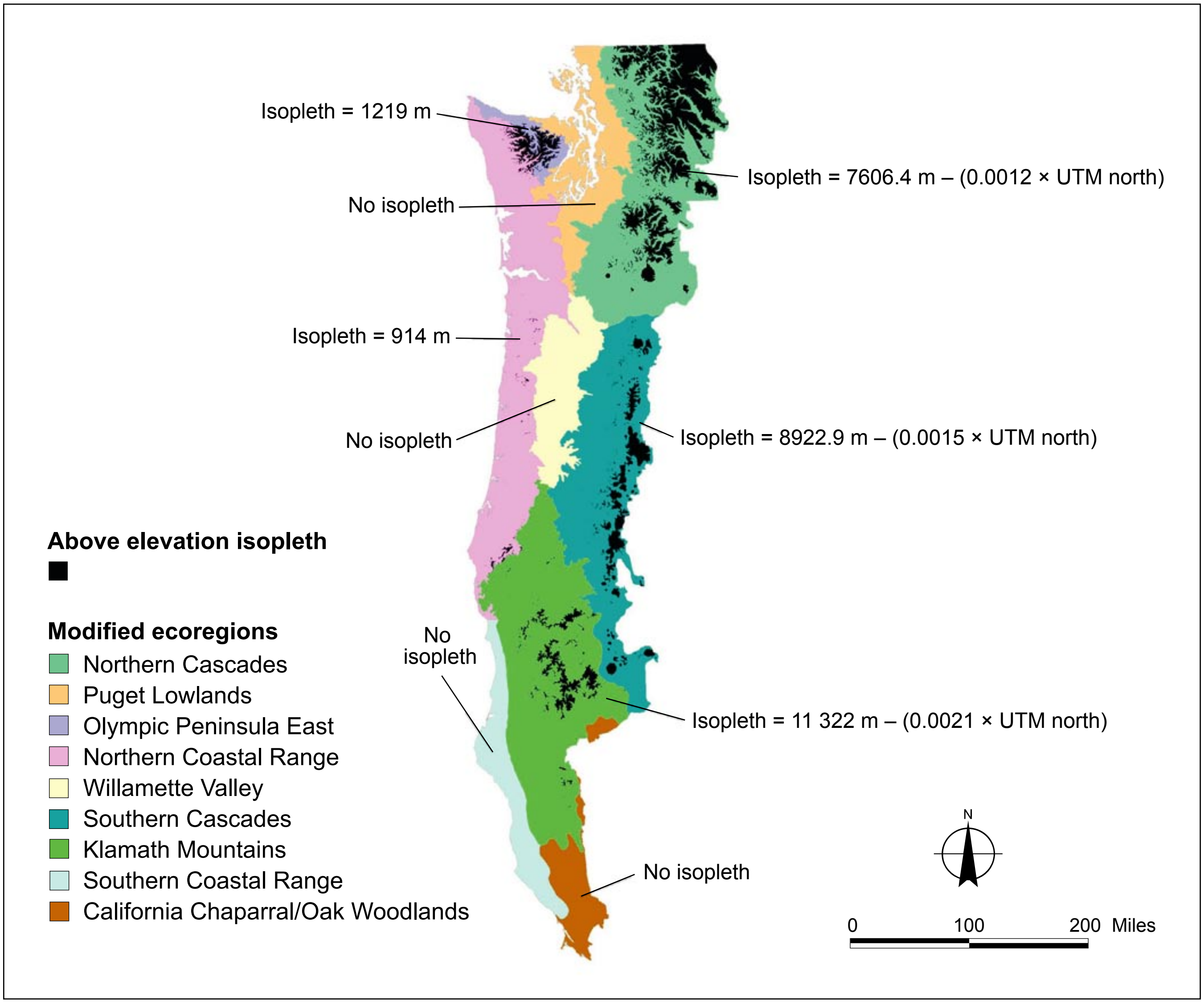

Figure 3-5—Elevation isopleths by modified ecoregions. By using the regression equations that define the linear relation between owl-pair location elevations and latitude (UTM northings), the isopleth increases in elevation from north to south (R^2 values ranged from 0.73 to 0.99).

and Roseburg BLM District, the geologic map of California (Jennings 1977), and a California potential natural vegetation map (Eyre 1980). They were used to modify the federal land GIS layer to exclude areas incapable of developing owl habitat.

The map of habitat-capable federal area was created by omitting land above the elevation isopleth and in the serpentine soil areas from the forest-capable federal land map. It delineates the federal land in the range of the owl that could produce owl habitat (fig. 3-7). This map was queried by using GIS techniques to estimate habitat-capable federal area in each physiographic province. The estimates were summed to obtain estimates for each state and the range.

Estimating Habitat Suitability

The owl monitoring plan stated that the habitat maps should be developed by using the best-suited, current technology (Lint et al. 1999). The maps produced should also be of known accuracy and the mapping process repeatable to allow for future iterations and revisions (Lint et al. 1999).

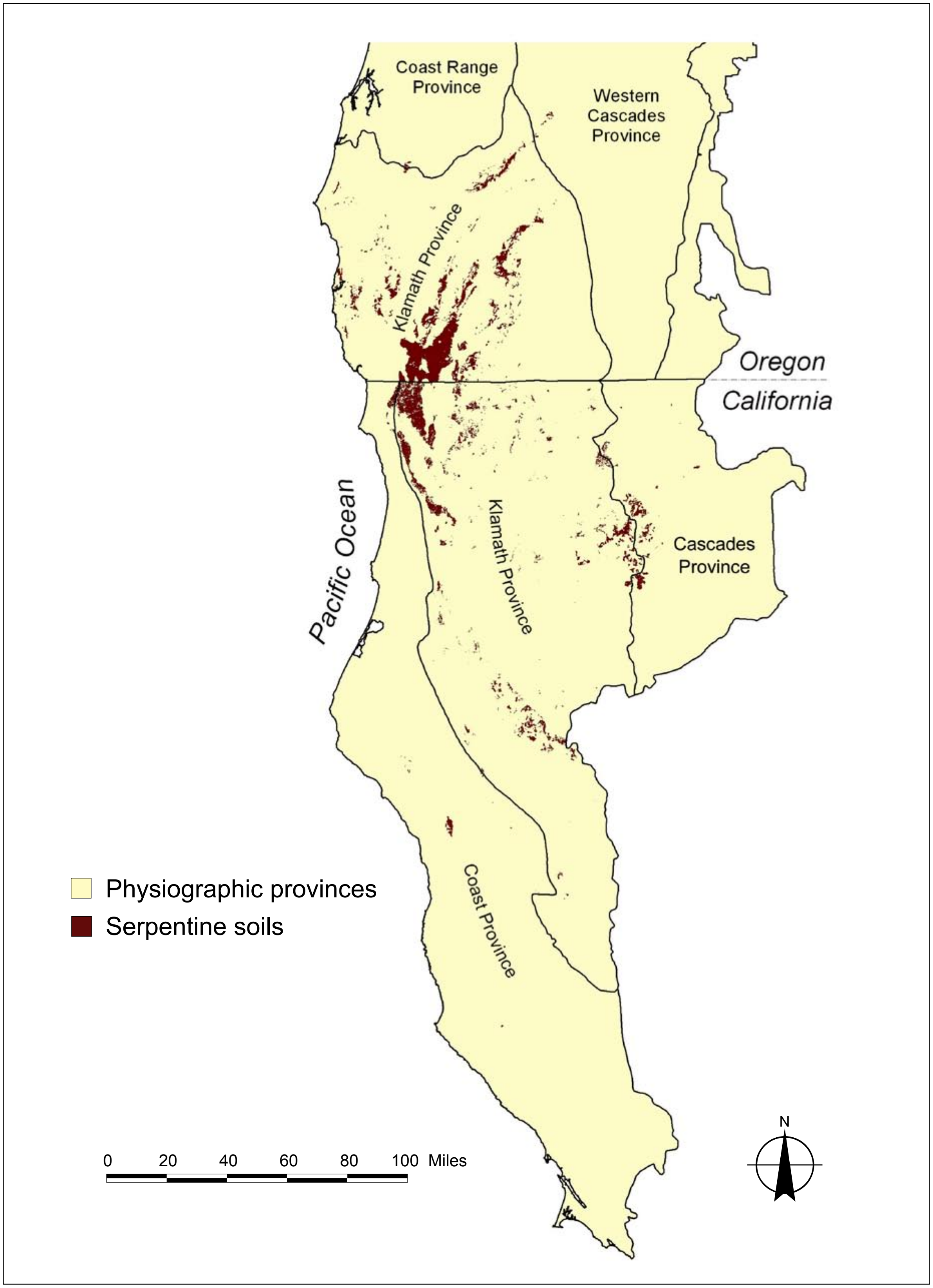

Figure 3-6–Serpentine soil areas associated with federal area not habitat-capable in the range of the northern spotted owl.

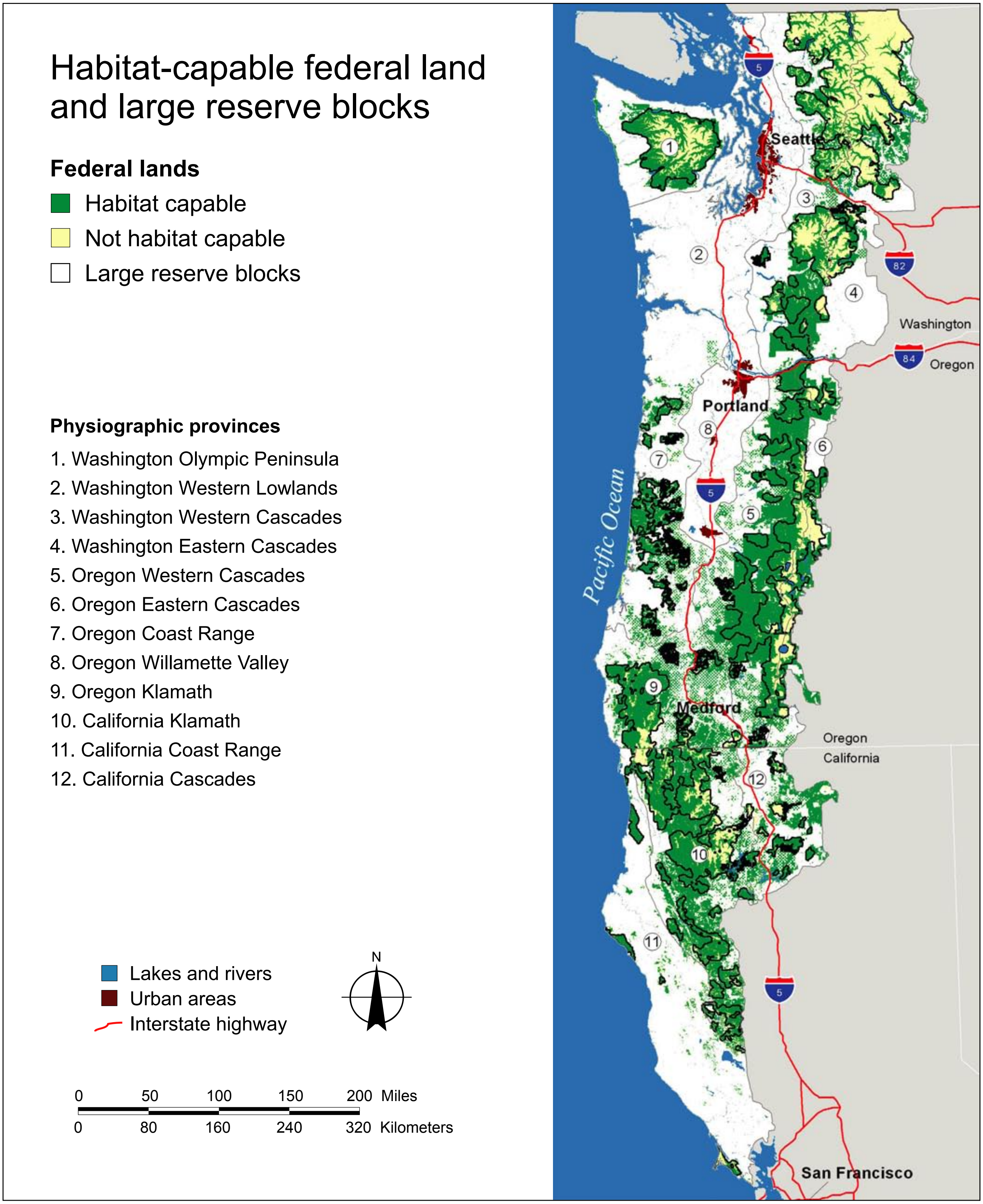

Figure 3-7—Northern spotted owl habitat-capable areas inside and outside of large, reserve blocks in Washington, Oregon, and California.

A commonly used and cost-effective method to produce habitat maps is through habitat modeling (Williams 2003). Although habitat models are often used by scientists and managers in support of species conservation, the maps they produce are never 100-percent correct. As Box (1979) noted, "All models are wrong, but some are useful." Selecting an appropriate habitat modeling method should consider the goals of the project and the usability of the model, and not depend solely on statistical considerations (Guisan and Zimmermann 2000). Furthermore, the data available often influence the model selection (McComb et al. 2002).

BioMapper v3.0 (Hirzel et al. 2004a) was chosen as the tool to model owl habitat for the monitoring program. One of the main reasons it was chosen was because it operates on species-presence-only data, which was the type of owl location data available—as is often the case with rare, threatened, or endangered species (Engler et al. 2004). Owl absence data are often difficult to obtain and frequently not reliable. Reasons for its unreliability may include local species extirpation (for example, barred owl displacement of a spotted owl), species' daily activity patterns, or territoriality of adjacent owls. Any of these reasons might explain why a spotted owl may not have been detected in a particular stand of habitat where a survey was conducted. It does not mean the forest stand surveyed was not habitat, but only that a spotted owl was not detected. Lack of absence data results in severe limitations for many statistical models that require it, such as linear regression models (Engler et al. 2004). Where absence data are not available or not reliable, models based on presence-only data are appropriate (Engler et al. 2004, Hirzel et al. 2002). BioMapper has been demonstrated to successfully perform multivariate habitat modeling with only presence data (Brotons et al. 2004; Chefaoui et al. 2005; Dettki et al. 2003; Freer 2004; Gallego et al. 2004; Hirzel et al. 2002, 2004b; Leverette 2004; Mandleberg 2004; Patthey 2003; Reutter et al. 2003; Sachot 2002; Williams 2003; Zaniewski et al. 2002; Zimmermann 2004).

Another reason BioMapper was chosen was because its underlying assumptions are founded on peer-reviewed theories and equations well documented in the scientific literature. In addition, Hirzel et al. (2001) compared it with the more commonly used generalized linear model (GLM) and showed it to be better at predicting habitat suitability for species with expanding distributions, equally effective for species with equilibrium distributions (for example, the species uniformly occupies all suitable habitat), but poorer for predicting suitability when the species was over-abundant (for example, high densities force the species to occupy less-favorable habitat). In instances where the sample size of presence data were large ($n > 300$), BioMapper and GLM performed equally well for all three species-distribution scenarios (Hirzel et al. 2001).

BioMapper is a recently developed software package that contains GIS and statistical tools designed to build habitat suitability models and maps. It is based on the theory of the ecological niche (Hutchinson 1957). There are many definitions of ecological niche dating back almost a century. Grinnell (1917) defined it as the physical area in which a species exists (owing to the combination of ecological conditions that allow it to live). Another definition describes the niche as a function (not a physical property) performed by a species in the area in which it lives with other species (Elton 1927). Currently, the generally accepted definition is that of Hutchinson (1957), where the niche is described as a "space" that has many dimensions equal to the number of environmental variables that limit the survival and reproduction of the species. This "multidimensional volume of space" defines the environmental conditions that allow the species to exist and is synonymous with the "fundamental niche." The "realized niche" is a subset of the fundamental niche where, owing to competition and other processes, the species actually occurs.

The modeling conducted for this report used only physical environmental variables found in the owl's environment and did not consider other factors such as inter- or intraspecific competition that influence the owl's occurrence and persistence. Thus, important niche elements may have been omitted, and the results should be viewed as a first iteration but not a complete representation of the owl's realized niche.

BioMapper performs an ecological-niche factor analysis (ENFA) that summarizes multiple habitat variables into a few uncorrelated ecological factors in a process similar to principal component analysis (PCA). For a thorough explanation of the differences between ENFA and PCA, the reader is referred to Hirzel et al. (2004b). In factor analysis, the use of a covariance matrix implies that all of the original habitat variables are in the same units. If not, (for example, one variable is quadratic mean diameter in inches and another variable is elevation in meters above sea level) then the variable with the largest variability (in this case elevation) would have more influence in the analysis. This problem can be eliminated by using a correlation matrix, which converts all of the original habitat variables into the same units. This process also gives each variable equal weight in the analysis. BioMapper performs this variable standardization by taking the mean of each habitat variable within the global area and dividing by its standard deviation (Hirzel et al. 2002). Therefore, the global covariance matrix is, in fact, a correlation matrix. These same standardized variables are then used to compute a species covariance matrix by taking into account only presence points. Therefore, strictly speaking, the species matrix is a covariance and not a correlation matrix; however, the variables are still without units (Hirzel 2005).

The ENFA compares ecological conditions that correspond with species presence to conditions across the entire area being analyzed (Hirzel et al. 2002). The marginality factor explains most of the difference between the "species-presence" conditions and the conditions of the whole landscape. It is a linear combination of habitat variables where the average species presence values differ most from the average values of the available habitat. The larger the absolute value of a habitat variable coefficient, the more important that habitat variable is for defining the areas that have species presence. Negative habitat variable coefficients indicate that the species prefers lower values of that variable, and positive coefficients indicate species preference for higher values (Hirzel et al. 2002). Specialization factors are linear combinations of the original habitat variables where the distribution of the species-presence conditions shows the lowest variance relative to that of the province (fig. 3-8). They help explain how selective the species is compared to the available environmental conditions (Hirzel and Arlettaz 2003). For these

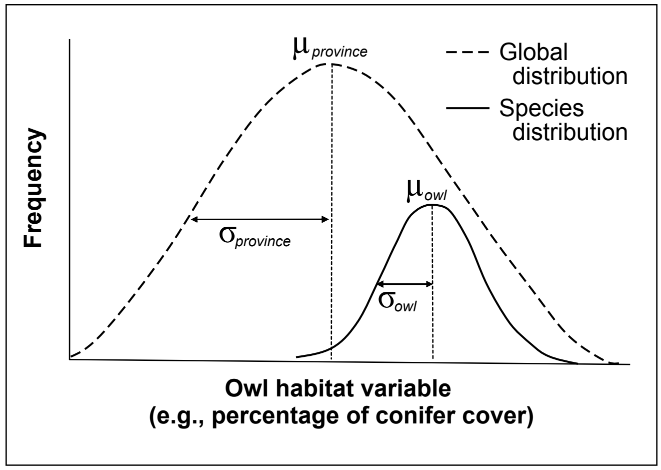

Figure 3-8—Distribution of a habitat variable for both the global area (the province) and the area within the province where owl presence is known (species distribution). The difference between the global and species means (μ) defines the marginality factor and the ratio of the standard deviations (σ) of the global and species distributions defines the specialization factors.

factors, only the absolute value is informative, and their sign (+ or -) does not matter. Most of the relevant ecological information is normally accounted for by the first few factors (marginality factor, plus the first few specialization factors). Together, the marginality and specialization factors define the multidimensional space that approximates the realized niche of the species.

To create a two-dimensional representation of this "niche" (in other words, a map) the "habitat suitability" value of every map unit (pixel) in the area being modeled is calculated by comparing its "ecological position" within the multidimensional space described by ENFA. To do this, the frequency distribution and the median of the presence-data pixels are computed along each ecological factor. Then, every map pixel is compared to these distributions, and the farther that cell's value is from the presence-data median, the less suitable it is. The species distribution along the factors is assumed to be normal, and the tails of the distribution have the lowest habitat suitability. The final habitat suitability index of each grid cell is based on the weighted average of these distances to the medians of each factor. For a more detailed description of ecological-niche factor analysis and the mathematical methods used in BioMapper, see Hirzel et al. (2002).

Calibrating the Model

BioMapper is a raster-based analysis tool, where the individual pixel is the unit of analysis. It has been shown to perform better when using larger presence-data samples (Hirzel et al. 2001, Williams 2003). We used a range of 1,890 to 49,100 (average = 20,120) pixels of owl presence data. Owl presence pixels were selected by buffering each owl-pair-location point by two pixels to create a 5- by 5-pixel (5×5) "window" of owl presence data. These 5×5 windows represent an area (a square approximately 4 ac) of concentrated owl pair activity (fig. 3-9). In other words, they are locations within a forest stand with recorded evidence of use by territorial spotted owls.

Northern spotted owls are only known to nest and roost and predominantly forage in forested areas (Thomas et al. 1990). A small subset of owl-pair-presence points occurred along forest/nonforested edges (such as meadows and recent clearcuts). These points were manually shifted away from the edges but kept within the forest stand in which they occurred. This was done prior to buffering the points to create the 5×5 window. The purpose of these slight spatial shifts was to avoid creating a buffer that would include obviously faulty presence data (for example, owls do not nest or roost in clearcuts) into the model training data set (fig. 3-9).

Spatial autocorrelation is commonly present in ecological data sets (Legendre 1993); however, it does not always generate bias (Dinzi-Filho et al. 2003). The similarity of adjacent pixels caused by environmental factors that influence species presence may produce positive autocorrelation when modeling with grid data (Diniz-Filho et al. 2003). Therefore, we conducted a sensitivity analysis to test for spatial autocorrelation that may have resulted from using the 5×5 windows of owl-pair-presence data. We did this by comparing outputs from model runs using only single pixels (the central pixel) from the grid to those where all pixels in the 5×5-grid data set were used. Outputs from both the single-pixel and 5×5 data showed almost no change in percentage of habitat suitability between the 0 to 40 and 41 to 100 habitat suitability categories (0.01 to 0.70 percent). Slightly greater changes (0.31 to 4.48 percent) were seen within the narrower habitat suitability intervals (0 to 20, 21 to 40, …81 to 100). The results also showed that marginality and specialization factors differed by only small amounts (1 to 4 percent) between the two data sets, and consisted of the same combination of habitat variable coefficients with similar real and absolute values. The mean variance between replicates (using cross-validation) increased by 17 to 29 times for models using single-pixel data indicating poorer model repeatability when using smaller presence samples rather than larger ones (5×5 window). Because both model outputs were nearly identical, spatial autocorrelation was not considered to be a problem. These results are

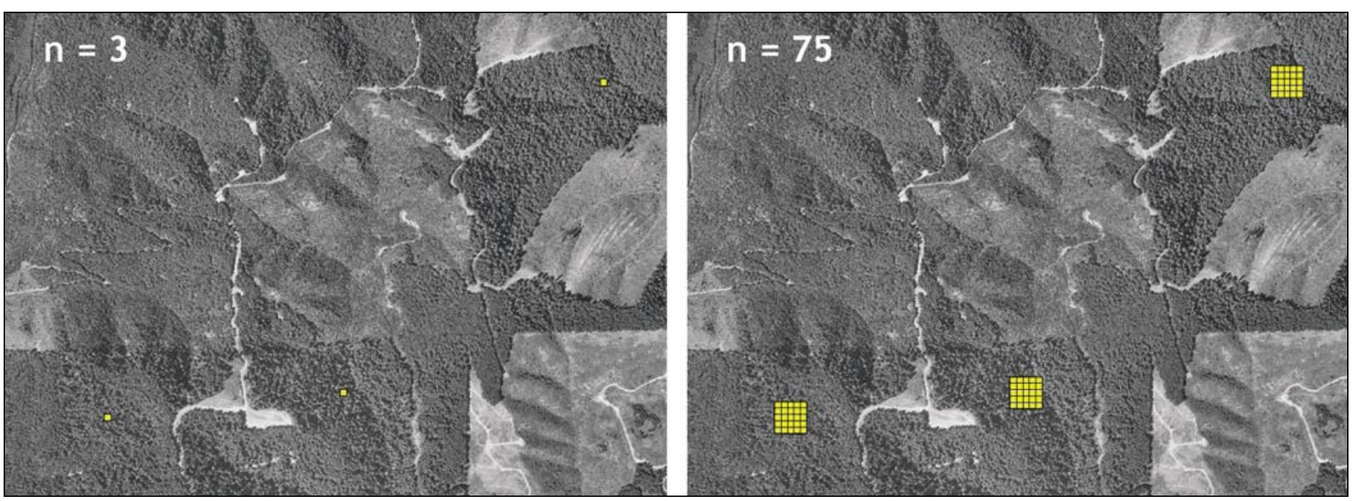

Figure 3-9—Owl-pair location points were converted into individual pixels to match the resolution of the underlying habitat variable data (for example, IVMP 25-m pixels) and then "buffered" by a 2-pixel width to create a 1.6 to 2.25 hectare "5×5 window" of owl presence data that BioMapper used to describe the species niche (n = number of pixels).

similar to those found by Leverette (2004) in a sensitivity analysis on presence-data sample sizes. According to Hirzel (2005), 50 points should be enough to adequately model habitat, provided they come from as many different individual owls as possible and are not too clumped within the area being modeled. In fact, given the choice, it would be preferable to use fewer points with good distribution than many points that are only clumped in one or two places within the modeled area. In summary, it appears that larger samples (5×5 window) improve model repeatability and accuracy (based on the k-fold cross-validation technique).

Validating the Model

When modeling habitat, it is important to determine if the model is based on "discrete" or "ambiguous" concepts; otherwise the model may be misinterpreted and not be defendable (Hill and Binford 2002). Models such as BioMapper, which are founded on theories of the niche and use terms like habitat suitability, are based on the fuzzy-set theory and should be tested in a manner consistent with ambiguous categories (Hill and Binford 2002). Correlation tests are well-suited for testing the relative accuracy of these types of models. Boyce et al. (2002) recommended that such models be evaluated for their predictive capabilities with a k-fold cross-validation technique (Fielding and Bell 1997) and Spearman rank correlation statistic. Hirzel et al. (2004a) incorporated this model validation procedure into version 3.0 of the BioMapper software. It produces an area-adjusted frequency graph (fig. 3-10) where the x-axis is the continuum of habitat suitability categorized into bins (categories, for example 0 to 20, 21 to 40,…81 to 100 habitat suitability) of equal sizes, and the y-axis is the area-adjusted frequency (AAF), which is the percentage of total owl points in the bin divided by the percentage of the global area (here, the forested portion of the province) in the same bin. The smaller the percentage of owl points and the larger the percentage of the global area in the bin, the smaller the AAF. For example, if 50 percent of both owl points and the global area are in the bin, the AAF for that bin would equal 1. This point (AAF = 1) separates the model predictions into two groups. One group contains bins with more validation points than expected by chance and the other group contains bins with fewer validation points than expected by chance.

The lower the variance between the replicated cross-validation curves, the better the predictive power. If all of the curves are close together, the model is highly reproducible. A linear curve with a positive slope is an indicator of a good model. The higher the Spearman rank correlation coefficient, the stronger the relation between predicted habitat suitability and owl presence. If the curve is a relatively flat line that hovers around the random frequency line (AAF = 1), the model is not much better than just giving random habitat suitability values to the cells in the map (Hirzel et al. 2004a).

Model Limitations

As with all models, there are limitations that should be recognized and addressed. One such limitation is in the use of the median algorithm in BioMapper. This algorithm assumes a normal and roughly symmetrical distribution in each environmental variable Hirzel et al. 2002). This is not always the case, and although Box-Cox transformations help to improve normality, they are not always successful. In addition, species distributions along a variable may not always be normal either, as some species may have positive linear correlations with the variable, and the species' preferred habitat may occur at an extreme of the gradient. Asymmetry may also occur if the global area is situated in a marginal or highly fragmented portion of the species range, where the most suitable environmental conditions are scarce and the species is forced to use less suitable areas (Hirzel and Arlettaz 2003). This asymmetry will cause the median algorithm to overrate suboptimal areas and underrate the most suitable ones.

BioMapper now incorporates other algorithms based on distance metrics that compute habitat suitability in the environmental space without assuming any distribution of the species points (Hirzel and Arlettaz 2003), therefore solving the problems potentially encountered by the "median" algorithms. Use of these distance algorithms (or a combination of the median and a distance algorithm) in future iterations of modeling may improve the quality of the model.

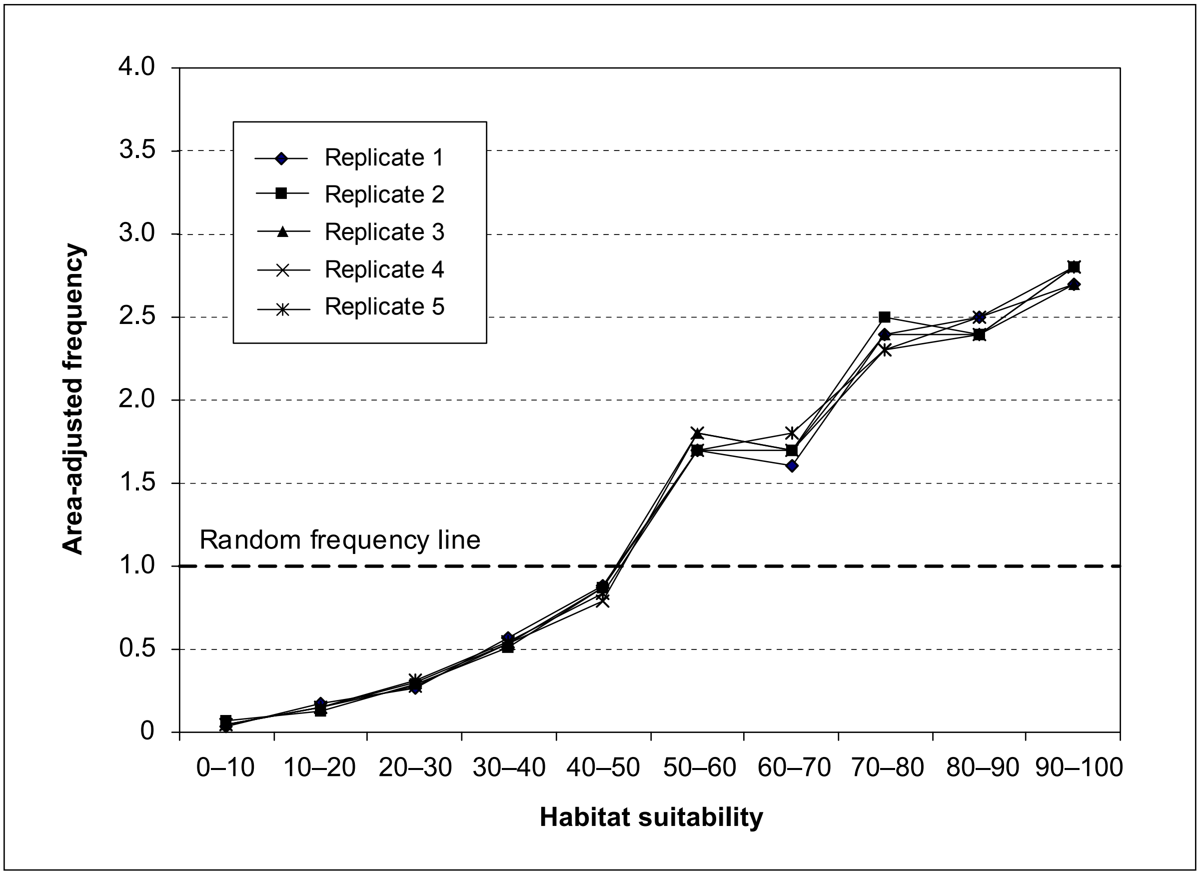

Figure 3-10—Area-adjusted frequency of habitat-suitability categories (bins) for locations of spotted owl presence data used to validate the model in the k-fold cross-validation process.

Profile models like BioMapper are also known to sometimes overpredict species presence (Engler et al. 2004). However, this occurs mainly when arbitrary decisions are made to categorize the continuum of habitat suitability (0 to 100) into terms such as "habitat" and "nonhabitat." This arbitrary categorization was avoided in our analysis.

In a "perfect world," the presence data should come from an unbiased sample of the species distribution within each physiographic province. However, this is not the case with the presence data currently available. Because these presence data are compared with the environmental background in which they occur, their distribution within that area can influence the outcome of the model. For this reason, we analyzed the distribution of our presence data within each physiographic province and the habitat-capable land within it. Nearest neighbor analysis of presence points (Clark and Evans 1954) indicates that the presence data in most provinces is fairly well distributed, although there is some tendency toward clumping (app. B). Presence data in Oregon Western Cascades and California Klamath provinces were not clumped and had good spatial distributions.

An Example of Model Application

Owl habitat suitability was mapped for all physiographic provinces by using physical, biotic, and abiotic habitat variables such as quadratic mean diameter of trees, canopy cover of coniferous trees, and elevation. Where possible, variables were kept in a continuous format. A description of the variables is summarized in appendix C.

The results from modeling owl habitat within the Oregon Coast Range are provided here to illustrate the modeling process and specific model outputs. A total of 1,560 owl-pair-location points were used to identify forest stands used by owls in this province (fig. 3-2). The application of the 5×5 window to these locations identified 34,073 pixels with owl presence. Six habitat variables, normalized by using Box-Cox transformations, were used and converted into five ecological factor maps (table 3-2) based on comparing their eigenvalues to MacArthur's broken-stick advice (Hirzel et al. 2002). All factors used had eigenvalues greater than one. These five ecological factors explained 97.5 percent of the difference between species occurrence and the habitat-capable portions of the Oregon Coast Range province. The median algorithm was used to calculate habitat suitability.

For the Oregon Coast Range province, the ecological-niche factor analysis resulted in a marginality of 0.916 and specialization of 2.339. A high marginality factor score (close to 1.0) indicates that the species occupies a very particular habitat compared to the global set of conditions. The marginality factor is also directly correlated to the predictive accuracy of the model (Brotons et al. 2004). The absolute value of the specialization factor (range from 1.0 to infinity) indicates how selective the species is in its use of available habitat. This sensitivity is explained, more simply, in terms of a tolerance index, which is the inverse of specialization (1/Specialization Factor). A species showing a tolerance value close to 1.0 is more of a habitat generalist and inhabits a wider niche than a species with a tolerance close to zero. The tolerance value for the owl in the Coast Range province was 0.43.

The first two ecological factors (the marginality factor and the first specialization factor) explain more than 70 percent of the owl's ecological niche space. The habitat variable coefficients that make up these two factors correlate with elements often cited as particularly relevant for spotted owl habitat selection. For instance, the strongest habitat variable was the product of tree diameter and conifer cover. The next strongest variable was a positive association with the quadratic mean tree diameter (QMD) followed by conifer cover (CC). The structure index "variety," which is the number of tree-size classes within the 5×5 window, also showed a positive relation. In this coastal Oregon province, elevation played a minor role in describing the niche space, but in some provinces it played a more important role (for example, the Washington Eastern Cascades province).

Model results were tested by using the k-fold cross-validation technique with five replicates. For each replicate, 80 percent of the presence data was randomly selected to

Table 3-2—Ecological factors and the habitat variables they were computed from in the ecological niche factor analysis for the Oregon Coast Ranges

	Marginality factor	Specialization factors			
	Factor 1 (35.0%)	Factor 2 (36.3%)	Factor 3 (14.5%)	Factor 4 (8.5%)	Factor 5 (3.2%)
Habitat variables	qmdcc (0.57)	qmdcc (-0.77)	cc (-0.67)	elev (-0.78)	bdlf (0.86)
	qmd (0.56)	qmd (0.55)	qmdcc (0.62)	cc (0.47)	qmdcc (0.32)
	cc (0.40)	cc (0.33)	qmd (-0.33)	qmdcc (-0.36)	cc (-0.28)
	variety (0.36)	bdlf (0.01)	bdlf (-0.23)	qmd (0.14)	qmd (0.25)
	bdlf (-0.27)	variety (0.01)	variety (0.09)	bdlf (0.12)	elev (0.13)
	elev (0.01)	elev (0.00)	elev (-0.03)	variety (-0.07)	variety (0.06)

Note: Variance and specialization accounted for by each factor is given in the parentheses in the column headings. Habitat variables with the largest absolute coefficient values have the most ecological meaning for describing the niche space. For the marginality factor only, positive values indicate the owl's preference for locations with higher values of that variable; negative signs indicate owl preference for lower values of that variable. The sign of the specialization factor has no ecological significance, but its absolute value relates to the niche space width along that factor's axis.

qmd = quadratic mean diameter.

cc = canopy cover of coniferous trees.

qmdcc = product of conifer tree size and canopy cover [(qmd × cc) / 10].

bdlf = canopy cover of deciduous trees.

variety = index of stand structure based on the number of tree diameter size classes within the 5×5 window.

elev = elevation from USGS digital elevation models.

model habitat, and the remaining 20 percent was used for validation. The area-adjusted frequencies for each replicate were averaged to produce an average Spearman rank correlation coefficient for the model's performance (fig. 3-10). The average Spearman rank correlation for the Oregon Coast Range was 0.988 ($P<0.001$) indicating the model predicted owl use locations well.

Simple statistics describing general habitat structure for each of the five habitat suitability bins are shown in table 3-3. The mean conifer size and cover measures in the last three bins (41 to 100) indicated that average QMD was at least 18 in and that conifer cover was greater than 76 percent. These values are consistent with our knowledge of spotted owl habitat relations. Standard deviations indicated overlap between the bins and emphasize the continuous nature of habitat conditions.

Table 3-3—A general description of owl-presence point distribution and forest structure attributes in the habitat suitability bins from raw BioMapper model output

Habitat suitability scores	Percentage of owl-presence point locations	Mean quadratic mean diameter (±1 SD)	Mean conifer cover (±1 SD)
		Inches	*Percent*
0–20	2.2	4 (0–7)	16 (0–37)
21–40	15.1	9 (0–22)	53 (26–80)
41–60	23.7	18 (3–33)	77 (57–97)
61–80	21.3	23 (9–37)	84 (68–100)
81–100	37.7	29 (17–41)	88 (75–100)

The raw (or pure) model output is a pixel map of owl habitat suitability from 0 to 100 (app. D fig. D-6). For the Coast Range, most of the owl pairs (90 percent) coincide with a raw model output value for habitat suitability greater than 37 as shown by the top arrow in figure 3-11. Raw model outputs have high heterogeneity (fig. 3-12) because of the underlying satellite imagery vegetation data where each individual pixel was classified separately. Although the heterogeneity captured on the satellite maps might be important to spotted owls, land managers identify more commonly with patches (Glenn and Ripple 2004). In addition, the spatial accuracy of owl location points is coarser than the raw model pixel resolution (100 m vs. 25 m or 328 vs. 82 ft). Therefore, model outputs were smoothed by using a raster algorithm that matched the 5×5 window resolution (125 × 125 m or 410 × 410 ft) representing owl presence and assigning to the center pixel the mean habitat suitability value of the 5×5 window. Smoothing is a commonly used map simplification practice that eliminates unwanted details while maintaining the level of information desired for further analysis or use of the map.

When the map is "smoothed" by calculating the mean habitat suitability in the 5×5 window, 90 percent of owl pair sites were in areas with average habitat suitability of more than 52, as shown by the bottom arrow in figure 3-11. By displaying the continuous (0 to 100) range of conditions, we avoided the arbitrary categorizing of the range of conditions into discrete categories of habitat (Hill and Binford 2002, Schreuder et al. 2004), while still describing, in general terms, the likely use of this range of conditions by the owl for nesting, roosting, and foraging (fig. 3-11). This strategy also supports the use of fuzzy accuracies for the vegetation variables used in the modeling. The method of display also allows the continuum of habitat-capable lands to be tracked over time as habitat conditions change.

Estimating Habitat Conditions in the Spotted Owl Reserve Network

A premise of the Plan was that a network of designated areas would be managed primarily to protect and enhance habitat for the spotted owl and other late-successional and old-growth forest related species. These designated areas are the reserved lands in the land use allocation map (fig. 3-1). They include late-successional reserves, congressionally reserved areas, administratively withdrawn areas, adaptive management reserves, managed late-successional areas, 100-ac owl core areas, and occupied marbled murrelet (*Brachyramphus marmoratus*) reserves. These areas, individually and in aggregate, form a network of small to large block- and linear-shaped patches of federal land in reserve status across the range of the owl. They range in size from tens of acres to tens of thousands of acres. However, not all reserves are of sufficient size to support reproductive pairs of owls (USDA USDI 1994).

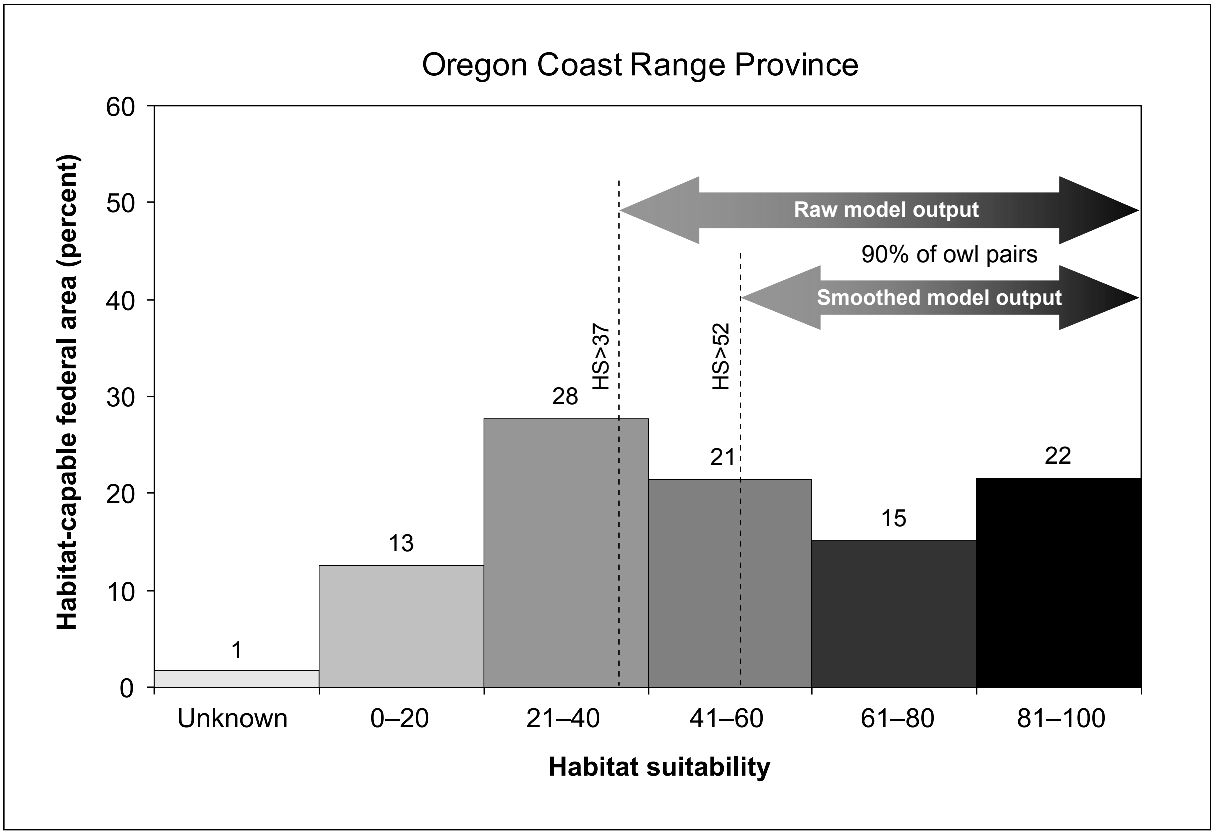

Figure 3-11—Owl habitat conditions expressed in terms of a habitat suitability histogram, shows the continuum of habitat conditions in the area being analyzed. The arrows above the graph show the range of conditions under which 90 percent of owl-pair activity occurs for both the raw and “smoothed” (5×5 window) model outputs. The owls occur mainly in the top three habitat suitability bins. In our analysis, portions of the raw data in each province were not able to be classified, and we were not able to estimate its habitat suitability. This proportion is shown by the”Unknown” bar in the graph.

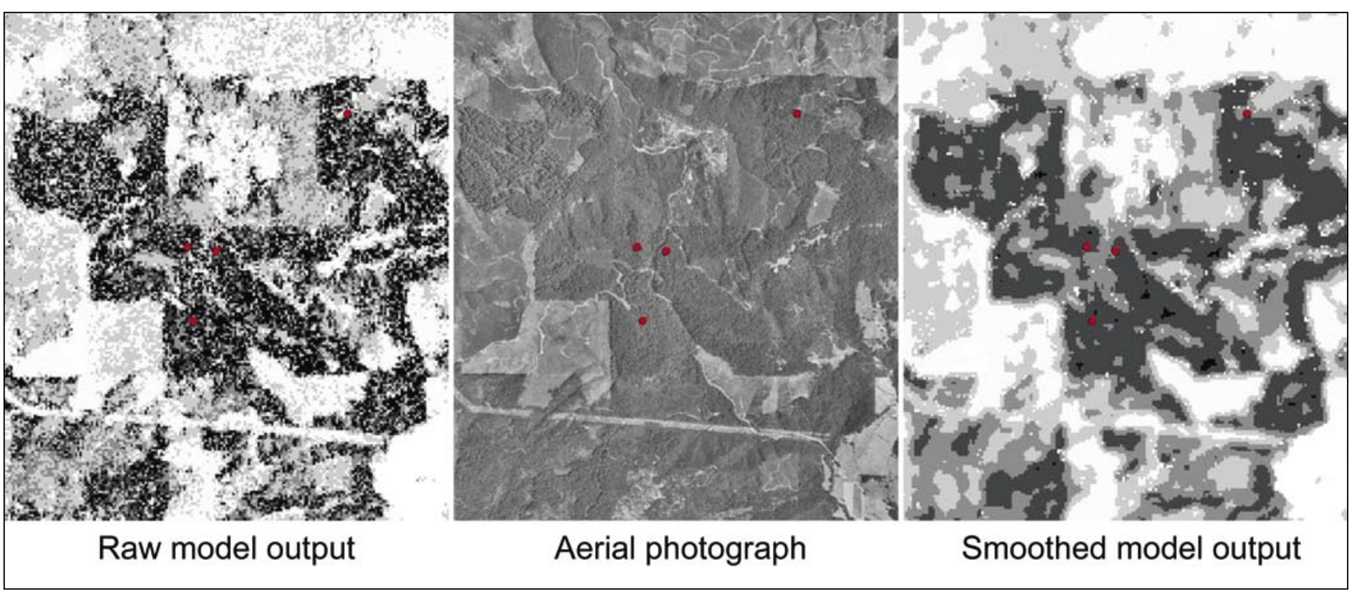

Figure 3-12—An example of the heterogenous raw model output and the more generalized smooth model output (5×5 window) from the Oregon Coast Range. Red points represent owl locations.

Prior to determining habitat conditions within the reserved network, we used the PATCH program from the HABSCAPES software package (Mellen et al. 1995) to aggregate the various sizes and shapes of reserved patches into large, reserved blocks to represent areas capable of supporting multiple pairs of owls. The PATCH program applies an algorithm that slowly "grows" patches of like values (in this case reserved land) by first identifying the patch core areas and then incrementally "growing" these cores by adding adjacent [reserved] pixels in accordance to specific rules set forth in the program's parameter file (Mellen et al. 1995).

Recognized differences in the owl's home range size from north (larger) to south (smaller) were represented by varying the minimum size of patches by state (Thomas et al. 1990). We modified the PATCH algorithm to aggregate adjacent reserved acres that met or exceeded 15,000 in Washington, 10,000 in Oregon, and 5,000 in California. The PATCH program provided a consistent, repeatable procedure to delineate the large, reserved blocks across most of the owl's range (fig. 3-13). However, because of discontinuity created by intervening nonfederal land—primarily associated with BLM lands in western Oregon—the program was not able to satisfactorily aggregate reserved patches by using the alternating sections on "checkerboard" lands. Because the Plan identified these large, checkerboard, late-successional reserves as areas capable of supporting multiple pairs of owls, they were added back into the map of large reserved blocks manually, based on the land use allocation layer.

The condition of owl habitat in the large, reserved blocks was estimated by querying the "raw" model (single-pixel) output for area in five equal-interval habitat suitability categories (0 to 20, 21 to 40…81 to 100). The resulting habitat suitability conditions inside the reserved blocks were compared to the habitat suitability conditions outside of the reserved blocks and portrayed in habitat suitability histograms for each province. They were then summed for state and rangewide estimates. In addition, the mean habitat suitability from the 5x5 grid was compared against historical conditions of owl habitat by using the 1930 PNW inventory map (Harrington 2003) and the 1945 map of California forests (Wieslander and Jensen 1946) for both inside and outside of the reserved blocks. These estimates indicate how vegetation conditions may have deviated from premanagement conditions and is portrayed in tabular form.

Estimating Habitat Change

To measure habitat change, the preferred approach would be to run the models by using the same type of habitat variable data from the time periods representing "before" and "after" (in our case, 1994 and 2003). The 2003 data did not exist, so we used the "change detection" data set to quantify the changes in habitat conditions from the baseline. Habitat change was estimated by using GIS and overlaying the change data (fire and harvest) on the habitat condition maps and subtracting the areas of overlap. The results were portrayed similarly to the baseline habitat condition profiles by using histograms to show the amount of change in each habitat condition category (fig. 3-14).

Changes were estimated for each physiographic province and the land use allocations in them. These changes were summed to get state and range estimates. Changes in habitat conditions inside and outside the large, reserved blocks in the spotted owl habitat management network were also calculated by using the same method.

Estimating Habitat Fragmentation and Patch Metrics

Both patch and fragmentation metrics were used to quantify landscape changes in owl habitat over time. Fragmentation occurs when a contiguous patch of habitat is perforated or incised, and the remaining habitat is separated into smaller, isolated patches (Jaeger 2000, Neel et al. 2004).

The FRAGSTATS program (McGarigal and Marks 1995) was used to analyze patch metrics on federal lands. However, masking out nonfederal lands created some artificial patch edges; therefore, results should only be used to describe patch changes and trends between periods. We used the class area, number of patches, mean patch size, total edge, total core area (habitat more than 100 m from edge), and mean core area patch indices (McGarigal and Marks 1995, Rempel and Carr 2003) to compare patch metrics for the 1994 and 2003 maps. We also compared

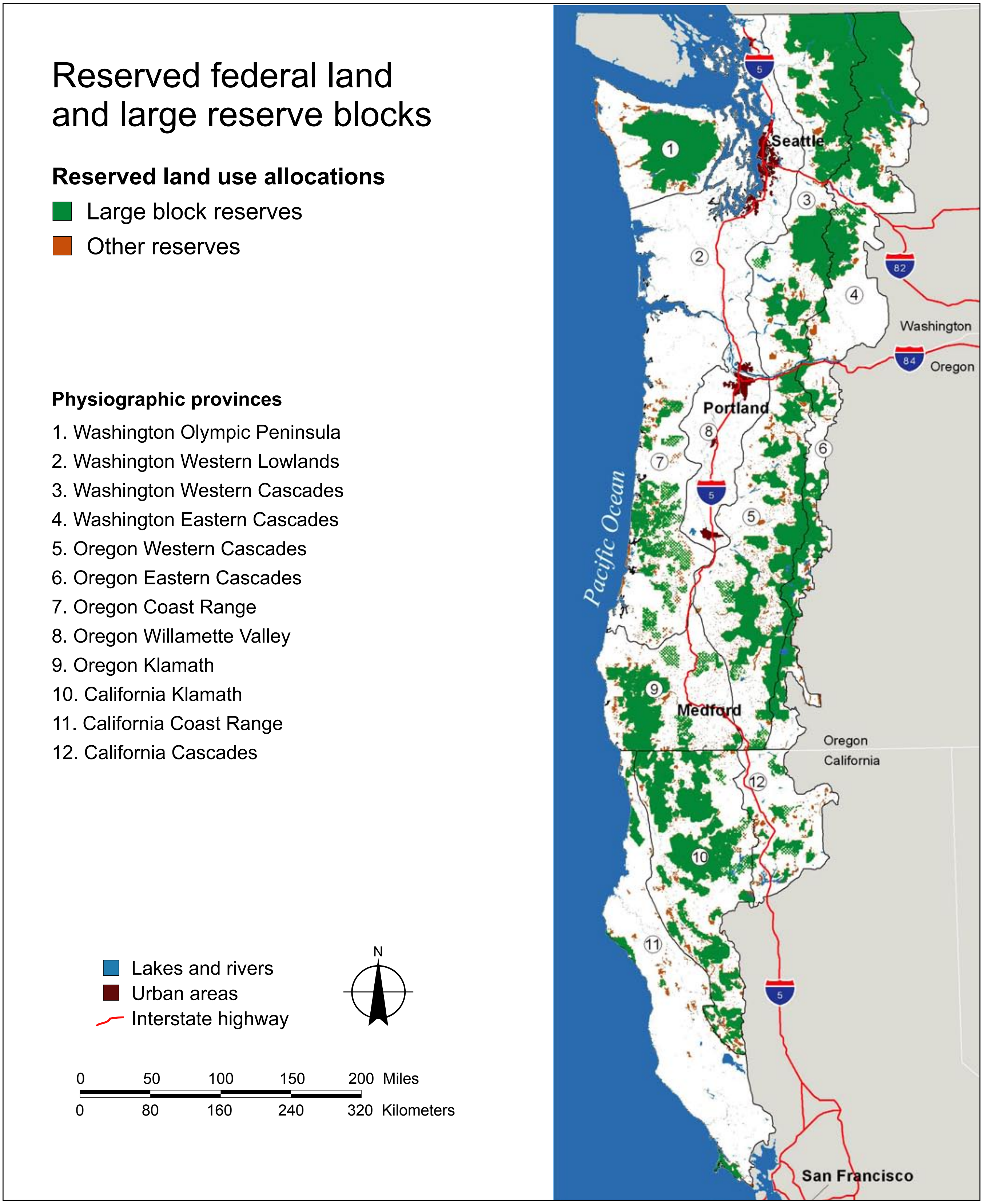

Figure 3-13—Large, reserve blocks intended to support clusters of reproducing spotted owls under the Northwest Forest Plan.

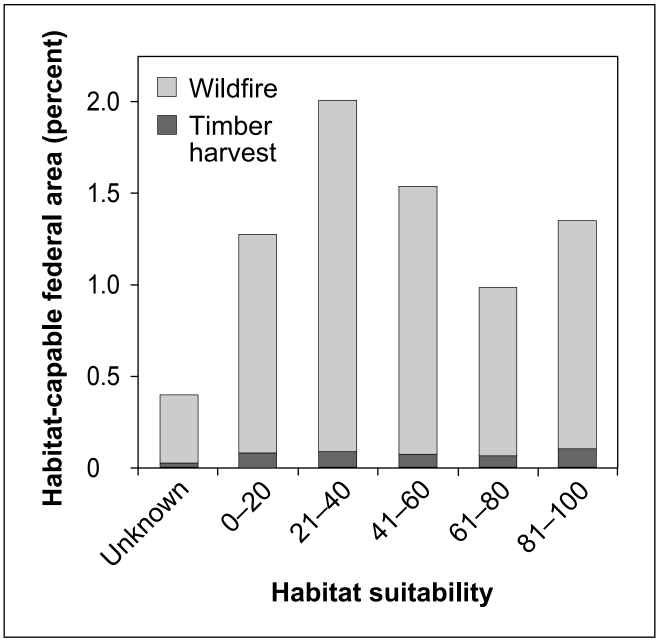

Figure 3-14—Change across the continuum of habitat conditions (before disturbance) in the area being analyzed. In this example, the majority of the change caused by fire was in habitat of lower suitability for owl nesting, roosting, and foraging.

these maps with the historical map (1930–40s). Because both the 1994 and 2003 maps were derived from satellite imagery, they had smaller minimum mapping units and more patch heterogeneity than the historical maps, which were hand drawn from field inventories and photointerpretation. This produced a problem that commonly arises when conducting spatial comparisons between maps of different origins (Glenn and Ripple 2004). Indices from FRAGSTATS have been shown to be sensitive to minimum mapping units and are considered poor indicators of fragmentation when comparing between maps of different origins (Saura 2002). To address this problem, we "smoothed" habitat suitability maps derived from the satellite imagery to reduce the amount of pixel noise. Each map was resampled to a 1-ha (2.47-ac) pixel size and finally, isolated pixels or clusters of pixels smaller than 10 ha (24.7 ac) were removed by using an eight-neighbor pixel-filtering procedure in the grid generalization tools extension of ArcView.[5] Habitat suitability values that corresponded with 90 percent of owl-pair occurrence represented the proxy for owl habitat for 1994 (table 3-4). The 2003 map was created by using the stand-replacing disturbance map as an overlay to identify habitat to be removed from the 1994 map.

Table 3-4—Mean habitat suitability range that accounted for 90 percent of the owl-presence points based on the average habitat suitability of the 5×5-pixel grid for each of the owl points

State/ physiographic province	Mean habitat suitability range	Habitat-capable area in mean habitat suitability range
		Acres
Washington		
Eastern Cascades	≥44	577,600
Western Cascades	≥45	1,204,900
Olympic Peninsula	≥56	549,100
Oregon		
Klamath	≥51	768,300
Eastern Cascades	≥50	442,300
Western Cascades	≥56	2,007,100
Coast Ranges	≥52	628,000
California		
Coast Range	≥33	215,500
Klamath	≥36	2,522,800
Cascades	≥36	387,800
Total		9,303,400

Metrics introduced by Jaeger (2000) were used to analyze the degree of habitat fragmentation across all land ownerships within each physiographic province. Jaeger indices—landscape division, splitting index, and effective mesh—were useful because they allowed us to compare landscapes of different size and were not sensitive to the omission or addition of very small patches. The landscape division metric is based on a degree of coherence. Coherence is defined as the probability that two animals randomly placed in different areas within the landscape might find each other (Jaeger 2000). Landscape division is the complement of coherence and is defined as the probability that two randomly chosen places in the landscape do not occur in the same patch. The lower the coherence index, the higher the landscape division index and the more fragmented the landscape. The splitting index is the number of patches that result when the landscape is divided into patches of equal size such that the new configuration leads to the

[5] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

same degree of landscape division. The effective mesh is the size of those patches and its lowest value is constrained by the map's pixel size (in our case it was resampled to 1-ha [2.47 ac] pixels) and is achieved when the landscape is maximally subdivided, or in other words, when every pixel is a separate patch. The mesh is at its maximum when the landscape consists of one single patch. Therefore, the higher the splitting index value, the smaller the effective mesh size and the more fragmented the landscape.

The Subdivision Analysis extension for ArcView (Lang 2004) and FRAGSTATS (McGarigal and Marks 1995) as part of the Patch Analyst extension for ArcView GIS (Rempel and Carr 2003) were the tools used to analyze the spatial arrangement of owl habitat for each physiographic province. Fragmentation and habitat patch indices were compared for three periods: (1) 1930–40s, representing historical conditions before widespread timber harvesting on federal lands; (2) 1994, representing conditions at the initiation of the Plan, and (3) 2003, representing conditions at the end of the first monitoring period.

Estimating Dispersal-Capable Federal Area

The condition of forest land between the large, reserved blocks is an important component of spotted owl habitat management because it allows for owl movement, or dispersal, from one large block to another. Thomas et al. (1990) explained that habitat between blocks functions better to allow owls to move the more nearly it resembles suitable habitat for the species in question. Dispersal movements are made primarily by nonterritorial spotted owls (juveniles and subadults) and, to a lesser degree, by adult spotted owls (Forsman et al. 2002). Assuring conditions to allow owls to move between the reserved blocks was an important facet of owl management under the Plan.

The federal forest-capable layer also represented the dispersal-capable layer. It shows the federal land that can develop and maintain forested conditions suitable for dispersing owls. Serpentine soils were not excluded because they are usually capable of growing vegetation that is at least minimally suitable for dispersal. No elevation limit was imposed on forests for calculating dispersal habitat.

Estimating Dispersal Habitat Conditions

We lacked sufficient owl dispersal "presence" data to develop a BioMapper model for predicting the full range of dispersal habitat conditions by using the same methods we used for owl habitat. Although the owl habitat maps did provide habitat conditions equally suitable for dispersal, the owl-presence points used to develop those models came from territorial owls, not juvenile owls dispersing from their natal areas. To do a credible job of modeling dispersal habitat, the presence points would have had to represent known locations of dispersing juveniles and subadults. These data were not available across the range of the owl because usable data points were only those from radio-marked birds, and that data set was limited.

Instead, we mapped dispersal habitat conditions based on queries of IVMP and CALVEG data for conifer size and cover to represent the forest conditions commonly used to describe dispersal habitat throughout the range of the owl (Thomas et al. 1990). This universal query selected all forest stands ≥11 in QMD and ≥40 percent canopy cover. Because of the lack of continuous size-class data in the Eastern Cascades provinces of Oregon and Washington and in the CALVEG data, the query was slightly different for those provinces. Size cutoffs ranged from 10 in (IVMP) to 12 in (CALVEG) rather than 11 in. Estimates of dispersal habitat conditions were summarized by physiographic province by using the dispersal-capable federal area layer as the basis for the analysis and summed for the states and range.

Estimating Owl Habitat Quality From Plot Data

A data query was developed for the current vegetation survey data by using expert knowledge to create a spectrum of conditions from low to high similarity with areas known to be used by spotted owls (table 3-5). Quadratic mean diameter (<10.5 in, 10.5 to 20.5 in and >20.5 in), canopy cover (≤40 percent and >40 percent) and canopy structure (single layer and multilayer canopy) data attributes were matched in all possible combinations and placed in six query groups (A through F). Group A includes federal area with <10.5 in QMD, 0- to 100-percent canopy closure, and both single- and multicanopy structure. Areas in this group were on the low end of the owl-habitat-similarity spectrum.

Table 3-5—Forest stand condition query for current vegetation survey plot data

	Low -------------------- Spotted owl habitat similarity -------------------- High					
	Query group					
Query attributes	A	B	C	D	E	F
Query part 1:						
Quadratic mean diameter (inches)	<10.5	10.5+	10.5–20.5	10.5–20.5	20.5+	20.5+
Canopy cover (percent)	0–100	0–40	41–100	41–100	41–70	>70
Strata	ALL	ALL	1 (single)	2+ (multi)	2+	2+
Query part 2:						
Quadratic mean diameter (inches)	NA	NA	NA	20.5+	NA	NA
Canopy cover (percent)				41–100		
Strata				1		

NA = Not applicable.

Groups B through F represented a progression of stand conditions increasing in tree diameter, canopy cover, and stand structure complexity as well as similarity to conditions used by spotted owls. Group F, for example, includes area with >20.5 in QMD, >70-percent canopy cover, and two or more canopy layers. Group F represents area on the high end of the conditions similar to those used by owls for nesting, roosting, and foraging. The data query was applied to current vegetation-survey-plot data in each physiographic province at elevations territorial owls are known to occupy delineated by the elevation isopleth. The query produces a numeric baseline of acres with confidence limits for each of the six query groups.

The query results are reported for the six data query groups by physiographic province and also by inside and outside of the large, reserved blocks in the province. Confidence intervals are provided for the 68- and 90-percent intervals for all area estimates by group The use of two common confidence intervals that span the range of reasonable intervals is an attempt to address the needs (or curiosities) of the audience. We thought this would be helpful as the confidence intervals were derived by bootstrapping, not by using the standard deviation, thus precluding the creation of other confidence intervals by the reader.

Confidence intervals for estimates were constructed by using a stratified two-stage bootstrapping routine. Each first-stage bootstrap sample consisted of n_h randomly selected samples (with replacement) from each of the h strata to produce one bootstrap estimate. This was repeated 500 times. From each first-stage plot, five subplots were randomly selected with replacement. The second-stage resample was conducted independently for each first-stage plot. The results were adjusted by using the Bias-Corrected and accelerated (Bc_{α}) method as detailed in Efron and Tibshirani (1993).

Because the current vegetation survey plot data includes only FS lands in the Pacific Southwest and Pacific Northwest Regions (Regions 5 and 6, respectively), and BLM lands in Oregon, the results are restricted to that inference area.

Results

Spatial Analyses

Estimated federal area—
Estimated acres of federal land administered by the FS, BLM, and NPS within the boundaries of the Plan is 24,444,100 (table 3-6 and fig. 3-1), which is about 44 percent of the total land in the Plan area. The federal acres were distributed across the three states under the Plan in the following proportions: Washington, 36 percent; Oregon, 39 percent; and California, 25 percent.

The distribution of federal land among the 12 physiographic provinces in the owl's range is shown in table 3-6. Of the total federal land area, Oregon's Willamette province had only 0.08 percent and Washington's Western Lowlands province had only 0.009 percent. No further analysis was conducted for these provinces because of their few federal acres. Five of the remaining provinces—the Western Cascades provinces in Oregon and Washington, the Eastern Cascades province in Washington, and the

Table 3-6—Federal land by province, state, and the range of the spotted owl by land use allocation

Province	Area	CR	LSR	AMR	MLSA	AW	LSR3	LSR4	AMA	Matrix/ RR	ND
	Acres	*- - - - - - - - - - - - -*				*Percent*				*- - - - - - - - - - - - -*	
Washington:											
Eastern Cascades	3,502,400	42	25	0	3	7	0	<0.5	4	20	<0.5
Olympic Peninsula	1,522,300	64	27	0	0	0	<.5	<.5	8	0	<.5
Western Cascades	3,721,000	47	27	2	0	5	<.5	<.5	4	13	<.5
Western Lowlands	2,300	76	0	0	0	0	0	0	0	24	0
Total	8,748,000	48	26	1	1	5	<.5	<.5	5	13	<.5
Oregon:											
Coast Range	1,413,300	2	54	12	0	3	3	<0.5	6	22	<0.5
Eastern Cascades	1,551,800	28	24	0	0	11	0	1	0	36	0
Klamath Mountains	2,118,200	12	39	2	0	2	1	2	11	32	<.5
Western Cascades	4,476,700	17	28	<.5	0	8	0	2	5	40	<.5
Willamette Valley	21,000	0	6	0	0	15	0	1	2	71	5
Total	9,581,000	15	34	2	0	6	1	1	6	35	<.5
California:											
Cascades	1,091,300	4	22	0	1	9	0	<0.5	15	49	0
Coast	503,600	38	25	0	0	10	<.5	<.5	0	27	1
Klamath	4,520,200	26	27	<.5	0	7	0	1	8	30	0
Total	6,115,100	23	26	<.5	<.5	8	<.5	<.5	9	33	<.5
Total		29	29	1	<.5	6	<.5	1	6	27	<.5
Reserve total	16,347,900	(67 percent)									
Nonreserve total	8,096,200	(33 percent)									
Plan total	24,444,100										

Note: See figure 3-1 for land use codes.

Klamath provinces in Oregon and California—contained 75 percent of the federal land in the Plan area. The remaining 25 percent of federal land was spread among the other five provinces.

The congressionally reserved land use allocation contained 29 percent of the federal land, rangewide. Another 30 percent is in the late-successional reserves allocation and adaptive management reserves (late-successional reserves) (table 3-6). These reserve allocations, along with the riparian reserves, provide the foundation for conserving late-successional forest under the Plan. The matrix and riparian reserve allocations[6] (combined in land use allocation map, fig. 3-1) contained 27 percent of the federal land, and the remaining 14 percent was spread among the other land allocations shown in table 3-6.

Estimated forest-capable federal area—
About 95 percent of total federal area in the range of the spotted owl can grow forests (Moeur et al. 2005). With the exception of the Coast province in California (70 percent), more than 90 percent of federal land in all provinces is considered forest-capable. Although a portion of the forest-capable federal land was assumed able to provide dispersal habitat for the northern spotted owl, not all of it could provide habitat for territorial spotted owls.

Estimated habitat-capable federal area—
About 74 percent of federal land has the capability to develop habitat for territorial spotted owls (table 3-7). Habitat-capable federal area (habitat-capable area)

[6] In this report, the matrix and riparian reserve allocations refers to the matrix land use allocation and that portion of the riparian reserve allocation that is intermingled with the matrix. This is necessary because the riparian reserves were not mapped; thus we were unable to discern what portion of the lands outside reserves were matrix and which were riparian reserves, so they are reported as combined allocations.

Table 3-7–Habitat-capable federal land by land use allocation in the range of the spotted owl

State/ physiographic province	Estimated habitat-capable area	Habitat-capable land in range	Reserve							Nonreserve		
			CR	LSR	AMR	MLSA	AW	LSR3	LSR4	AMA	MATRR	Not designated
	Acres		*Percent*									
Washington:												
Eastern Cascades	1,360,800	7.5	18.2	27.5	0	6.3	5.0	0	0.5	5.7	36.2	0.6
Western Cascades	2,363,300	13.1	28.4	36.0	3.1	0	5.7	<.5	<.5	6.1	19.8	<.5
Western Lowlands	NC											
Olympic Peninsula	1,067,000	5.9	51.7	36.3	0	0	0	.5	<.5	11.4	<.5	0
Total	4,791,100	26.5	30.7	33.6	1.5	1.8	4.2	<.5	<.5	7.1	20.0	<.5
Oregon:												
Klamath	1,818,700	10.1	11.2	39.0	1.6	0	1.3	0.9	1.7	11.4	32.6	<.5
Eastern Cascades	1,052,800	5.8	14.7	30.7	0	0	7.8	0	.7	0	46.1	<.5
Western Cascades	4,084,500	22.6	12.5	30.0	<.5	0	6.5	0	2.1	5.6	42.8	<.5
Coast Range	1,391,100	7.7	1.6	53.7	11.8	0	1.5	2.6	<.5	5.5	21.7	<.5
Willamette Valley	NC											
Total	8,347,100	46.2	10.7	36.0	2.4	0	4.7	0.6	1.6	6.1	37.5	<.5
California:												
Coast Range	346,700	1.9	40.0	31.7	0	0	9.2	<.5	<.5	0	17.3	1.6
Klamath	3,703,500	20.5	22.6	30.1	<.5	0	5.3	0	.7	9.5	31.3	0
Cascades	876,200	4.8	1.6	24.0	0	.8	8.0	0	<.5	15.0	50.4	0
Total	4,926,400	27.3	20.0	29.1	<.5	<.5	6.0	<.5	.6	9.8	33.7	<.5
Plan total	18,064,600	100	18.5	33.5	1.6	0.5	4.9	<.5	1.0	7.4	31.8	<.5

Note: NC = not calculated because of too little federal area in the province.

Note: see figure 3-1 for land use codes.

includes that below the elevation limits of occupancy by territorial owls (fig. 3-5) and not on serpentine soil areas (fig. 3-6).

Rangewide, over half (52 percent) of the habitat-capable area occurred in the combination of congressionally reserved land (18.5 percent), and late-successional reserves (33.5 percent). Another 32 percent occurred in the combination of matrix and riparian reserve allocations (table 3-7). Administratively withdrawn areas accounted for 5 percent, and the adaptive management areas contained 7 percent. The remaining allocations each contained less than 1 percent of the total.

In Oregon, 87 percent of federal land was habitat-capable, in Washington 55 percent, and in California 81 percent (tables 3-7 and 3-8). The elevation limit for occupation of habitat by territorial owls was primarily responsible for the pattern. Habitat-capable area was less in Washington compared to the other two states, where the elevation limit was at higher elevations (fig. 3-5).

The proportion of total habitat-capable area in the 10 provinces modeled was varied (table 3-8). The proportion in the Olympic Peninsula and Western Cascades provinces of Washington and the Eastern Cascades province in Oregon ranged between 60 and 70 percent (table 3-8). The proportion of the other three Oregon provinces was >85 percent. The Eastern Cascades province in Washington had the lowest proportion, only 39 percent. In California, more than 80 percent of the federal land area was habitat-capable in the Klamath and Cascades provinces. In the Coast province, the proportion was about 70 percent. Combined, the Western Cascades provinces in both Oregon and Washington and the Klamath provinces in Oregon and California contain two-thirds of the habitat-capable land in the Plan area (table 3-7). The higher the percentage of habitat-capable area,

Table 3-8—Habitat-capable federal land inside and outside of large, reserved habitat blocks in the range of the spotted owl

State/ physiographic province	Total federal land	Habitat-capable federal land	Habitat-capable land outside large reserved blocks	Habitat-capable land land inside large reserved blocks	Reserved block land: Habitat-capable	Reserved block land: Not habitat-capable
	Acres	*Percent*				
Washington:						
Eastern Cascades	3,502,400	39	53	47	26	74
Western Cascades	3,721,000	64	35	65	55	45
Western Lowlands		NC	NC	NC	NC	NC
Olympic Peninsula	1,522,300	70	24	76	65	35
Total	8,745,700	55	38	62	46	54
Oregon:						
Klamath	2,118,200	86	52	48	84	16
Eastern Cascades	1,551,800	68	55	45	54	46
Western Cascades	4,476,700	91	58	42	84	16
Coast Range	1,413,300	98	42	58	99+	<1
Willamette Valley		NC	NC	NC	NC	NC
Total	9,560,000	87	54	46	81	19
California:						
Coast Range	503,600	69	46	54	77	23
Klamath	4,520,200	82	48	52	79	21
Cascades	1,091,300	80	76	24	77	23
Total	6,115,100	81	53	47	78	22
Plan total	24,420,800	74	49	51	65	35

Note: NC = not calculated because of too little federal area in the province.

the greater the capacity of the land to produce owl habitat as long as the area fell within those land use allocations intended to support territorial owls (for example, congressionally reserved lands and larger blocks of late-successional reserves).

At the province scale, the distribution of habitat-capable area among the land use allocations intended to support territorial owls greatly depended on the presence of the allocations in the province (fig. 3-1). The congressional-reserve allocation was an important source of base habitat-capable area in some provinces, but not all. The proportion of habitat-capable area in the congressionally reserved allocation ranged from only 1.6 percent in the Coast Range province of Oregon and the Cascades province of California to 52 percent in the Olympic Peninsula province (table 3-7). All other provinces, except the Western Cascades province in Washington (28 percent) and the Coast province in California (40 percent), had less than 25 percent of their habitat-capable area in the congressionally reserved allocation.

The percentage of habitat-capable area in the late-successional reserves and adaptive management reserves ranged from 24 percent in the Cascades province of California to 66 percent in the Coast Range province of Oregon. The proportion of habitat-capable area in the late-successional reserves and adaptive management reserves in the remaining provinces was from 27 to 40 percent (table 3-7). The late-successional reserves were important sources of habitat-capable area for maintaining and restoring owl habitat.

The percentage of habitat-capable area in the matrix/riparian reserves (combined) ranged from 0 (the Olympic Peninsula has no matrix) to 50 percent (Cascade province of California). Percentages of habitat-capable area in the remaining provinces ranged from 17 to 46 percent. A portion of the habitat-capable area in these allocations contributes habitat for territorial owls in the short term and for dispersal habitat both short and long term.

The pattern of federal lands inside and outside the large, reserved blocks (reserved blocks) is depicted in figure 3-7. Rangewide, about 58 percent of federal land area was in the reserved blocks intended to provide habitat for clusters of owls under the Plan. However, about 35 percent of the land in the reserved blocks was not expected to provide habitat for territorial spotted owls because it is not habitat-capable. Rangewide, 51 percent of the habitat-capable federal area was in the reserved blocks and 49 percent was outside the blocks (table 3-8).

The federal land outside the reserved blocks was in smaller tracts of late-successional reserves, administratively withdrawn, matrix and riparian reserves. Under the Plan, all federal land area outside of the large, reserved blocks, regardless of allocation, contributes to dispersal habitat for movement of owls between the blocks and is not expected to provide habitat for territorial owls in the longer term, although some owls may be found there.

At the province scale, the proportion of habitat-capable area inside the large, reserved blocks varied (fig. 3-7 and table 3-8). With the exception of the Cascades province in California (24 percent), all provinces had at least 40 percent of their habitat-capable area in reserved blocks. The Olympic Peninsula and Western Cascades provinces in Washington and the Coast Range province in Oregon had the highest proportion of habitat-capable area inside the large reserved blocks with 76, 65, and 58 percent, respectively. Values in the other provinces ranged between 42 and 54 percent (table 3-8).

Within the reserved blocks, the proportion of habitat-capable area was lowest in the Eastern Cascades provinces of Washington (26 percent) and Oregon (54 percent). In the Olympic Peninsula province, 65 percent of the land in the blocks was habitat-capable (table 3-8). More than 75 percent of land in the reserved blocks was habitat-capable in the remaining provinces in Oregon and all provinces in California. In the Coast Range province in Oregon, almost all of the federal land in the reserved blocks was habitat-capable.

Estimated habitat suitability—
Maps depicting habitat suitability for territorial owls on federal lands were derived for each physiographic province from the IVMP and CALVEG vegetation data by using the BioMapper software program (app. D, figs. D-1 through D-10).

Our assessment of the model output relied on current scientific knowledge of habitat use by the owl in the activity centers around nest trees. These areas are used for nesting, roosting, and foraging by the owls. Marginality factor scores for the model output ranged between 0.72 and 0.96 for all provinces except the Klamath province in California where the score was 0.41 (app. E). This range of marginality scores is similar to those noted by Brotons et al. (2004) where BioMapper marginality scores ranged from 0.41 to 0.99, with model accuracies from 60 to 95 percent (mean accuracy of 74 percent) for 30 species of forest-dwelling birds. Specialization factor scores from our models ranged between 2.0 and 2.9 for all provinces in Washington and Oregon (app. E). In California, the scores were between 1.3 and 1.8. The tolerance indices for all provinces in Washington and Oregon ranged from 0.35 to 0.49. In California, the tolerance index values ranged from 0.56 in the Cascades province to 0.76 in the Coast province and 0.85 in the Klamath province. The higher index values in California suggest that the owl may use a wider range of habitat conditions compared to Washington and Oregon. This apparent use of a broader variety of habitats in the southern portion of the owl's range is consistent with findings by others (Zabel et al. 2003). However, the higher tolerance values may also be due to differences in vegetation data sources (IVMP vs. CALVEG).

Cross-validation of the Spearman rank correlations (r_s) indicated that our models predicted owl use locations well (table 3-9). On a scale of 0 to 1.0, the average r_s values ranged from 0.83 to 0.99 (P<0.001). In addition, we used owl telemetry data (independent of model training data) from 19 owl home ranges to test the models in three of the physiographic provinces in Oregon (app. F). The results from these independent data tests also indicated that the models predicted owl-use locations well (in those provinces) with average Spearman rank correlations greater than 0.93 (P<0.001).

Estimated Habitat Suitability for Habitat-Capable Area—

For each analysis scale, a portion of the total habitat-capable area had insufficient data to classify the vegetation attributes of the pixels, so this area is reported in the histograms as "unknown" (app. G). The classified portion, rangewide, (94 percent) was analyzed by using the BioMapper software.

Table 3-9—Cross-validated Spearman's rank correlations (r_s) between habitat suitability classes of equal intervals and area-adjusted frequencies for individual model replicates for each physiographic province modeled

	Olympic Peninsula		Western Cascades (WA)		Eastern Cascades (WA)		Coast Range (OR)		Klamath Mountains (OR)	
Replicates	r_s	*P*	r_s	*P*	r_s	*P*	r_s	*P*	r_s	*P*
1	0.84	<0.01	0.88	<0.001	0.82	<0.01	0.99	<0.001	0.96	<0.001
2	.84	<.01	.88	<.001	.83	<.01	.98	<.001	.98	<.001
3	.84	<.01	.89	<.001	.87	<.01	.99	<.001	.99	<.001
4	.84	<.01	.85	<.01	.82	<.01	.99	<.001	.99	<.001
5	.84	<.01	.89	<.001	.88	<.001	1.00	<.001	.95	<.001
Average	.84	<.001	.88	<.001	.83	<.001	.99	<.001	.96	<.001

	Western Cascades (OR)		Eastern Cascades (OR)		California Coast		Klamath Mountains (CA)		Cascade Mountains (CA)	
Replicates	r_s	*P*	r_s	*P*	r_s	*P*	r_s	*P*	r_s	*P*
1	0.94	<0.001	0.96	<0.001	0.99	<0.001	0.92	<0.001	0.96	<0.001
2	.94	<.001	.94	<.001	1.00	<.001	.99	<.001	.94	<.001
3	.84	<.01	.96	<.001	.99	<.001	.98	<.001	.98	<.001
4	.90	<.001	.94	<.001	.99	<.001	.94	<.001	.98	<.001
5	.88	<.001	.96	<.001	.98	<.001	.98	<.001	.96	<.001
Average	.87	<.001	.96	<.001	.99	<.001	.98	<.001	.99	<.001

Habitat suitability of habitat-capable area is displayed in histograms by five equal categories ranging from 0 to 100 (that is, 0 to 20, 21 to 40, and so on) for the range, by state and by province (app. G). Habitat suitability is also reported for the individual land-use allocations for each of the scales above. These histograms provide a habitat condition profile of the habitat-capable area. Habitat-capable area that falls on the right side of the profile (habitat suitability of 41 to 100) has characteristics similar to the characteristics of areas where territorial owls have been found. The closer to 100, the more similar they are. The habitat-capable area on the left side of the histogram (habitat suitability of 0 to 40) is less similar to the owl-presence locations and that area approaching 0 is the most dissimilar.

Tracking the change in the respective profiles over time is expected to provide useful information for judging the success of the Plan in maintaining and restoring habitat in the reserves, in general, and the reserved blocks, in particular. In time, the percentage of habitat-capable area in the 41 to 60, 61 to 80, and 81 to 100 categories should increase as habitat conditions improve in the reserved blocks. Conversely, the expected decline in habitat conditions in the matrix allocation can be monitored. Monitoring the proportion of the habitat-capable area in the 0 to 40 range will track the recruitment of area to the right side of the profile, especially from area in the 21 to 40 category, a large portion of which should move, by forest succession, from the left to right side of the profile in the next few decades. Thomas et al. (1990) noted that considerable owl use of midaged and young stands also occurred, suggesting that as forests develop along the continuum from young to old, they gradually become more suitable for spotted owls. The habitat condition profiles provide a useful tool for tracking habitat condition over time at various scales.

Across the owl range, about 57 percent of the habitat-capable area had a habitat suitability of ≥41. About 36 percent had a score in the range of 0 to 40, and the remaining 7 percent was in the unknown class (app. G, fig. G-1).

The histogram of habitat suitability for the land use allocations at the rangewide scale is shown in app. G, fig. G-1. The congressional reserves, late-succession reserves, and the combined matrix and riparian reserve allocations were the major contributors of habitat-capable area in the 41 to 100 range at the beginning of the monitoring period. More than 67 percent of the habitat-capable area in these combined allocations were in the habitat suitability range of 41 to 100. The congressionally reserved land had the highest percentage (67 percent) with a habitat suitability score of ≥41. The late-successional reserves were a close second with 60 percent of habitat-capable area ≥41 percent.

We assumed that at least 50 percent of the habitat-capable land in the adaptive management areas and the combined matrix/riparian reserve land use allocations would fall into the riparian reserves. Under that assumption, we estimated that, rangewide, over 80 percent of the habitat-capable area in the 41 to 100 range of habitat suitability occurs in a reserved land use allocation.

About 36 percent of habitat-capable area at the rangewide scale had habitat suitability scores of <41, indicating the presence of habitat-capable area that could grow into habitat over time depending on the allocations they were in. Almost half of the habitat-capable area in the lower suitability categories was in the congressionally reserved and late-successional reserve allocations, where the management focus is maintenance and restoration of late-successional forest and habitat.

At the state scale, the unknown category included 9 percent of habitat-capable area in Washington, 4 percent in Oregon, and 9 percent in California. In Washington, 52 percent had a habitat suitability score in the 41 to 100 range and another 39 percent was in 0 to 40 range (app. G, fig. G-2). Corresponding values for Oregon were 60 percent, ≥41, and 37 percent, <41 (app. G, fig. G-3). In California, 57 percent was ≥41 and 33 percent was <41 (app. G, fig. G-4).

In Washington, 63 percent of habitat-capable area in the congressional reserves had a habitat suitability score in the range of 41 to 100 (app. G, fig. G-2). In Oregon, although the percentage of habitat-capable area in congressional reserves was only 11, the percentage of habitat-capable area with a habitat suitability score ≥41 was 74 percent (app. G, fig. G-3). This land use allocation in California contained 20 percent of the habitat-capable area and 66 percent of that had habitat suitability scores of ≥41 (app. G, fig. G-4).

The late-successional reserves and adaptive management reserves contained 35 percent of the habitat-capable area in Washington compared to 38 percent in Oregon and 29 percent in California. The percentage in the 41 to 100 range of habitat suitability scores was 53 for Washington, 61 for Oregon, and 64 percent for California.

The managed late-successional areas were in Washington and California. In Washington, only about 2 percent of the habitat-capable area in the state was in this allocation and in California, less than 1 percent; more than 50 percent of habitat-capable area in the managed late-successional areas in Washington and 68 percent in California had a habitat suitability score of ≥41.

At the province scale, the proportion of habitat-capable area that could not be classified because data were lacking (reported as "unknown") ranged from 1.0 to 2.0 percent in the coast provinces in Oregon and California and the Eastern Cascades province in Oregon to 10 percent in the Cascades province in California and 15 percent in the Eastern Cascades province of Washington. The unknown category ranged between 5 and 9 percent in the five other provinces.

Habitat suitability for each province is displayed in the histograms in appendix G, (figs. G-5 through G-14). All provinces, except the Eastern Cascades in Washington (44 percent) and the Cascades in California (41 percent), had 50 to 63 percent of the habitat-capable area in the habitat suitability range of 41 to 100. Seven of ten provinces had between 30 and 40 percent of the habitat-capable area in the <41 category.

Histograms of habitat suitability for land use allocations by province are also shown in figures G-5 through G-14 in appendix G. Habitat suitability is provided by individual allocations and by province. For the congressionally reserved allocations, 36 to 83 percent of the habitat-capable area had a habitat suitability of ≥41 across the 10 provinces. For those four provinces where the congressionally reserved allocation contained >20 percent of the habitat-capable area in the province, 47 to 73 percent of such reserves had habitat suitability ≥41.

The late-successional reserves and adaptive management reserves were combined for analysis. Among the provinces, the proportion of habitat-capable area with habitat suitability of 41 to 100 in these reserves ranged from 53 to 69 percent. All of the provinces in Oregon and California had more than 57 percent of their habitat-capable area in the ≥41 habitat suitability range.

Habitat suitability was also analyzed for habitat-capable area inside and outside of the large, reserved blocks (fig. 16, app. D, and table 3-10). Across the range, about 62 percent (19.7 + 16.3 + 26.4) of habitat-capable area inside the reserved blocks had habitat suitability of ≥41, with two-thirds of that in the 61 to 100 range (table 3-10). Of the 32 percent of the habitat-capable area with <41 habitat suitability, slightly less than half was in the 0 to 20 category.

Habitat suitability conditions outside of the reserved blocks were different than inside. About 52 percent of the habitat-capable area was in the 41 to 100 category, and 41 percent was in the ≤41 category. The 0 to 20 category contained 21 percent of the habitat-capable area outside the reserved blocks.

The percentages of habitat-capable area in the ≥41 and <41 categories inside the reserved blocks in each state were relatively consistent and tracked proportionally with values at the rangewide scale. Outside of the blocks, California and Oregon mirrored the rangewide percentage for the ≥41 habitat suitability (52 percent), but Washington's (42 percent) was lower. All of the states had more habitat-capable area with habitat suitability of 0 to 20 outside of the reserved blocks compared to inside. Washington, in particular, had about 20 percent of its habitat-capable area in the 0 to 20 category inside the reserved blocks, and a notable 31 percent in the category outside the blocks.

At the province scale, the proportion of area inside the reserved blocks with a habitat suitability ≥41 was highest in the Olympic Peninsula (67 percent) of Washington, the Eastern Cascades (71 percent) and Western Cascades (68 percent) provinces in Oregon, and the Klamath province (66 percent) in California. In the other provinces, the percentage of habitat-capable area with a ≥41 habitat suitability ranged from 54 to 60 percent (table 3-10). Habitat suitability <41 ranged from 25 percent to 41 percent. None of the provinces had more than 25 percent of their habitat-capable area in the 0 to 20 habitat suitability category inside the reserved blocks, and 7 of 10 had less than 15 percent.

Table 3-10—Habitat-capable federal land inside and outside of large reserved habitat blocks, by habitat suitability category, in the range of the spotted owl

	Area inside habitat blocks, by habitat suitability category						Area outside habitat blocks, by habitat suitability category					
Physiographic province by state	Unknown	0–20	21–40	41–60	61–80	80–100	Unknown	0–20	21–40	41–60	61–80	80–100
							Percent					
Washington:												
Eastern Cascades	10.4	22.3	13.4	8.4	27.0	18.4	19.5	33.1	12.0	5.7	18.0	11.7
Western Cascades	6.2	22.0	16.5	16.6	12.3	26.4	5.8	29.8	16.8	13.2	12.1	22.2
Western Lowlands	NC											
Olympic Peninsula	5.9	13.6	13.4	20.1	9.2	37.8	8.0	30.6	18.1	17.7	8.3	17.2
Total	7.0	19.8	15.0	15.8	14.7	27.7	11.5	31.3	15.1	10.9	13.9	17.3
Oregon:												
Klamath	4.2	14.9	23.9	20.3	14.2	22.5	5.5	18.8	22.1	18.6	13.5	21.5
Eastern Cascades	0.7	19.5	9.0	35.3	16.5	19.0	0.8	31.4	12.3	29.5	12.1	13.9
Western Cascades	4.5	13.6	13.3	21.3	12.4	34.8	5.7	20.0	18.9	19.3	9.4	26.7
Coast Range	1.5	11.2	26.9	21.8	15.5	23.1	1.5	14.3	28.7	21.0	14.8	19.7
Willamette Valley	NC											
Total	3.3	14.2	18.0	22.8	14.0	27.7	4.5	20.5	20.0	20.7	11.3	23.0
California:												
Coast Range	1.8	8.4	32.3	21.9	19.3	16.3	2.6	30.6	24.8	18.7	14.3	9.0
Klamath	8.5	4.2	21.0	20.2	22.9	23.2	9.4	7.0	24.9	18.1	21.1	19.5
Cascades	8.9	13.6	23.2	13.0	20.8	20.5	11.1	30.6	21.0	13.5	13.4	10.3
Total	8.0	5.4	22.1	19.6	22.5	22.4	9.4	14.4	23.9	17.0	18.7	16.5
Plan total	5.7	13.8	18.1	19.7	16.3	26.4	7.4	20.9	20.1	17.6	14.0	20.0

Note: NC = not calculated because of too little federal area in the province.

Outside of reserved blocks, the proportion of habitat-capable area with a score ≥41 differed among provinces (table 3-10). All of the provinces in Oregon, along with the Klamath province in California, had 54 to 59 percent of the habitat-capable area in the ≥41 category. All of the other provinces had between 35 and 48 percent of the habitat-capable area in the 41-100 range. Percentage of area in the <41 habitat suitability category was much higher outside than inside the reserved blocks for most of the provinces. The Western Cascades province in Oregon and the Klamath provinces in Oregon and California all had 31 to 41 percent of the habitat-capable area in the <41 category. All the rest of the provinces had between 45 and 55 percent of the capable area in the <41 habitat suitability category.

Estimated change of condition for habitat-capable federal area—
Decreases in forest condition from stand-replacing wildfire and timber harvest were assessed for the habitat-capable area. Rangewide, 1.5 percent of the habitat-capable area was changed by stand-replacing events based on information from the regional change-detection data (table 3-11). Losses to harvest and wildfire are shown by province and land use allocation within province in table 3-11 and appendix H, figures H-5 through H-14. Total stand-replacing timber harvest affected about 0.26 percent of the habitat-capable area rangewide. Most of this change (35 percent of total change) was in the Western Cascades province in Oregon. About 90 percent of the stand-replacing timber harvest occurred in the matrix and riparian reserve (combined) allocation and adaptive-management area allocation.

Loss of forest in habitat-capable areas was less than 2.5 percent in each of the three states (app. H, figs. H-2 through H-4 and table 3-11). Washington had only a 0.44-percent loss, Oregon lost 2.38 percent, and California lost 1.32 percent. Loss of habitat-capable forest in the individual provinces was less than 1 percent in five provinces and less than 2 percent in four other provinces. The Klamath province in Oregon (7.5 percent) was the only province that lost forest on more than 5 percent of the habitat-capable area to stand-replacing harvest or wildfire.

The percentages of habitat-capable area lost in the habitat suitability categories ≥41 by timber harvest and wildfire are shown in table 3-12. Rangewide, stand-replacing timber harvest affected only 0.26 percent. No province lost more than 0.90 percent of the habitat-capable area to stand-replacing timber harvest, and all but one were under 0.5 percent.

The effect of stand-replacing wildfire events on habitat-capable area was less widespread, but it had more locally negative effects than did timber harvest. Only 1.3 percent of the habitat-capable area was affected by wildfire (table 3-11). The loss of habitat-capable area to wildfire as a proportion of province habitat-capable area, was greatest in the Eastern Cascades provinces of Washington (1.2 percent) and Oregon (0.85 percent), the Western Cascades province (0.68 percent) in Oregon, and the Klamath provinces in California (1.5 percent) and Oregon (7.1 percent).

The congressionally reserved and late-successional reserve allocations had the greatest proportional change of forest condition in habitat-capable area from wildfire (table 3-11 and app. H, figs. H-1 through H-14). Rangewide, 2.7 percent of the habitat-capable area in the congressionally reserved areas was affected, and about 1.6 percent in the late-successional reserves was affected. The highest percentage loss of habitat-capable area in all of these reserve allocations was in the Klamath province where about 24 percent of the habitat-capable area in the congressional reserves was lost and about 9 percent in the late-successional reserves. Losses in reserve allocations in other provinces were much lower.

Wildfire, unlike timber harvest, affected all categories of habitat suitability. Rangewide, 1.3 percent of the habitat-capable area in the 41 to 100 category was lost to wildfire (table 3-12). The loss of habitat-capable area with ≥41 habitat suitability was greater in provinces with more wildfires. In the Klamath province of Oregon, about 6.6 percent of the habitat-capable area in the 41 to 100 category was lost to wildfire, and nearly all (86 percent) of the loss was in the congressional and late-successional reserves. Loss of habitat-capable area in the ≥41 habitat suitability range was less than 1.6 percent in all other provinces (table 3-12).

Table 3-11—Habitat-capable federal land where stands were lost to stand-replacing timber harvest (H) and wildfire (F) in the range of the spotted owl

State and physiographic province	Total habitat-capable land	Area lost by land-use allocation: Total		CR		LSR		AMR		AW		MLSA		LSR3		LSR4		AMA		MATRR/ND	
		H	F	H	F	H	F	H	F	H	F	H	F	H	F	H	F	H	F	H	F
	Acres	*Percent*																			
Washington:																					
Eastern Cascades	1,360,800	0.26	1.17	0	2.20	0.07	0.46	0	0	<0.01	2.4	0.04	0.60	0	0	0.25	0	0.78	0	0.51	1.30
Western Cascades	2,363,300	.06	<.01	.02	<.01	<.01	0	0	0	0	0	0	0	0	0	.01	0	.13	0	.25	0
Western Lowlands	NC																				
Olympic Peninsula	1,067,000	.02	<.01	<.01	<.01	.02	0	0	0	0	0	0	0	<.09	0	0	0	.10	0	0	0
Total	4,791,100	.11	.33	<.01	.38	.02	.11	0	0	<.01	0.8	.04	0.6	.05	0	.11	0	.27	0	.39	.67
Oregon:																					
Klamath	1,818,700	.44	7.10	<.01	24.17	.16	8.90	0	0	<.01	11.1	0	0	.53	.90	.05	1.13	1.08	.86	.75	2.00
Eastern Cascades	1,052,800	.46	.85	<.01	.20	.52	1.12	0	0	.02	2.70	0	0	0	0	.12	0	0	0	.95	.59
Western Cascades	4,084,500	.39	.68	<.01	1.92	.07	1.14	0	0	<.01	.07	0	0	0	0	.06	.27	.47	<.01	.78	.20
Coast Range	1,391,100	.23	0	0	0	.08	0	<.01	0	<.01	0	0	0	<.01	0	.03	0	.50	0	.72	0
Willamette Valley	NC																				
Total	8,347,100	.38	2.0	<.01	6.70	.09	2.7	<.01	0	<.01	1.30	0	0	.16	.28	.60	.46	.72	.35	.80	.58
California:																					
Coast Range	346,700	.04	<.01	.09	0	.01	0	0	0	.02	.01	0	0	0	0	0	0	0	0	0	0
Klamath	3,703,500	.10	1.47	.05	3.17	.03	1.40	0	0	.09	1.71	0	0	0	0	.04	.46	.22	.24	.18	.66
Cascades	876,200	.66	.13	0	0	.13	.14	0	0	.16	.03	.01	0	0	0	0	0	1.37	<.01	.81	.18
Total	4,926,400	.19	1.13	.05	2.70	.04	1.14	0	0	.10	1.13	0	0	0	0	.03	.44	.54	.18	.37	.51
Plan Total	18,064,600	.26	1.30	.02	2.70	.057	1.63	<.01	0	.04	1.13	.04	.57	.14	0.23	.06	.41	.54	.20	.59	.57

Note: NC = not calculated because of too little federal area in the province.

Note: See figure 3-1 for land use codes.

Table 3-12—Habitat-capable federal land with a habitat suitability ≥41 where stands were lost to timber harvest and wildfire in the range of the spotted owl

	Loss of habitat-capable area with a habitat suitability ≥41	
State/physiographic province	Stand-replacing timber harvest	Stand-replacing wildfire
	Percent	
Washington:		
Eastern Cascades	0.38	1.10
Western Cascades	.10	<.01
Western Lowlands	NC	NC
Olympic Peninsula	.02	<.01
Total	.11	.32
Oregon:		
Klamath	.44	6.6
Eastern Cascades	.26	.74
Western Cascades	.36	.84
Coast Range	.23	0
Willamette Valley	NC	NC
Total	.35	1.87
California:		
Coast Range	.06	<.01
Klamath	.10	1.56
Cascades	.88	.14
Total	.19	1.28
Plan total	.26	1.30

Note: NC = not calculated because of too little federal area in the province.

Loss of habitat-capable area to timber harvest and wildfire amounted to 2.1 percent of the habitat-capable area inside large, reserved blocks (table 3-13). Loss in the reserved blocks was greatest in Oregon (3.7 percent) followed by California (1.9 percent) and Washington (0.3 percent). The provinces with the greatest losses inside the reserved blocks were the Klamath provinces in Oregon (13.0 percent) and California (2.3 percent). Nearly all of the loss inside the reserved blocks was caused by wildfire and concentrated in the Klamath province in Oregon. Losses inside the reserved blocks in other provinces ranged from 0 percent to about 1.4 percent.

Loss of habitat-capable area outside of the reserved blocks was less than 1 percent (0.48 + 0.47) at the rangewide scale and 1.2 percent at the state scale (table 3-14). The largest percentage loss of forest on habitat-capable area outside the reserved blocks was 2.42 percent in the Klamath province of Oregon. With the exception of the Eastern Cascades provinces in Oregon (1.27 percent) and Washington (1.46 percent), all other provinces lost less than 1 percent.

Loss of habitat-capable area with a habitat suitability of ≥41 because of stand-replacing timber harvest was assessed inside and outside of the large, reserved habitat blocks (table 3-15). Rangewide, the loss inside the reserved blocks from stand-replacing timber harvest was 0.04 percent and outside the blocks it was only 0.54 percent. Losses at the state scale paralleled the rangewide values both inside and outside the reserved blocks. In the provinces, losses ranged from 0 to 0.22 percent inside the blocks and 0.03 to 1.2 percent outside the blocks.

Losses of habitat-capable area in the ≥41 habitat suitability range because of wildfire were greater than those from timber harvest, but as noted earlier were limited to specific provinces (table 3-11). About 2.0 percent of the ≥41 habitat-capable area was lost, rangewide, inside the reserved blocks. Less than 0.5 percent of the area in this range of habitat suitability was lost outside the blocks, rangewide. Washington lost only 0.23 percent of the habitat-capable area ≥41 habitat suitability (table 3-15). Oregon lost about 3.2 percent and California about 2.0 percent. The Klamath provinces in Oregon and California had the highest percentage losses, 11.5 and 2.30 percent, respectively. They were followed by the Western Cascades province in Oregon with a 1.6 percent loss and the Eastern Cascades provinces in Washington and Oregon where each lost about 1 percent of the habitat-capable area inside the reserved blocks in this range of habitat suitability. All other provinces had less than 1 percent loss.

Losses of habitat-capable area in the ≥41 habitat suitability range outside the reserved blocks to stand-replacing fire was less than 0.6 percent rangewide. Only two provinces lost more than 1 percent of this habitat-capable area outside the reserved blocks. These provinces were the Klamath in Oregon (1.7 percent) and the Eastern Cascades in Washington (1.1 percent).

Table 3-13—Habitat-capable federal land inside of large, reserved habitat blocks where stands were lost to timber harvest and wildfire, by habitat suitability category, in the range of the spotted owl

Physiographic province by state	Area inside large reserved blocks lost to stand-replacing timber harvest, by habitat suitability category							Area inside large reserved blocks lost to stand-replacing wildfire, by habitat suitability category						
	Unknown	0–20	21–40	41–60	61–80	81–100	Total	Unknown	0–20	21–40	41–60	61–80	81–100	Total
							Percent							
Washington:														
Eastern Cascades	0.01	0.01	0.04	0.07	0.06	0.06	0.04	2.64	1.19	1.51	1.30	1.06	1.17	1.35
Western Cascades	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western Lowlands	NC													
Olympic Peninsula	0	0	0	0	.01	.01	.01	.01	.02	.01	0	.01	0	.01
Total	0	0	.01	.01	.02	.01	.01	.85	.29	.29	.15	.42	.17	.29
Oregon:														
Klamath	.10	.13	.08	.09	.14	.14	.11	16.24	14.88	14.77	13.12	11.51	9.94	12.96
Eastern Cascades	0	.09	.10	.03	.01	.01	.04	2.01	1.93	.42	.96	1.35	1.00	1.18
Western Cascades	.11	.13	.04	.02	.01	.03	.05	.48	.97	.95	1.34	1.65	1.69	1.36
Coast Range	.44	.12	.05	.05	.13	.02	.07	0	0	0	0	0	0	0
Willamette Valley	NC													
Total	.14	.12	.06	.04	.07	.05	.06	4.91	4.3	4.77	3.37	3.5	2.86	3.68
California:														
Coast Range	0	.04	.01	.10	.06	.09	.05	0	0	0	0	0	0	0
Klamath	0	.06	.03	.02	.05	.05	.04	2.23	1.79	2.15	2.41	2.23	2.42	2.28
Cascades	.09	.13	.08	.21	.27	.18	.16	.07	.06	.12	.08	.33	.12	.15
Total	.01	.07	.04	.04	.07	.06	.05	1.97	1.17	1.70	2.05	1.91	2.09	1.90
Plan total	.04	.06	.04	.03	.06	.04	.04	2.25	2.12	2.61	2.20	2.05	1.78	2.13

Note: NC = not calculated because of too little federal area in the province.

Table 3-14—Habitat-capable federal land outside of large, reserved habitat blocks where stands were lost to timber harvest and wildfire, by habitat suitability category, in the range of the spotted owl

Physiographic province by state	Area outside large reserved blocks lost to stand-replacing timber harvest, by habitat suitability category							Area outside large reserved blocks lost to stand-replacing wildfire, by habitat suitability category						
	Unknown	0–20	21–40	41–60	61–80	81–100	Total	Unknown	0–20	21–40	41–60	61–80	81–100	Total
	Percent													
Washington:														
Eastern Cascades	0.13	0.19	0.60	0.75	0.78	0.91	0.45	1.52	0.58	1.21	1.96	0.90	0.88	1.01
Western Cascades	.02	.06	.12	.21	.20	.41	.18	0	0	0	0	0	0	0
Western Lowlands	NC													
Olympic Peninsula	.01	.06	.09	.07	.15	.07	.07	0	0	0	0	0	0	0
Total	.09	.12	.27	.29	.50	.49	.27	1.01	.25	.38	.41	.46	.24	.40
Oregon:														
Klamath	.64	.76	.68	.70	.81	.79	.74	1.59	1.26	1.92	1.91	1.84	1.54	1.68
Eastern Cascades	.10	.52	.91	.82	.78	.79	.72	.01	.61	.18	.59	.79	.46	.55
Western Cascades	.81	.70	.47	.66	.68	.68	.65	.14	.14	.14	.18	.19	.22	.18
Coast Range	2.14	.58	.39	.43	1.12	.07	.50	0	0	0	0	0	0	0
Willamette Valley	NC													
Total	.81	.66	.54	.67	.80	.64	.66	.51	.44	.53	.56	.65	.47	.52
California:														
Coast Range	0	.02	.05	.03	.04	.02	.03	0	0	0	0	0	0	0
Klamath	.26	.15	.15	.11	.19	.19	.17	.90	.68	.50	.63	.65	.48	.60
Cascades	.74	.63	.50	.99	1.21	1.45	.82	.02	.14	.16	.13	.11	.12	.12
Total	.4	.39	.22	.29	.36	.38	.33	.62	.30	.39	.49	.52	.40	.44
Plan total	.42	.44	.39	.51	.57	.55	.48	.71	.35	.46	.52	.56	.42	.47

Note: NC = not calculated because of too little federal area in the province.

Table 3-15—Habitat-capable federal land inside and outside of large reserved habitat blocks with a habitat suitability ≥41 in the range of the spotted owl

	Area with a habitat suitability ≥41 lost inside habitat blocks		Area with a habitat suitability ≥41 lost outside habitat blocks	
State/physiographic province	Stand-replacing timber harvest	Stand-replacing wildfire	Stand-replacing timber harvest	Stand-replacing wildfire
		Percent		
Washington:				
Eastern Cascades	0.06	1.13	0.82	1.06
Western Cascades	0	<.01	.30	0
Western Lowlands	NC			
Olympic Peninsula	.01	<.01	.08	0
Total	.01	.23	.44	.35
Oregon:				
Klamath	.12	11.5	.76	1.74
Eastern Cascades	.02	1.06	.80	.60
Western Cascades	.03	1.6	.67	.20
Coast Range	.06	0	.48	0
Willamette Valley	NC			
Total	.05	3.18	.68	.54
California:				
Coast Range	.08	0	.03	<.01
Klamath	.04	2.35	.16	.58
Cascades	.22	.20	1.20	.12
Total	.06	2.01	.35	.47
Plan total	.04	1.98	.54	.49

Note: NC = not calculated because of too little federal area in the province.

Estimated total wildfire occurrence—
Approximately 13,200 wildfires were recorded on federal lands from 1994 to 2002 in the 10 provinces where we mapped owl habitat (Brown et al. 2002). About half were caused by lightning and half were human caused. However, about 75 percent of the total area burned was the result of a lightning ignition.

Using these data, about 1.7 million ac of federal land (USFS, NPS, and BLM) burned within the range of the northern spotted owl. Wildfire data (Healey et al. n.d.) show that about 230,000 ac were affected by stand-replacement fires—equating to about 14 percent of the total area burned. We assumed the remaining 86 percent burned at lower intensities and severities as they were not mapped as stand-replacing fires by Healey et al. (n.d.). We were unable to describe the effect this may have had on owl habitat conditions.

Because lightning-ignited wildfire accounts for the most area of habitat burned, the density of lightning fires was calculated in ArcView Spatial Analysis (by using a 10-mi search radius) and is shown in figure 3-15. Density of lightning-ignited wildfire occurrence is highest (>30 wildfires/100 mi^2) in the Cascade province of Oregon and Klamath province of California. It is moderate (10 to 30 wildfires/100 mi^2 in the higher Cascades of Washington, the northeastern portion of the Olympics, and the Klamath provinces. Of the over 6,000 lightning fires that have occurred from 1994 to 2002, we considered 17 as notable, based on their large sizes in relation to the minimum reserved block criteria used (for example, fires ≥15,000 acres in Washington, ≥10,000 acres in Oregon, and ≥5,000 acres in California are included). These larger fires were concentrated in areas of moderate to high lightning-ignited wildfire density (fig. 3-15), suggesting that those portions

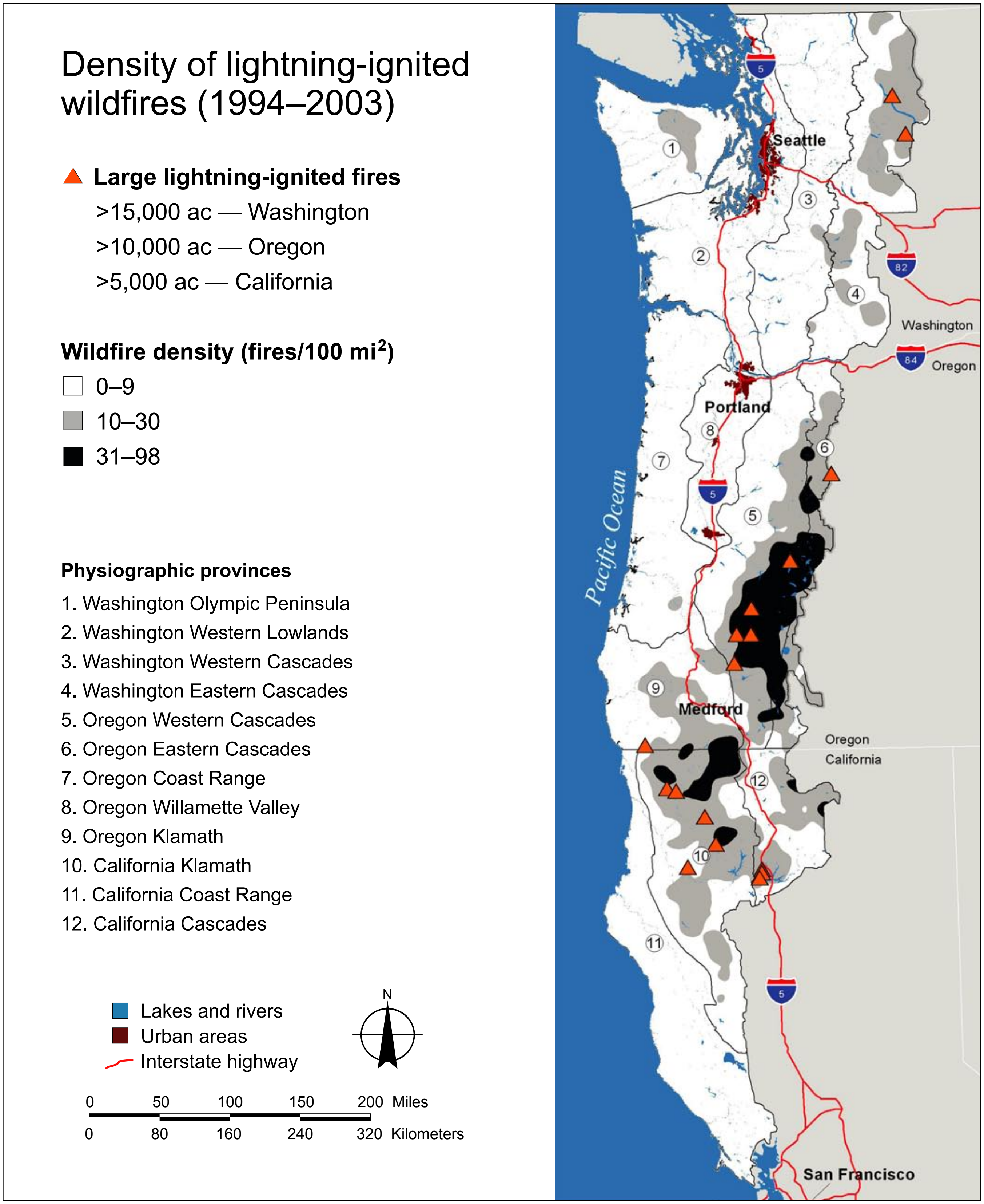

Figure 3-15—Spatial density of lightning fires in the range of the northern spotted owl.

of the owl's range may be more likely to experience large, habitat altering, lightning-ignited wildfires.

Table 3-16 shows the lightning fire density (number of fires divided by federal land area) in each province. It also shows the percentage of that federal land burned by these fires. Although the highest density of fires was in the Cascades of Oregon, the fires burned only 1 to 3 percent of the federal land. Although, in the eastern Cascades of Washington the fire density was only about one-third that of the Oregon Cascades, the fires burned a larger percentage (7.6 percent) of the federal land. The province with the highest amount of burned federal land is the Klamath province in Oregon, which has moderate lightning fire densities. Lightning fires did not appear to be significant in the coastal areas of the range.

Table 3-16—Lightning-fire density (number of fires divided by federal land area) in each province and the percentage of that federal land burned

Province	Fires per square mile	Percentage burned
Oregon Eastern Cascades	0.320	0.726
Oregon Western Cascades	.279	2.966
California Cascades	.219	3.454
California Klamath	.195	4.431
Oregon Klamath	.166	24.766
Washington Eastern Cascades	.131	7.624
Washington Olympic Peninsula	.063	.038
Washington Western Cascades	.029	.022
Oregon Coast Range	.029	.009
California Coast Range	.009	.001

Estimated habitat fragmentation and patch metrics— Jaeger indices describing fragmentation of habitat are shown in table 3-17. Based on all four of these indices, all provinces in Washington and Oregon appear more fragmented today than in the 1930s, especially in the provinces west of the crest of the Cascade Mountains. Provinces east of the Cascade Mountains show only slightly higher levels of fragmentation since the 1930s. The Olympic Peninsula of Washington was one of the least fragmented provinces historically (1930s), but has undergone the highest amount of landscape division change, a 53 percent increase (64.9 to 99.5). The habitat-capable lands in the Eastern Cascades province of Washington were naturally, highly subdivided (based on division and splitting indices) because of elevation. This province has had the least amount of fragmentation from stand-replacing timber harvest and wildfires. However, it still has one of the highest levels of habitat fragmentation exceeded only by the Coast and Klamath provinces of Oregon followed closely by the Eastern Cascades province of Oregon. Trends in most Washington and Oregon provinces, since 1994, indicate slight increases in habitat fragmentation based on landscape division indices. The Oregon Coast Range province shows the most increase in fragmentation since 1994, based on the splitting index.

In California, despite an increase in the number of habitat patches, fragmentation (based on all indices) appears to be less today than it was in the 1940s. This condition is most apparent in the Klamath province of California where the effective mesh size has quadrupled since the 1940s. We speculate that this may be due to differences in the historical map sources for the historical and contemporary periods. Or it may be that decades of fire suppression has resulted in decreased habitat fragmentation.

FRAGSTATS metrics describing the patches of habitat at the province scale at the beginning (1994) and the end of the monitoring period (2003), independent of land use allocations, are shown in table 3-18. There was very little change in any of the patch metrics during the Plan monitoring period (1994 to 2003). The changes that did occur were greatest in the Western Cascades and Klamath provinces in Oregon and the Cascades and Klamath provinces in California.

The patch metric results inside the reserved blocks were similar to those for the whole landscape, although they varied in magnitude for some (table 3-19). For example, the ratio of number of patches in the 1930s and 1940s to number of patches in 2003 was lower inside reserves indicating a smaller increase in the number of patches for lands inside the blocks over time. The average size of core areas was also larger inside the blocks than the landscape, in general.

Estimated dispersal-capable federal area— Rangewide, 95 percent of federal land was estimated to have potential to produce forest conditions to support dispersal habitat for spotted owls. Dispersal-capable federal

Table 3-17—Jaeger indices for habitat patches from 1930s and 1940s, 1994, and 2002 for the range of the spotted owl

State/physiographic province	Year	Number of patches	Jaeger indices: Coherence	Division	Splitting index	Effective mesh
			- - - - Percent - - - -			*Hectares*
Washington:						
Eastern Cascades	1930	767	0.38	99.62	266.04	4,769
	1994	12,053	.32	99.68	315.40	4,020
	2002	12,532	.24	99.76	420.30	3,016
Western Cascades	1930	1,114	5.09	94.91	19.64	94,464
	1994	11,456	.80	99.20	124.66	14,878
	2002	11,384	.79	99.21	125.86	14,735
Olympic Peninsula	1930	537	35.14	64.86	2.85	350,088
	1994	4,838	.51	99.49	195.71	5,089
	2002	4,705	.51	99.49	196.54	5,068
Oregon:						
Klamath	1930	648	13.94	86.06	7.17	188,372
	1994	9,263	.17	99.83	586.86	2,301
	2002	9,642	.13	99.87	793.50	1,702
Eastern Cascades	1930	381	.71	99.29	140.30	4,839
	1994	4,066	.40	99.60	248.31	2,732
	2002	4,209	.37	99.63	273.80	2,478
Western Cascades	1930	578	36.18	63.82	2.76	887,536
	1994	12,525	18.65	81.35	5.36	457,132
	2002	13,337	17.57	82.43	5.69	430,609
Coast Range	1930	996	10.95	89.05	9.13	237,703
	1994	13,974	.15	99.85	646.08	3,359
	2002	14,416	.05	99.95	2,113.12	1,027
California:						
Klamath	1930	948	8.65	91.35	11.56	174,051
	1994	5,150	41.95	58.05	2.38	842,852
	2002	5,905	40.29	59.71	2.48	809,479
Cascades	1930	274	4.19	95.81	23.84	31,234
	1994	1,991	5.42	94.58	18.45	40,325
	2002	2,147	5.26	94.74	19.02	39,105
Coast	1930	1,247	4.34	95.66	23.04	70,145
	1994	5,573	10.49	89.51	9.54	168,965
	2002	5,881	10.18	89.82	9.82	164,005

Table 3-18—FRAGSTATS metrics for habitat patches on federal lands from 1930s and 1940s, 1994, and 2002 in the range of the spotted owl

State/physiographic province	Year	Number of patches	Total patch area	Average patch size	Habitat edge	Total core area	Average core area size
		Acres			*Miles*	*Acres*	
Washington:							
Eastern Cascades	1930	495	437,523	884	3,876	329,432	568
	1994	2,044	678,615	332	12,254	386,639	119
	2002	2,016	668,237	331	12,074	380,637	119
Western Cascades	1930	515	1,432,652	2,782	7,419	1,221,803	2,190
	1994	2,467	1,313,521	532	20,087	815,225	162
	2002	2,454	1,312,250	535	20,093	813,863	162
Olympic Peninsula	1930	234	786,795	3,362	3,307	690,061	3,366
	1994	933	615,431	660	8,036	421,019	221
	2002	929	615,228	662	8,029	420,974	221
Oregon:							
Klamath	1930	863	1,001,418	1,160	7,573	774,289	621
	1994	3,405	899,845	264	18,001	459,234	78
	2002	3,426	837,289	244	17,435	413,870	71
Eastern Cascades	1930	274	308,337	1,125	2,320	242,639	820
	1994	1,067	462,367	433	8,190	259,516	106
	2002	1,079	456,901	423	8,119	256,111	106
Western Cascades	1930	851	2,812,209	8,166	10,364	2,495,754	1,971
	1994	2,693	2,867,721	2,631	32,081	2,027,954	307
	2002	2,674	2,834,176	2,619	32,461	1,987,537	295
Coast Range	1930	659	941,233	1,428	5,930	748,136	670
	1994	3,074	704,962	229	13,774	359,443	75
	2002	3,019	701,769	232	13,731	357,582	75
California:							
Klamath	1930	714	2,238,585	3,135	9,276	1,964,117	2,067
	1994	2,948	2,925,126	992	25,163	2,231,696	568
	2002	3,060	2,886,142	943	25,753	2,181,835	532
Cascades	1930	221	294,306	1,332	1,739	242,239	859
	1994	1,220	427,567	350	5,650	276,903	171
	2002	1,223	424,108	347	5,705	272,482	167
Coast	1930	225	159,849	710	970	131,544	678
	1994	891	222,740	250	2,765	150,714	200
	2002	893	222,671	249	2,764	150,667	200

Table 3-19—FRAGSTATS metrics for habitat patches inside the large reserved habitat blocks from 1930s and 1940s, 1994, and 2002 in the range of the spotted owl

State/physiographic province	Year	Number of patches	Total patch area	Average patch size	Habitat edge	Total core area	Average core area size
			Acres		*Miles*	*Acres*	
Washington:							
Eastern Cascades	1930	359	247,670	690	2,541	178,644	442
	1994	973	398,700	410	6,436	243,489	165
	2002	950	393,719	414	6,317	241,115	167
Western Cascades	1930	407	960,680	2,360	5,556	807,522	1,767
	1994	1,764	912,942	518	13,710	574,360	177
	2002	1,760	912,907	519	13,707	574,360	177
Olympic Peninsula	1930	107	588,531	5,500	2,507	517,738	4,502
	1994	605	550,423	910	6,427	392,856	295
	2002	605	550,410	910	6,427	392,849	295
Oregon:							
Klamath	1930	321	510,510	1,590	3,478	409,459	1,042
	1994	1,224	448,581	366	8,412	243,091	94
	2002	1,254	398,478	318	7,951	206,631	81
Eastern Cascades	1930	192	149,884	781	1,369	112,766	564
	1994	512	254,382	497	3,939	156,486	154
	2002	511	251,812	493	3,896	155,083	154
Western Cascades	1930	348	1,144,775	3,290	4,478	1,016,454	2,696
	1994	695	1,342,244	1,931	11,998	1,026,815	532
	2002	715	1,322,258	1,849	12,276	1,001,223	497
Coast Range	1930	327	546,348	1,671	3,047	448,855	1,097
	1994	1,384	439,641	318	7,956	239,029	96
	2002	1,360	439,006	323	7,942	238,705	96
California:							
Klamath	1930	290	1,209,984	4,172	4,548	1,079,802	3,292
	1994	1,181	1,600,347	1,355	12,550	1,257,322	848
	2002	1,272	1,568,236	1,233	13,043	1,215,806	745
Cascades	1930	63	112,079	1,779	580	94,693	1,297
	1994	260	143,869	553	1,649	99,002	275
	2002	260	143,494	552	1,659	98,437	273
Coast	1930	46	106,717	2,320	405	95,540	2,810
	1994	148	139,421	942	1,161	108,479	650
	2002	148	139,421	942	1,161	108,479	650

area was mapped for the physiographic provinces (app. I, and table 3-20); in all of them, except the Coast province in California (70 percent), more than 90 percent of federal land area could support forest with the potential to provide dispersal habitat for northern spotted owls (table 3-20). Not all land with potential was expected to support dispersal habitat at any one point in time. Riparian reserves, outside of the large reserved blocks, are counted on as major contributors to dispersal habitat under the Plan. Additional contributions come from smaller reserves (100-ac owl activity centers) and to a lesser extent from the matrix.

The assessment of dispersal habitat focused on land outside of the reserved blocks (app. I) because this land was identified in the Plan as key to movement of owls between the reserved blocks. The percentage of dispersal-capable area outside the large reserved blocks ranged from 18 to 30 percent in the Washington provinces and from 42 to 55 percent in the provinces in Oregon and California. The one exception was the Cascades province in California where about 75 percent of the dispersal-capable land fell outside of the large reserved blocks. These percentages indicate that the reserved blocks make significant contributions to dispersal conditions at the landscape scale in Washington and to a lesser degree in the other two states.

Estimated dispersal habitat condition—
At the range scale, 55 percent of the dispersal-capable area was in dispersal habitat. In 8 of 10 provinces, more than 50 percent was currently in dispersal habitat (table 3-20). The Eastern Cascades province of Washington had 35 percent in dispersal habitat and the Klamath province, 48 percent.

Table 3-20—Dispersal-capable federal land and current condition on the entire federal landscape and for that portion outside the large reserved blocks in the range of the spotted owl

		Total federal land		Federal land outside large, reserved blocks	
State/physiographic province	All land	Dispersal capable	Currently in dispersal habitat	Dispersal capable	Currently in dispersal habitat
	Acres	- - - - - - - -	- - - - *Percent*	- - - -	- - - - - - - -
Washington:					
Eastern Cascades	3,502,400	96	35	30	34
Western Cascades	3,721,000	95	56	26	55
Western Lowlands	NC				
Olympic Peninsula	1,522,300	93	60	18	49
Total	8,745,700	95	48	26	45
Oregon:					
Klamath	2,118,200	99	48	51	47
Eastern Cascades	1,551,800	95	61	45	57
Western Cascades	4,476,700	98	65	54	59
Coast Range	1,413,300	99	51	42	47
Willamette Valley	NC				
Total	9,560,000	98	59	50	54
California:					
Coast Range	503,600	70	68	47	61
Klamath	4,520,200	93	60	45	54
Cascades	1,091,300	91	57	75	53
Total	6,115,100	91	60	51	54
Plan total	24,420,800	95	55	42	52

Note: NC = not calculated because of too little federal area in the province.

Dispersal habitat conditions on the dispersal-capable area outside the large blocks for those provinces (mostly in Oregon and California) where more than 30 percent of the area was outside the reserved blocks, ranged from 47 to 61 percent. The variation in the pattern and amount of dispersal habitat present on the landscape at the beginning of the monitoring period is apparent (app. I). The dispersal habitat maps show the mosaic of dispersal-capable area currently in dispersal habitat condition.

Nonspatial Analyses

Estimated federal area in forest structure groups—
The FS and BLM land in the six data query groups (table 3-5) is reported by physiographic province (table 3-21). A portion of the plots in each province did not have any data for the attributes of interest so they were omitted from the analysis and reported in the summary tables under the "unknown" category. The unknown plot acreage ranged from 5 to 11 percent of the total acres in a province.

Table 3-21 shows the baseline acres in each of the six groups for the described FS and BLM land. At the beginning of the monitoring, groups D, E, and F, combined, accounted for about 28 percent of the FS and BLM land in the Eastern Cascades provinces of both Oregon and Washington and 34 percent of the FS land in the Coast Range of California. In the other provinces, about 40 to 50 percent of the FS and BLM land was in these three groups. On the other end of the habitat condition spectrum, the percentage of the FS and BLM land in category A, the poorest habitat condition, is fairly consistent among the provinces ranging between 20 and 30 percent. The exceptions are the FS land in Olympic Peninsula province in Washington (35 percent) and FS and BLM land in Oregon Klamath province (37 percent). Over time, monitoring the area change in the groups and the percentage of area in the groups will provide information on the maintenance and restoration habitat for spotted owls.

The area in the six data query groups inside and outside of the reserved blocks was also summarized. About 48 percent of the FS and BLM land fell inside the reserved blocks, and the remaining 52 percent was outside the blocks (tables 3-22 and 3-23). Taking into account the absence of all NPS land in the range and BLM land in California (about 2.5 million additional acres, most of which would be inside the blocks) in the plot data, we find that these percentages are similar to the results of the spatial analysis (51 percent inside and 49 percent outside). The area in groups D, E and F, combined, makes up 45 to 60 percent of the total in all provinces except the Eastern Cascades provinces of Washington and Oregon. In these provinces, about 35 percent of the area is in groups D, E, and F. Outside of the blocks, the area in groups D, E, and F accounts for a much smaller proportion of the total area. Between 22 and 50 percent of the area outside the blocks are in groups D, E, and F. Only one province, the Western Cascades province in Oregon (46 percent) has more than 45 percent of the area outside the blocks in groups D, E, and F. The area in groups A, B, and C, combined, is much higher outside of the reserved blocks than inside, as expected from the D, E, and F values reported above.

The plot data would be the most logical source to use in creating an estimate of owl habitat, but it would be incomplete because of the absence of data from NPS land in the range and BLM land in California. We did not create queries to estimate owl habitat, but instead chose to estimate habitat conditions across the full spectrum from low to high quality as we did with the spatial analysis.

Estimated change of federal area in forest structure groups—
Although some remeasured plot data are available, the processing of the canopy strata and cover attributes was not complete, thus we could not run the data query to assess the changes in the six data query groups from the first to second measurement occasion. The assessment of the change in the six groups will be completed during the next monitoring period.

Limitations of Analysis

Although we were able to quantify changes in habitat profiles from stand-replacing disturbances, we were unable to determine the effects of partial-cut harvest actions or lower intensity wildfires. We do know, from other sources, that there were about 287,000 ac of partial-cut harvest

Table 3-21—Vegetation survey plot data for federal land by data query group in the range of the spotted owl

State/ physiographic province	Forest structure group	Estimated area in forest structure group	Province area in forest structure group	Confidence intervals for estimated area: 68%	Confidence intervals for estimated area: 90%
		Acres	*Percent*	*Acres*	*Acres*
Washington:					
Eastern Cascades	A	374,467	28	354,027–391,302	343,705–404,009
	B	307,147	23	288,570–329,244	277,378–344,661
	C	140,904	11	129,209–153,419	121,922–160,411
	D	245,672	18	232,129–264,446	221,190–275,031
	E	86,447	7	74,892– 99,668	67,440–109,103
	F	26,468	2	22,073– 34,663	19,036–40,018
	Unknown	147,868	11		
Total		1,328,973	100		
Western Cascades	A	591,414	28	567,744–621,674	554,122–637,512
	B	131,884	6	119,243–148,675	111,575–157,327
	C	230,880	11	215,310–248,731	202,626–261,663
	D	455,601	21	430,207–477,251	417,818–491,014
	E	274,663	13	253,668–294,033	239,671–311,733
	F	295,554	14	272,796–318,176	259,372–332,585
	Unknown	156,552	7		
Total		2,136,548	100		
Olympic Peninsula	A	195,995	35	180,028–211,276	170,172–222,040
	B	23,342	4	19,201– 27,860	15,812–30,872
	C	76,755	14	67,768– 88,648	62,873–96,767
	D	110,320	20	101,169–122,990	93,127–130,814
	E	51,955	9	44,049– 57,979	40,284–62,873
	F	71,754	13	61,802– 82,190	55,778–88,821
	Unknown	28,188	5		
Total		558,309	100		
Washington total		4,023,832			
Oregon:					
Klamath	A	786,737	37	760,931–823,687	742,324–846,247
	B	173,190	8	160,584–186,342	152,690–193,752
	C	173,049	8	159,888–186,917	151,997–196,546
	D	430,214	20	412,307–450,377	401,504–465,558
	E	251,278	12	231,709–266,887	219,435–278,509
	F	221,992	11	206,373–238,755	198,162–251,734
	Unknown	90,511	4		
Total		2,126,971	100		
Eastern Cascades	A	355,018	31	331,007–375,580	320,641–389,867
	B	279,509	24	263,280–294,148	253,932–305,024
	C	145,798	13	131,320–157,248	123,076–165,417
	D	207,090	18	190,292–227,648	179,136–239,679
	E	88,144	8	73,048–102,039	65,586–111,110
	F	24,891	2	21,114– 31,535	16,442–34,066
	Unknown	47,442	4		
Total		1,147,892	100		

Table 3-21—Vegetation survey plot data for federal land by data query group in the range of the spotted owl (continued)

State/ physiographic province	Forest structure group	Estimated area in forest structure group	Province area in forest structure group	Confidence intervals for estimated area 68%	Confidence intervals for estimated area 90%
		Acres	*Percent*	*Acres*	*Acres*
Western Cascades	A	1,035,863	25	1,004,524–1,073,253	982,719–1,092,721
	B	418,893	10	398,511–439,364	386,101–452,866
	C	395,557	9	369,110–418,515	359,998–435,802
	D	900,299	22	868,464–933,570	847,498–954,090
	E	763,403	18	736,412–791,888	718,769–812,243
	F	454,054	11	435,191–479,298	418,643–496,922
	Unknown	198,456	5		
Total		4,166,525	100		
Coast Range	A	367,758	25	348,755–387,550	335,222–401,505
	B	124,234	8	118,735–139,547	108,963–149,693
	C	195,959	13	181,036–208,914	172,714–217,231
	D	329,327	22	312,684–346,583	303,048–359,872
	E	263,874	18	249,604–279,972	240,544–290,605
	F	116,122	9	105,858–127,832	98,736–134,514
	Unknown	84,248	5		
Total		1,481,522	100		
Oregon total		8,922,911			
California:					
Klamath	A	994,853	25	949,486–1,066,159	902,165–1,104,010
	B	569,384	15	527,782–618,418	502,136–647,109
	C	160,185	4	138,412–181,181	125,407–197,545
	D	786,214	20	743,889–840,217	713,405–863,548
	E	511,017	13	475,972–551,006	452,518–575,995
	F	473,055	12	430,323–512,071	402,510–536,987
	Unknown	407,339	10		
Total		3,902,047	100		
Cascades	A	206,450	21	181,854–234,495	162,406–256,289
	B	217,509	22	193,505–240,643	173,312–255,449
	C	66,530	7	53,740–80,302	45,585–89,407
	D	255,167	26	233,549–282,675	213,225–301,285
	E	92,625	9	76,779–110,284	69,511–123,336
	F	55,637	6	43,753–69,950	36,225–80,330
	Unknown	83,109	9		
Total		977,024	100		
Coast	A	39,931	50	27,156–49,967	18,872–56,257
	B	4,329	5	1,378–8,852	0–11,068
	C	1,573	2	0–3,145	0–4,718
	D	10,814	13	5,901–15,726	2,756–20,250
	E	10,035	12	4,718–16,521	1,378–21,449
	F	7,085	9	2,756–14,170	0–19,293
	Unknown		9		
Total		80,657	100		
California total		4,959,728			
Plan total		17,906,471			

Table 3-22—Vegetation survey plot data for federal land by data query group INSIDE large, reserved blocks in the range of the spotted owl

State/ physiographic province	Forest structure group	Estimated area in forest structure group inside reserved blocks	Province area in forest structure group inside reserved blocks	Confidence intervals for estimated area 68%	Confidence intervals for estimated area 90%
		Acres	*Percent*	- - - - - - - - - - - - - *Acres*	- - - - - - - - - - - -
Washington:					
Eastern Cascades	A	100,982	16.6	89,126–110,202	81,643–117,981
	B	120,356	19.8	106,899–137,643	98,502–148,179
	C	78,028	12.9	68,270–88,824	63,869–95,542
	D	134,313	22.1	122,337–151,045	115,476–159,718
	E	54,807	9.0	47,694–67,675	42,429–74,228
	F	12,215	2.0	7,858–16,571	5,661–20,793
	Unknown	105,968	17.5		
Total		606,670	99.9		
Western Cascades	A	342,323	25.4	321,565–365,946	305,346–380,697
	B	91,324	6.8	79,934–107,154	72,497–113,808
	C	129,445	9.6	113,303–144,346	104,010–155,212
	D	269,098	20.0	249,620–286,678	238,643–302,514
	E	198,971	14.8	184,949–221,814	172,599–236,911
	F	207,714	15.4	190,268–230,289	178,530–243,463
	Unknown	108,491	8.0		
Total		1,347,366	100		
Olympic Peninsula	A	109,779	31.8	98,485–122,957	90,955–132,214
	B	15,812	4.6	12,048–18,824	9,036–21,460
	C	34,588	10.0	28,613–46,858	24,472–58,587
	D	68,154	19.7	59,224–78,753	53,461–85,530
	E	39,908	11.5	33,507–45,931	30,119–50,449
	F	54,436	15.8	45,931–64,365	40,718–69,824
	Unknown	22,917	6.6		
Total		345,594	100		
Washington total:		2,299,630			
Oregon					
Klamath	A	379,036	37.4	356,584–407,034	342,709–425,226
	B	70,451	6.9	60,969–81,882	54,778–89,598
	C	76,925	7.6	69,180–85,863	63,778–93,191
	D	206,864	20.4	190,306–220,762	181,583–230,463
	E	121,499	12.0	108,126–133,914	98,416–142,504
	F	138,414	13.7	125,566–156,349	117,516–166,946
	Unknown	19,889	2.0		
Total		1,013,078	100		
Eastern Cascades	A	129,974	27.6	116,322–147,724	108,547–156,951
	B	94,471	20.0	85,286–106,918	78,274–115,177
	C	68,668	14.6	58,812–80,710	53,237–90,164
	D	99,786	21.2	86,153–119,694	76,975–133,510
	E	49,803	10.6	38,583–65,444	32,882–74,480
	F	12,577	2.8	9,127–19,231	6,844–24,351
	Unknown	15,280	3.2		
Total		470,559	100		

Table 3-22—Vegetation survey plot data for federal land by data query group INSIDE large, reserved blocks in the range of the spotted owl (continued)

State/ physiographic province	Forest structure group	Estimated area in forest structure group inside reserved blocks	Province area in forest structure group inside reserved blocks	Confidence intervals for estimated area 68%	90%
		Acres	*Percent*	- - - - - - *Acres* - - - - - -	
Western Cascades	A	314,038	18.5	297,090–336,444	284,773–354,799
	B	166,398	9.8	151,180–179,854	142,209–192,550
	C	174,441	10.3	156,983–190,464	145,168–203,797
	D	404,458	23.9	382,530–429,494	364,281–447,396
	E	365,841	21.6	339,740–380,354	328,111–393,311
	F	210,187	12.4	195,213–228,283	185,824–239,261
	Unknown	59,754	3.5		
Total		1,695,117	100		
Coast Range	A	198,823	24.1	184,007–214,969	169,959–224,264
	B	73,531	8.9	66,539–82,397	62,126–86,724
	C	88,453	10.7	80,555–97,856	75,419–105,459
	D	183,052	22.2	171,120–198,267	162,807–205,697
	E	184,218	22.3	171,141–195,181	163,684–204,075
	F	82,244	10.0	74,014–91,455	69,620–96,904
	Unknown	15,377	1.8		
Total		825,698	100		
Oregon total		4,004,452			
California:					
Klamath	A	431,457	21.5	397,472–475,217	373,762–499,105
	B	283,449	14.1	253,395–314,776	237,676–336,624
	C	68,610	3.4	57,172–85,489	49,953–95,794
	D	376,738	18.8	343,008–408,179	323,985–429,179
	E	333,988	16.7	301,652–363,875	280,135–386,752
	F	261,442	13.0	228,952–285,735	212,736–302,506
	Unknown	247,560	12.5		
Total		2,003,244	100		
Cascades	A	29,165	12.4	20,261–40,625	15,757–49,117
	B	44,923	18.8	34,586–59,042	27,630–66,616
	C	14,634	6.1	7,575–21,797	5,730–27,217
	D	66,616	27.9	55,466–79,612	49,323–88,104
	E	41,542	17.4	32,947–54,435	25,785–60,165
	F	24,352	10.2	15,757–32,947	11,460–40,110
	Unknown	17,190	7.2		
Total		238,422	100		
Coast	A	32,068	74.0	24,983–37,191	21,044–40,531
	B	2,756	6.4	0–4,134	0–5,512
	C	0	0.0	0–0	0– 0
	D	1,573	3.6	0–3,145	0–4,718
	E	1,378	3.2	0–2,756	0–4,134
	F	5,512	12.7	0–8,268	0–12,402
	Unknown	0	0.0		
Total		43,287	99.9		
California total		2,284,953			
Plan total		8,589,035			

Table 3-23—Vegetation survey plot data for federal land by data query group OUTSIDE large, reserved blocks in the range of the spotted owl

State/ physiographic province	Forest structure group	Estimated area in forest structure group outside reserved blocks	Province area in forest structure group outside reserved blocks	Confidence intervals for estimated area: 68%	Confidence intervals for estimated area: 90%
		Acres	*Percent*	*Acres*	*Acres*
Washington:					
Eastern Cascades	A	273,486	37.8	259,346–286,769	251,184–294,322
	B	186,791	25.8	174,496–200,541	166,108–211,830
	C	62,876	8.7	56,848–71,799	52,990–76,364
	D	111,358	15.4	102,161–120,955	97,486–127,342
	E	31,640	4.4	25,584–37,281	22,582–39,920
	F	14,253	2.0	11,221–17,963	9,376–19,865
	Unknown	41,900	5.8		
Total		722,304	99.9		
Western Cascades	A	249,091	31.6	233,501–264,909	224,677–276,713
	B	40,561	5.1	34,749–45,874	31,733–51,400
	C	101,435	12.8	91,756–110,825	85,781–117,185
	D	186,503	23.6	173,079–200,468	166,599–208,811
	E	75,692	9.6	67,681–84,350	62,589–91,279
	F	87,840	11.1	77,768–95,623	72,012–101,304
	Unknown	48,061	6.1		
Total		789,183	99.9		
Olympic Peninsula	A	86,215	40.5	77,933–93,745	73,791–99,392
	B	7,530	3.5	4,894–9,412	3,388–10,918
	C	42,166	19.8	36,143–47,814	32,378–51,955
	D	42,166	19.8	36,519–46,308	33,131–49,696
	E	12,048	5.7	8,659–15,436	6,777–17,695
	F	17,318	8.1	13,554–21,083	11,671–23,342
	Unknown	5,271	2.5		
Total		212,714	99.9		
Washington total:		1,724,201			
Oregon:					
Klamath	A	407,701	36.6	389,938–427,501	378,969–439,878
	B	102,739	9.2	93,615–111,586	87,715–117,324
	C	96,124	8.6	87,797–105,040	80,554–109,819
	D	223,350	20.0	210,765–235,872	203,608–243,556
	E	129,780	11.6	121,510–140,541	115,812–146,891
	F	83,578	7.5	75,530–92,224	70,433–97,068
	Unknown	70,623	6.3		
Total		1,113,895	99.8		
Eastern Cascades	A	225,044	33.2	213,211–243,779	202,860–254,045
	B	185,037	27.3	174,351–196,813	168,021–205,269
	C	77,129	11.4	69,857–84,535	64,371–89,683
	D	107,304	15.8	98,973–117,284	93,973–122,050
	E	38,342	5.7	33,343–44,698	30,159–48,396
	F	12,314	1.8	9,606–15,678	7,742–17,952
	Unknown	32,162	4.7		
Total		677,332	99.9		

Table 3-23—Vegetation survey plot data for federal land by data query group OUTSIDE large, reserved blocks in the range of the spotted owl (continued)

State/ physiographic province	Forest structure group	Estimated area in forest structure group outside reserved blocks	Province area in forest structure group outside reserved blocks	Confidence intervals for estimated area: 68%	Confidence intervals for estimated area: 90%
		Acres	*Percent*	*- - - - Acres - - - -*	
Western Cascades	A	721,825	29.2	698,524–751,820	682,981–765,131
	B	252,496	10.2	240,500–268,264	230,754–278,086
	C	221,116	8.9	207,988–233,860	197,243–243,312
	D	495,841	20.1	476,076–513,790	464,699–525,519
	E	397,562	16.1	384,803–418,694	374,317–433,449
	F	243,866	9.5	229,012–256,578	219,844–276,707
	Unknown	138,702	5.7		
Total		2,471,408	99.7		
Coast Range	A	168,935	25.8	154,762–180,754	146,309–188,999
	B	50,702	7.7	44,787–57,094	41,298–61,977
	C	107,506	16.4	100,484–118,753	95,031–126,232
	D	146,275	22.3	135,349–155,899	126,983–162,301
	E	79,655	12.1	71,692–87,837	66,279–93,234
	F	33,878	5.2	28,826–39,058	25,330–42,656
	Unknown	68,871	10.5		
Total		655,822	100		
Oregon total		4,918,457			
California:					
Klamath	A	563,396	29.7	516,193–604,552	487,910–638,165
	B	285,936	15.1	254,834–314,284	238,418–333,000
	C	91,575	4.8	79,698–109,939	70,378–123,873
	D	409,476	21.6	378,405–445,128	361,874–479,148
	E	177,030	9.3	154,434–201,235	141,950–216,616
	F	211,613	11.1	185,347–238,070	165,059–254,931
	Unknown	159,779	8.4		
Total		1,898,805	100		
Cascades	A	177,284	24.0	155,999–203,047	144,433–223,614
	B	172,584	23.4	151,839–193,284	139,002–209,849
	C	51,896	7.0	40,775–63,865	35,284–73,497
	D	188,551	25.5	166,397–213,886	149,321–227,980
	E	51,082	6.9	38,641–62,996	31,788–70,274
	F	31,285	4.2	21,269–42,102	15,848–48,462
	Unknown	65,919	8.9		
Total		738,601	99.9		
Coast	A	7,863	21.0	0–7,863	0–7,863
	B	1,573	4.2	0–3,145	0–4,718
	C	1,573	4.2	0–3,145	0–4,718
	D	9,241	24.7	4,523–13,764	1,573–16,910
	E	8,657	23.2	3,145–13,975	0–17,315
	F	1,573	4.2	0–3,145	0–4,718
	Unknown	6,890	18.4		
Total		37,370	99.9		
California total		2,674,776			
Plan total		9,317,776			

on federal land during the monitoring period (Baker et al., in press) and about 1.7 million ac of wildfire (Brown et al. 2002).

The Plan's record of decision estimated that about 2.5 percent of the existing owl habitat would be removed by harvest actions in the first decade. The changes we reported for loss of forest on habitat-capable federal area as a result of stand-replacing timber harvest represent the minimum area removed. Likewise, we were not able to account for loss of forest due to insects, disease, or windstorms. Bigley and Franklin (2004) relied on information assembled by the USDI Fish and Wildlife Service that estimated the loss of about 380,000 ac of owl habitat from 1994 to 2002. Losses from management (including partial harvest) were estimated to be 156,000 ac; wildfire, 168,300; windthrow, 100; and insects and disease, 55,640. Using 380,000 ac as the likely maximum removed, our analysis would show about a 3.6 percent removal of habitat-capable acres in the 41 to 100 range of habitat suitability compared to 1.5 percent from our change-detection analysis that used only data from stand-replacing timber harvest and wildfire and assumed all acres affected were habitat-capable. Based on the estimated loss from management (156,000 ac), it is reasonable to conclude that less than 2.5 percent of the existing habitat was removed by timber harvest during the monitoring period.

It is also likely that the coarse resolution of the polygon vegetation map in California led to an overestimation of area with 41 to 100 habitat suitability. Finer resolution input data are better suited for habitat modeling and would have given us better resolution and a consistent baseline across the range. This inconsistency between the Oregon-Washington and California maps introduces a measure of uncertainty to the results, particularly in comparing Oregon-Washington findings to those in California. In addition, analyzing and reporting results by physiographic province created an administrative division (Oregon and California border) in a biological analysis. However, the results were reported this way to be consistent with the FSEIS results. The use of ecological unit boundaries that ignore administrative boundaries may be more appropriate (for example, EPA ecoregions) for future monitoring analyses.

Lastly, we were not able to measure the change in habitat suitability over the monitoring period resulting from forest succession because we did not have remotely-sensed vegetation data that could have captured the ingrowth during the monitoring period. If we had had this data from 2002 or 2003, we could have compared the habitat condition at the beginning and end of the monitoring period and estimated changes in the habitat suitability profile from forest growth.

Discussion

One of the central purposes of the network of large reserved blocks was to maintain and restore habitat to support territorial owls under the spotted owl management framework of the Plan. Our analyses focused on understanding the capability of the reserve network to provide the large, reserved blocks of habitat and to determine the suitability of the habitat-capable lands and the loss of habitat suitability. The Plan's long-term strategy relies on the network of reserved blocks to support the territorial owl population, but in the first several decades there is a significant contribution of habitat-capable area with habitat suitability of 41 to 100 outside the reserved blocks. Almost as much (49 percent) of the habitat-capable area is outside of the reserved blocks as inside (51 percent). Forty-four percent of the habitat-capable land with 41 to 100 habitat suitability occurs outside the reserved blocks. The land outside the reserved blocks makes a valuable short-term contribution to the Plan's habitat management strategy for territorial owl pairs and is important in the long term by providing dispersal habitat.

At the beginning of the monitoring period, we estimated that 57 percent of habitat-capable federal area was in the range of 41 to 100 habitat suitability and 36 percent was in the 0 to 40 range. At the end of the monitoring period, 56.2 percent of the habitat-capable land was in the 41 to 100 range, with no recruitment accounted for. Loss of vegetation present at the beginning of the monitoring period on habitat-capable land from stand-replacing harvest and wildfire in the 41 to 100 range was greater (2.0 percent) inside the habitat blocks than outside (1.0 percent), but overall affected only about 0.8 percent of the habitat-capable area in the 41 to 100 range of habitat suitability.

In some provinces, the loss of habitat-capable land in the 41 to 100 range of habitat suitability was proportionally greater than the rangewide loss. At the beginning of the monitoring period, about 55 percent of the habitat-capable area in the Klamath province of Oregon was in the 41 to 100 range of habitat suitability. At the end of the monitoring period, 51 percent of the habitat-capable area was in the 41 to 100 range. Again, no recruitment of habitat was accounted for. Loss to stand-replacing events inside the habitat blocks was greater than outside in the Klamath province. About 11.5 percent of the habitat-capable area in the 41 to 100 range of habitat suitability inside the blocks was lost in contrast to 2.5 percent outside. In either case, a high percentage of the habitat-capable area most similar to that used by owl pairs was maintained even in the province where the loss to wildfire was greatest.

Initially, the Klamath province in California had about 62 percent of the habitat-capable area in the 41 to 100 range of habitat suitability. Over 61 percent of the area was in that suitability range at the end of the monitoring period. Again, loss of habitat in the 41 to 100 range inside the blocks (2.0 percent) was greater than outside the blocks (1.0 percent), but maintenance of existing habitat was still high. Maintaining 60 to 80 percent of the habitat-capable area in the 41 to 100 range of habitat suitability in reserved blocks that occur in the drier southern and eastern provinces, or areas of moderate to high risk of lightning-ignited wildfire may be a challenge without stand treatment to reduce the risk of loss to wildfire. However, understanding the effects on owl habitat and owls of stand treatments to reduce fire risk before they are applied is an important step so that the treatments do not have a greater effect than the wildfires.

During the next 50 years, owl populations are expected to decline to a lower (compared to 1994), but stable population level (USDA USDI 1994: 3&4-228). From the habitat perspective, the transition is less about loss of area or amount of habitat and more about its occurrence inside and outside of large, reserved blocks. Currently, there are about 10,300,000 ac of habitat-capable land in the 41 to 100 range of habitat suitability in the owl's range. Over time, that number is expected to decline, as management of the matrix lands removes forest stands that are owl habitat. Outside of the large, reserved blocks, habitat will be maintained and accrue in the smaller reserves (for example, riparian reserves and owl core areas) that are interspersed with the matrix allocation. At the same time, habitat is expected to increase on the 9,200,000 ac of habitat-capable land inside the large reserved blocks, of which about 62 percent (5,700,000 ac) is currently in the 41 to 100 range of habitat suitability. That means there is another 35-plus percent of the habitat-capable lands in the blocks that will continue to grow and, depending on the occurrence of natural events, develop into owl habitat. We know from experience that natural disturbances will keep a portion of the area from being in the 41 to 100 habitat suitability range. A snapshot of forest conditions present in the 1930s showed the amount of owl habitat (based on our interpretation of the data) for lands inside and outside of the reserved blocks. With the exception of the Eastern Cascades provinces in Washington and Oregon, all provinces had between 50 and 75 percent of the forest land in owl habitat. Today's conditions, some 70 years later, are not that different. The percentage of the habitat-capable area inside the reserved blocks in the provinces today ranges from 50 to 81 percent. However, we noted that it is more fragmented; there are three to five times the number of patches with about the same amount of habitat.

Lint et al. (1999) stated the expectation that owl populations would be self-sustaining where the land area (assumed to be habitat-capable land area) in individual late-successional reserves was at least 60 percent owl habitat. In the future, the 9,200,000 ac inside the habitat blocks will likely yield between 5,500,000 (60 percent) and 7,400,000 (80 percent) ac in the 41 to 100 range of habitat suitability taking into account losses to natural events. Although we did not evaluate individual habitat blocks, the province values for habitat-capable land inside the blocks indicate that conditions are not far from expected with the exception of the few reserved blocks where wildfire was a significant influence. Rangewide the habitat blocks are already in the 60- to 80-percent range.

Increases in the percentage of habitat-capable area in the 41 to 100 range of habitat suitability will accrue in the short term from the transition of area currently in the 21 to 40 range. Based upon the percentage of total habitat-capable area in the 21 to 40 range, the greatest increases in habitat suitability will likely be in the Western Cascades provinces of Washington and Oregon, the Klamath provinces of Oregon and California, and the Coast Range province of Oregon. This will result in significant increases in habitat in the 41 to 100 habitat suitability range in the coming decades as these provinces contain over two-thirds of the habitat-capable Plan area. One of the primary reasons for using the histogram format to track the BioMapper outputs and the query groups to track the plot data was to show the changes over time in terms of the habitat suitability scale (0 to 100). We expect to see increases in the bars on the right side of the histograms for habitat-capable land inside the reserved blocks. By tracking all levels of habitat suitability, we will also see decreases on the left side of the histograms in the 0 to 40 range of suitability as area is recruited into the 41 to 100 range.

Over time we should expect to see cumulative increases in the percentages of habitat-capable area in the 41 to 100 range of habitat suitability.

Conclusions

Vegetation conditions inside the reserved blocks in all habitat suitability categories (0 to 20, 21 to 40, etc.) improved during the decade because only a small percentage of the blocks' areas were set back by harvest or wildfire. The loss of owl habitat did not exceed the rate expected under the Plan. Habitat outside the reserved blocks provided habitat in the short term for territorial owls and also for dispersing owls. There were catastrophic wildfire events that changed the owl habitat in local areas in several of the provinces, but the analysis of the loss at the province and rangewide scales showed the strength of the Plan's repetitive, reserved-block design to absorb these losses. In the short term, the losses were also buffered by the better quality habitat outside the habitat blocks. It would have been better if the larger fires had not occurred inside the large reserved blocks, but it is better they occurred early in the Plan when more habitat remains outside the reserved blocks. The Plan has shown its strength in the short term for maintaining habitat and is expected to do equally well in restoring habitat over time. At the end of the first 10 years, habitat conditions are no worse, and perhaps better than expected. Refer also to discussions on wildfire in Moeur et al. (2005).

Our analyses, both spatial and nonspatial, indicate that there is considerably more habitat in California than was accounted for in the Plan FSEIS. The magnitude of this increase will depend on the owl habitat definition applied to the plot or spatial data. Assessments using a finer resolution, pixel-based map for the California provinces will provide a more consistent baseline of habitat-capable area across the range and may improve the estimates of owl habitat, whatever definition is used.

The only habitat warning light we noted is not new. It was recognized in the Plan FSEIS. Wildfire is an inherent part of managing owl habitat in certain portions of the range. We should not depend solely on the repetitive design of the Plan to mitigate the effects of catastrophic events. We may be able to influence, through management, how owl habitat will burn and the extent of the burn when the inevitable happens.

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Jason Mowdy

Chapter 4: Owl Movement

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Introduction

The Northwest Forest Plan's (the Plan) network of reserve land use allocations provides blocks of habitat for late-successional forest species such as the northern spotted owl (*Strix occidentalis caurina*) (USDA USDI 1994). The role of the reserved blocks is to support clusters of reproducing spotted owls. Within the reserves, existing owl habitat will be maintained, and other forest will be managed actively (tree density management) and passively (forest succession) to restore habitat. In addition, the federal land between the reserved blocks, primarily that in riparian reserves, is expected to contribute dispersal habitat for owl movement between the blocks. Movement is important for recruitment of owls in the reserved blocks and for genetic interchange. The 6- to 12-mi spacing of the blocks was based on the known dispersal capabilities of spotted owls from earlier data (Thomas et al. 1990).

The status of dispersal habitat was reported in chapter 3, "Habitat Status and Trends." This chapter provides information about owl movement across the landscape. This analysis does not address whether the recorded movements were adequate to assure continued population distribution and genetic interchange, but does show whether movement occurred across the allocation landscape created by the Plan.

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Data Sources and Methods

Banding and reobservation of northern spotted owls began in the mid-1980s and has continued to the present (Anthony et al. 2004). Forsman et al. (2002) published a comprehensive assessment of natal and breeding dispersal of spotted owls from records of banded dispersers (1,151) and radio-marked (324) owls studied between 1985 and 1996.

Forsman et al. (2002) presented the following findings on northern spotted owl movements:

- The straight-line distance from the natal site to the final location where the owl settled, died, or disappeared for banded juvenile owls ranged from 0.37 to 69.1 mi.
- The median, straight-line distance from the natal site to the final location where the owl settled, died, or disappeared for banded juveniles was 15.2 mi for females and 9.1 mi for males.
- Only about 6 percent of nonjuveniles changed territories each year. Median dispersal distance of adult owls (>3 years old) was 2.2 miles.
- Only 8.7 percent of dispersing individuals moved more than 31 mi.
- Dispersal of adults was often associated with the death or disappearance of a mate or with pair bond dissolution.
- Probability of movement was greatest for 1-year-old owls on territories, and female owls were more likely to disperse than males.
- Owls regularly dispersed across fragmented landscapes, but large valleys (Willamette, Umpqua, and Rogue valleys) were rarely crossed. However, owls did disperse between the Cascades and Coastal provinces via connecting forested lands in areas between the large valleys. They also occasionally dispersed both directions across the crest of the Cascade Range.

Forsman et al. (2002) did not analyze owl movements in relation to the reserve network of the Plan. Our analysis used an expanded version of the data used by Forsman et al. (2002) to assess owl movements in the reserve network. The additional records were from owls banded and observed in

Oregon and Washington from 1997 through 2003. No data were available for California. The full data set comprised movement records for 1,210 juvenile and 1,388 subadult and adult (nonjuvenile) spotted owls. Figure 4-1 shows the locations of the movement lines for both juvenile and nonjuvenile owls in relation to the large, reserved blocks. The data were analyzed according to their movement path into, out of, and between the reserved blocks. The movement paths we analyzed were as follows:

- From a large, reserved block to another reserved block.
- From a reserved block to outside of the reserved block.
- From outside of a reserved block to inside a reserved block.
- From outside of a reserved block to another point outside of a reserved block.
- Within a single reserved block.

The mapped points of the original bandings and the resighting points for all movement records were classified as either "inside" or "outside" of reserved blocks. The reserved block network used in the analysis was the same one described in chapter 3 of this report (fig. 3-13). A unique number was assigned to each reserved block. Individual owl movement records with origin or resighting points in specific blocks were coded with the block number to track movements within and between reserved blocks.

Movement distances were calculated as straight-line distances between the original banding locations and the resighting point. The minimum, maximum, median, and average movement distances were calculated for 1,210 juvenile movement records and the 1,388 nonjuvenile records. The movement distance statistics were reported by movement path for all records combined, and by selected physiographic provinces. Movements were assigned to a given province based on the resighting point regardless of the point of the original banding.

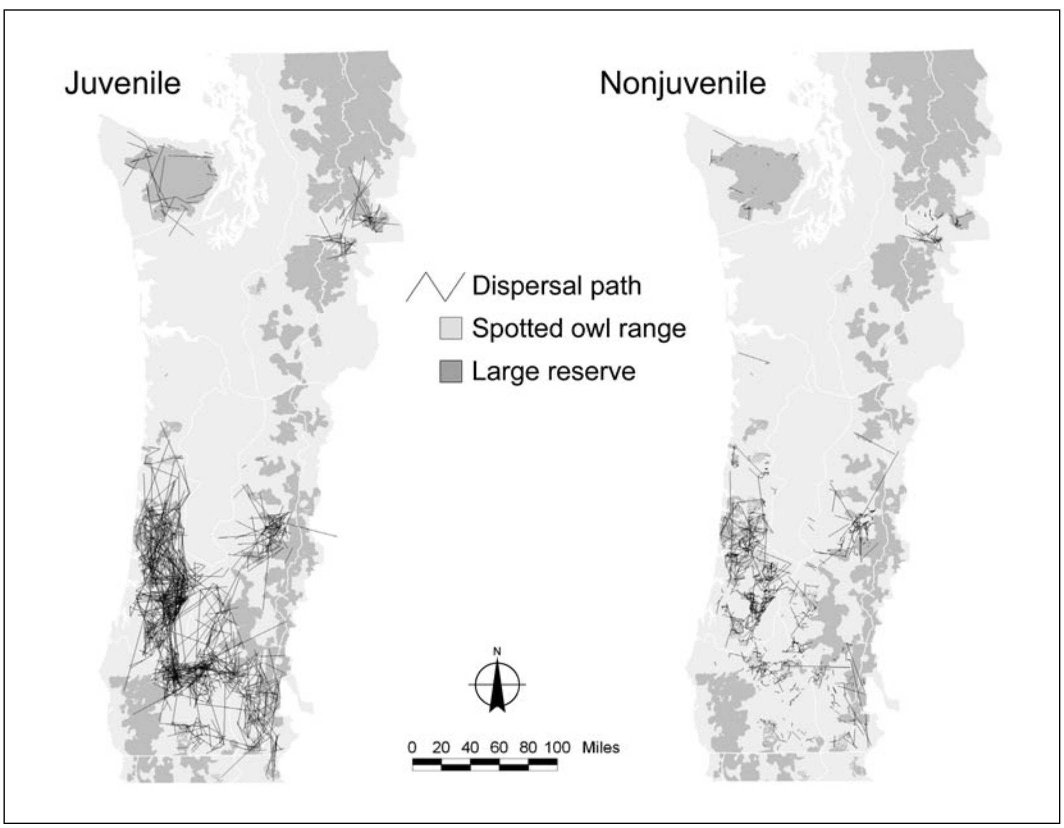

Figure 4-1—Straight-line paths from origin to resighting point of juvenile and nonjuvenile spotted owls from 1985 through 2003 in relation to large reserved habitat blocks and physiographic provinces.

Results

Results for analyses of movements, independent of physiographic province, are shown in figure 4-2. Juvenile and nonjuvenile movements were recorded for all movement paths. Juvenile movements occurred from one reserved block to another (142), from outside a reserve block to inside a reserved block (247), and within a single reserved block (232). All these movements had resighting points inside the reserved blocks and accounted for 51 percent of juvenile movement records. Fifty-eight percent of the juvenile owls that were fledged inside reserves (142 + 232) were resighted inside reserved blocks.

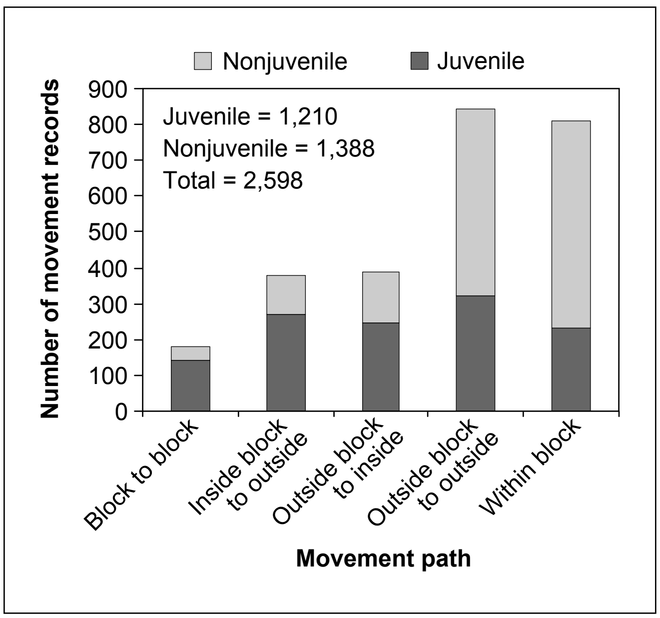

Figure 4-2—Movement paths for juvenile and nonjuvenile spotted owls between 1985 and 2003 in Oregon and Washington. (Refer to figure 4-1 for geographic location of movement records.)

Juvenile movements with resighting points outside the reserved blocks included 268 juveniles moving from a reserved block to outside of the block and another 321 that moved from outside a reserved block to another point outside a reserved block. These movements made up about 49 percent of the juvenile movement records.

Compared to juvenile movements, the nonjuvenile movements between reserved blocks was markedly lower; accounting for only 2.9 percent of all nonjuvenile records. When nonjuvenile owls became territorial, their movement frequency and distances moved decreased. The 576 nonjuvenile movements within a given single, reserved block accounted for 41 percent of all the nonjuvenile movements and averaged only 2.7 mi. The median distance for these movements was 1.9 mi (table 4-1).

As expected (based on Forsman et al. 2002), the maximum, median, and average movement distances of nonjuveniles were less than for juveniles on all movement paths (table 4-1). For juvenile spotted owls, the median distance traveled from one reserved block to another was 17.9 mi and the average distance moved was 21.8 mi. For those juvenile owls that moved from outside a reserved block to inside a block, the median distance was 12.7 mi, and the average distance was 16.9 mi. The median movement distances of juvenile and nonjuvenile spotted owls within a given reserved block were 7.3 and 1.9 mi, respectively.

Movement data were also analyzed for selected physiographic provinces (table 4-2). Movement records were available for all nine Oregon and Washington provinces, but three provinces had only a few movement records and were not included in the province analysis. The number of

Table 4-1—Movement statistics for juvenile and nonjuvenile spotted owls in Oregon and Washington from 1985 to 2003 by movement path

Movement distance measures	Habitat block to habitat block		Inside habitat block to outside habitat block		Outside habitat block to inside habitat block		Outside habitat block to outside habitat block		Within a single habitat block	
	Juvenile n = 142	Nonjuvenile n = 40	Juvenile n = 268	Nonjuvenile n = 110	Juvenile n = 247	Nonjuvenile n = 140	Juvenile n = 321	Nonjuvenile n = 522	Juvenile n = 232	Nonjuvenile n = 576
	Miles									
Minimum	5.39	1.57	1.86	0.93	0.65	0.76	0.16	0.16	0.54	0.16
Maximum	71.85	51.89	58.41	52.93	74.02	39.56	53.82	35.68	45.40	35.74
Median	17.90	12.04	12.40	3.91	12.72	4.87	9.52	1.94	7.32	1.91
Average	21.86	13.22	15.02	6.83	16.95	6.81	12.43	3.08	8.79	2.73

Table 4-2—Movement statistics for juvenile and nonjuvenile spotted owls in selected physiographic provinces in Oregon and Washington from 1985 to 2003 by movement path

Physiographic province	Sample size (n) and distance measures	Habitat block to habitat block		Inside habitat block to outside habitat block		Outside habitat block to inside habitat block		Outside habitat block to outside habitat block		Within a single habitat block	
		Juvenile	Nonjuvenile	Juvenile	Nonjuvenile	Juvenile	Nonjuvenile	Juvenile	Nonjuvenile	Juvenile	Nonjuvenile
Oregon Eastern Cascades	n	0	0	2	4	10	4	8	7	11	4
	Minimum (miles)			12.89	1.42	7.61	5.33	5.60	1.39	.54	1.83
	Maximum (miles)			20.83	52.93	74.02	23.09	40.22	32.41	37.43	6.51
	Median (miles)			16.86	3.14	22.47	18.77	12.22	9.03	10.54	3.06
	Average (miles)			16.86	15.16	25.55	16.49	18.79	11.78	14.69	3.61
Oregon Western Cascades	n	8	1	58	18	51	36	117	231	36	84
	Minimum (miles)	5.39	20.05	4.19	1.13	3.01	1.19	.16	.16	.89	.51
	Maximum (miles)	43.38	20.05	57.90	46	59.70	29.80	46.10	35.68	26.59	35.74
	Median (miles)	13.99	20.05	16.97	3.50	12.94	5.56	11.06	1.93	9.29	1.37
	Average (miles)	20.12	20.05	18.59	8.64	16.12	8.06	12.60	3.15	10.50	2.24
Oregon Coast Range	n	116	37	101	61	114	67	64	161	94	339
	Minimum (miles)	6.06	1.57	1.86	.93	.65	.99	1.25	.49	1.11	.27
	Maximum (miles)	71.85	51.89	56.03	31.25	54.61	39.56	53.82	22.92	20.84	20.69
	Median (miles)	17.97	11.92	12.04	4.23	12.72	4.81	10.84	1.96	6.23	2.01
	Average (miles)	21.38	12.85	14.97	6.77	17.05	6.75	15.12	2.90	6.92	2.97
Washington Eastern Cascades	n	3	1	7	5	8	5	8	14	18	51
	Minimum (miles)	12.54	25.81	4.35	4.86	5.79	3.32	2.99	.73	2.85	.57
	Maximum (miles)	20.52	25.81	18.21	11.07	49.99	12.31	26	7.15	44.71	9.14
	Median (miles)	19.58	25.81	10.58	9.70	13.05	5.32	7.03	1.57	11.15	2.53
	Average (miles)	17.55	25.81	10.83	8.26	19.96	6.28	12.37	2.44	14.72	3.06
Oregon Klamath Mountains	n	14	1	93	20	57	26	121	107	50	69
	Minimum (miles)	12.64	7.38	2.33	1.11	2.09	.76	1	.59	.89	.16
	Maximum (miles)	69.06	7.38	58.41	9.26	48.57	12.22	41.76	15.42	12.03	5.39
	Median (miles)	17.73	7.38	10.38	2.48	12.13	3.33	7.84	1.93	5.91	1.75
	Average (miles)	28.18	7.38	13.24	3.51	14.67	3.97	10.54	2.54	6.33	2.04
Washington Olympic Peninsula	n	0	0	4	1	7	2	2	1	23	29
	Minimum (miles)			4.72	8.94	11.66	2.44	6.10	22.69	.82	.32
	Maximum (miles)			22.24	8.94	31.87	7.62	13.84	22.69	45.40	10.43
	Median (miles)			7.01	8.94	22.78	5.03	9.97	22.69	7.97	1.64
	Average (miles)			10.24	8.94	24.11	5.03	9.97	22.69	11.64	2.31

movement records per province ranged from less than 50 in three provinces to over 480 records in the Oregon Coast Range province. This variation was the result of study area size, years of banding effort, and owl population size.

The median distance moved by juvenile owls from one reserved block to another ranged from about 14 mi in the Oregon Western Cascades province to 19.6 mi in the Eastern Cascades province in Washington. Similar median distances were observed for juvenile movements from outside a reserved block to inside a block (12.1 to 22.8 mi) across the provinces. Median movement distances of juvenile owls that moved within the same block ranged from 5.9 mi in the Klamath province of Oregon to 11.2 mi in the Eastern Cascades province of Washington. In four of six provinces, movements with resighting points in reserved blocks accounted for about two-thirds of juvenile movement records. In the other two provinces, about one-third of the records involved juvenile movement with resighting points inside reserved blocks.

Discussion and Conclusions

Dispersal of juvenile and subadult owls is an important mechanism for the recruitment of replacement owls into the territorial population. Forsman et al. (2002) observed that juvenile owls move rapidly away from their natal site in the fall, settling in one or more temporary home range areas before acquiring a territory. The majority of young spotted owls are integrated into the territorial population within the first 2 years, but 32 percent of males and 23 percent of females from a sample of radio-marked owls did not acquire territories until they were >3 years old (Forsman et al. 2002).

The spatial assessment of dispersal habitat in this report indicated both numerically and visually that nearly half of the federal forest acres are providing dispersal habitat for spotted owls. These acres are dispersed across the landscape providing a mosaic of dispersal habitat. The results from our analysis of owl movement showed that movements with resighting points inside reserved blocks accounted for 51 percent of juvenile movement records. Over 30 percent of the juvenile movements were into reserved blocks from outside points.

The movement records provide tangible evidence that spotted owls are dispersing across the landscape under the Plan, and supports the conclusion by Forsman et al. (2002) that a conservation strategy that consists of numerous, closely spaced reserves of old forest (for example, the Northwest Forest Plan) would not likely result in genetic or demographic isolation of local populations because dispersal between reserves will be a common occurrence even if the landscapes between the reserves consist of highly fragmented forests.

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Jason Mowdy

Chapter 5: Related Research

Joseph Lint[1]

Introduction

The effectiveness portion of the northern spotted owl (*Strix occidentalis caurina*) monitoring plan focused on estimating population demographic rates and assessing habitat conditions. Equally important, however, was the related research on predictive models funded through the monitoring program. The aim of the model research was to provide a monitoring tool for predicting occupancy, distribution, and demographic performance of spotted owls based on a map of habitat conditions.

On another related research front, data on barred owls collected incidental to the survey of the demographic study areas, along with data from other spotted owl surveys, spawned research papers that provided insight on the occurrence and distribution of the barred owl (*Strix varia*) in the range of the spotted owl.

This chapter summarizes information on barred owls from selected research papers to provide managers with a perspective on the arrival and spread of the barred owl in the range of the spotted owl. We also review research on the relations of climate and habitat quality to spotted owl populations and report on the progress of development of models to predict demographic rates and occupancy.

Barred Owl

The monitoring plan did not contain any provisions for the monitoring of barred owls (*Strix varia*). However, in the course of collecting demography data on spotted owls, ancillary information on the occurrence and distribution of barred owls was recorded. Gutierrez et al. (2004) pointed out there is uncertainty about the barred owl's pattern of range expansion, interactions with spotted owls (*Strix occidentalis caurina*), and the contribution of barred owls to the decline of spotted owls because the information on barred owls was collected incidental to spotted owl surveys, and neither consistently collected nor consistently reported. In this chapter, we review information on barred owl distribution and general population trend from selected publications. Five peer-reviewed, published papers on barred owls were selected to provide insight on barred owl distribution and population trend for our report. Kelly et al. (2003) and Anthony et al. (2004) used barred owl data gathered in the demography study areas in their analyses. Some key findings of these five papers are summarized below. A more complete review of the barred owl-spotted owl issue is found in Gutierrez et al. (2004).

Data Sources and Methods

Refer to the cited, peer-reviewed papers for information on the sources of data and the analyses methods used.

Results

The barred owl's gradual movement across the Canadian provinces and northern Rocky Mountains from the Eastern United States in the past 50 years resulted in its eventual entry into the Pacific Northwest (Gutierrez et al. 2004). The barred owl was not prevalent in the demographic study areas at the beginning of the monitoring period (1985), it had only recently been detected in west-side forests of Washington (1965), Oregon (1979), and California (1981). The barred owl range now overlaps most of the range of the northern spotted owl (Kelly et al. 2003).

Over the past two decades, the barred owl has increased in numbers and extended its distribution in the range of the northern spotted owl (Dark et al. 1998, Herter and Hicks 2000, Kelly et al. 2003, Pearson and Livezey 2003). Anthony et al. (2004) presented information on the proportion of spotted owl territories that were occupied by barred owls each year. This coarse-grained estimate of barred owl occurrence, by year, provided a depiction of the barred owl increase across the range of the spotted owl (fig. 5-1). The relative differences in barred owl occurrence between the three states, the north-to-south gradient in occurrence, and the increasing occurrence of barred owls are evident from figure 5-1.

The first pair of barred owls was recorded in Washington in the northern portion of the Cascade Mountains in 1974 (Taylor and Forsman 1976). Pearson and Livezey

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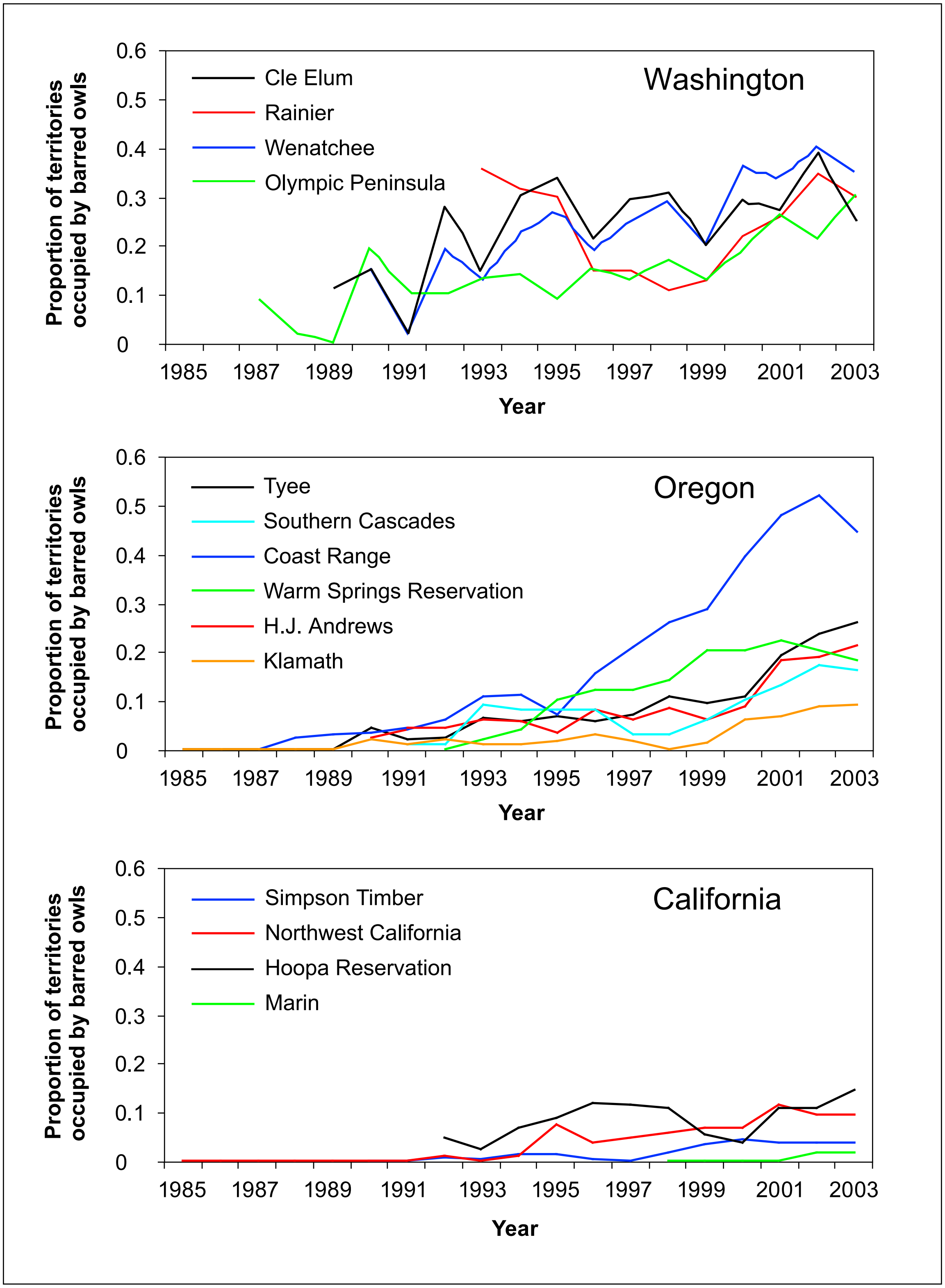

Figure 5-1—Proportion of spotted owl territories occupied by barred owls (BO) each year in study areas within Washington, Oregon, and California (Anthony et al. 2004).

(2003) reported that barred owl detections increased 8.6 percent annually from 1982 to 2000 in their southwest Washington study area, with no indication of any leveling-off of this increase. Herter and Hicks (2000) stated that barred owls have completely overlapped the known geographic range of the spotted owl in central Washington.

Pearson and Livezey (2003) determined that barred owl sites surpassed the number of occupied spotted owl sites in late-successional reserves in southwest Washington. Barred owls were at least as numerous as spotted owls in their study area. They also noted there were significantly more barred owl sites within 0.8-km-, 1.6-km- and 2.9-km-radius circles centered on unoccupied spotted owl sites than occupied spotted owl sites. Pearson and Livezey (2003) suggested that spotted owls are more likely to abandon a site if barred owls take up residence close to that site.

Barred owls were first recorded in Oregon in 1974 in the eastern part of the state in the Blue Mountains. Barred owls were noted in the range of the spotted owl in the northern part of the Western Cascades Mountains of Oregon around Mount Hood in 1979, and were confirmed in the southern portion of the Western Cascades Mountains and on the west flank in Lane County by 1981.

By 1998, Kelly et al. (2003) estimated that there were 706 territories in Oregon where barred owls had been observed one or more years since 1974 (fig. 5-2). Most of these were in western Oregon forests, owing, in part, to the number and extent of spotted owl surveys conducted in western

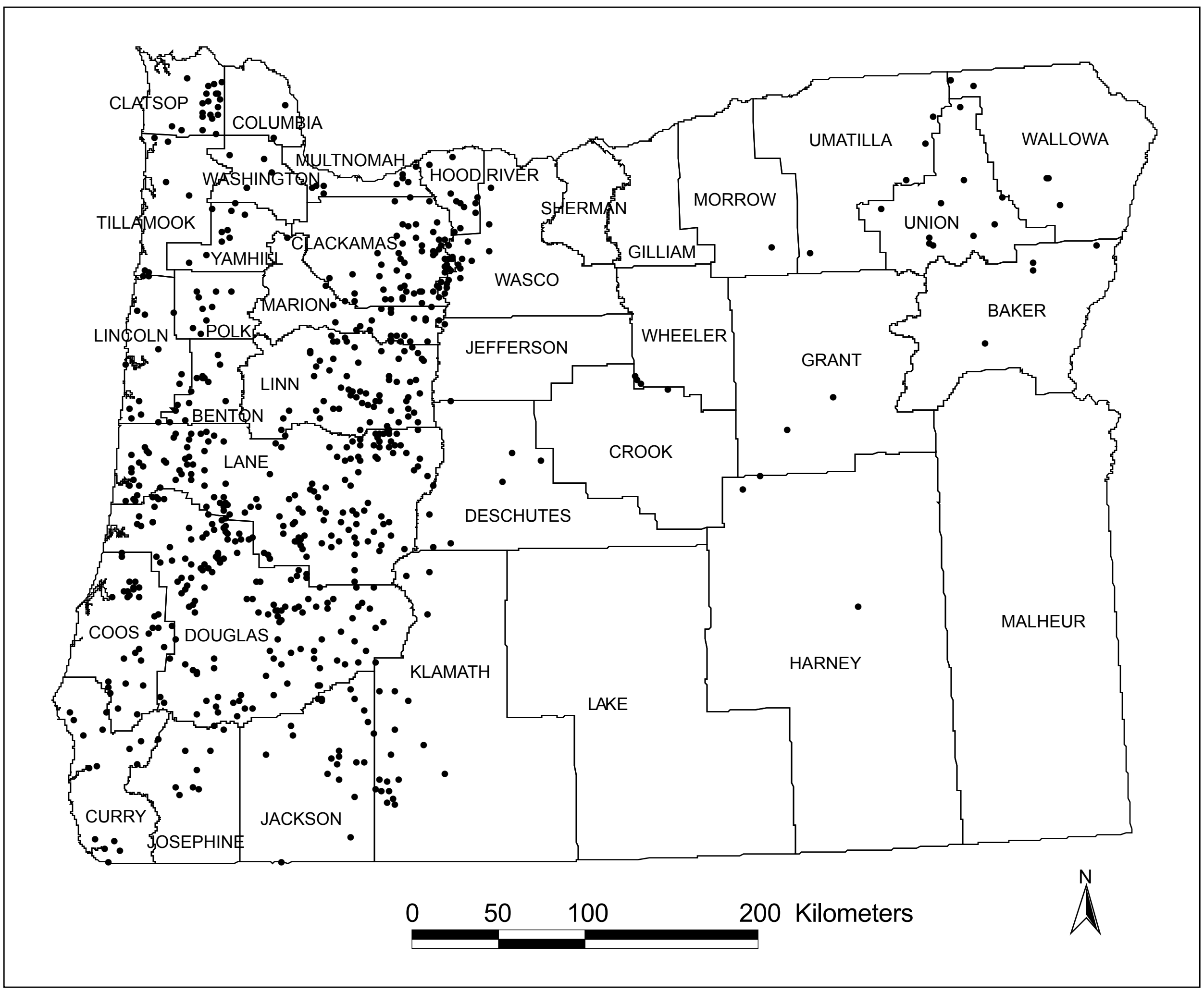

Figure 5-2—Barred owl locations in Oregon through 1998 (Kelly et al. 2003).

Oregon as opposed to none in eastern Oregon. A steady, linear increase in new barred owl territories occurred in Oregon between 1974 and 1998 with approximately 60 new barred owl territories reported annually in Oregon between 1989 and 1998 (Kelly et al. 2003). Kelly et al. (2003) stated it was obvious from their analyses that the barred owl population was increasing rapidly in Oregon. This trend appears to have continued between 1998 and 2003 based upon the data presented by Anthony et al. (2004) (fig. 5-1).

Kelly et al. (2003) examined data on five of the demographic study areas under the monitoring plan in Oregon and Washington and found steady increases in the percentage of spotted owl territories with barred owl detections between 1987 and 1999. This was validated by data presented in Anthony et al. (2004).

Kelly et al. (2003) assessed the mean occupancy by spotted owls for spotted owl territories where barred owls were detected. There was a decline when barred owls were detected within 0.80 km of the territory center, but when the barred owl detection occurred 0.81 to 2.4 km from the center, occupancy was only marginally less.

Dark et al. (1998) presented information on the range expansion of barred owls in California since they were first documented in 1981 (Evens and LeValley 1982). Dark et al. (1998) identified 61 barred owl sites in 12 counties in California since 1980. The first documented sightings (Evens and LeValley 1982) occurred in Del Norte and Trinity Counties in northern California in 1981 followed by observations in Humboldt County in 1983. From 1986 to 1996, barred owl detections appeared to expand to the south and east from the initial northern locations (Dark et al. 1998). Their information indicated an increase in barred owl detections in the early 1980s with an accelerated increase in the mid 1990s. Dark et al. (1998) characterized the expansion of barred owls in California as rapid and widespread. Information provided in Anthony et al. (2004) indicates that barred owls were present in the demographic study areas in California, but were not nearly as prevalent there as in study areas in Oregon and Washington.

Effect of the Barred Owl

The papers reviewed in this chapter revealed the continued range expansion and increase in numbers of barred owls in the range of the northern spotted owl along with an indication of likely competitive interaction between the two species.

The concern is whether the barred owl is a threat to the conservation and eventual recovery of the spotted owl. This concern was evaluated by Gutierrez et al. (2004). Their chapter in the *Scientific Evaluation of the Status and Trend of the Northern Spotted Owl* provides an informative examination of the barred owl-spotted owl issue. They pointed out:

> The greatest uncertainties associated with the actual and potential effects of the Barred Owl on the Northern Spotted Owl is that we lack accurate information on Barred Owl density, numbers, and population trends, and that we are unable to resolve with certainty whether the observed changes of Barred Owls and Spotted Owls are causal or merely correlated in opposite ways with some other, unknown, factor(s). While the evidence for a negative effect of Barred Owls is clearly correlational, we believe the Barred Owl is having a substantial effect on the Spotted Owl in some areas because of the preponderance of circumstantial and anecdotal information. In our evaluation, the Barred Owl currently constitutes a significantly greater threat to the Northern Spotted Owl than originally envisaged at the time of listing.

Gutierrez et al. (2004) offered a nonexhaustive set of nine alternative hypotheses on the potential outcome of barred owl-spotted owl interactions. They categorized them as either clearly plausible, plausible, and not plausible or not clear. Those listed in the clearly plausible category were:

- Barred owls will replace the northern spotted owl throughout its range (behavioral and competitive dominance hypothesis).
- Barred owls will replace the northern spotted owl in the northern, more mesic areas of its range (moisture-dependent hypothesis).

- Barred owls and northern spotted owls will compete, with the outcome being an equilibrium favoring barred owls over spotted owls in most but not all of the present northern spotted owl habitat range (quasi-balanced competition hypothesis).

In light of these potential outcomes, the barred owl may present a concern for the conservation and recovery of the spotted owl. It is not an issue limited to the confines of federal land under the habitat-based Northwest Forest Plan. Because it is likely a species interaction-competition issue, it deserves broader consideration at the species-status scale. A status review of the spotted owl by the USDI Fish and Wildlife Service (FWS) was completed in November of 2004. The FWS considered information on the barred owl in the status review. The FWS recommended that the northern spotted owl remain listed as a federal threatened species. The status review is available online at: http://pacific.fws.gov/ecoservices/endangered/recovery/pdf/NSO_5-yr_Summary.pdf.

Predictive Model Development

Lint et al. (1999) recommended the development of models for predicting occupancy, distribution, and demographic performance (survival and reproductive success) of spotted owls based on vegetative characteristics assessed at a variety of spatial scales. They envisioned a shift from mark-recapture studies to increased reliance on habitat monitoring by using predictive models to indirectly estimate the occurrence and demographic performance of spotted owls (Lint et al. 1999).

Lint et al. (1999) provided the following explanation of the task of building predictive models.

> To accomplish this transition, [from mark-recapture to habitat-based monitoring] we must identify those aspects of vegetation structure and composition that have the greatest power and precision to predict the number, distribution, and demographic performance of owls at the landscape scale, as well as to explain the observed variation in demographic rates (owl birth and death rates) at a local, home range-level scale. Accomplishing this task will require characterizing the vegetation at a variety of spatial scales in the existing demographic study areas. The combination of spatially referenced data from both the owl demographic studies and mapped vegetation attributes provides the fundamental data for the model-building phase. The degree to which these models explain the observed variation in owl distribution and demographic performance will estimate the certainty with which habitat variation predicts population performance and stability. Explained variation is thus a direct measure of the confidence we have in habitat as an appropriate monitoring surrogate for population performance.

Questions from Lint et al (1999) provided the impetus for exploring the efficacy of predictive models. They were:

1. Can the status and trends in spotted owl abundance and demographic performance be inferred from the distribution and abundance of habitat?
2. Can the relation between owl occurrence and demographic performance be reliably predicted given a set of habitat characteristics at the landscape scale?
3. How well do habitat-based models predict occurrence and demographic performance in different land allocations?

The initial research on the relations between landscape habitat configuration and spotted owl survival and reproduction was completed by Franklin et al. (2000) in the north Coast Range and Klamath Mountains in northwestern California. They explored the variation in survival and reproduction of spotted owls relative to landscape habitat characteristics at the individual owl-territory scale. Franklin et al. (2000) were particularly interested in the effects of fragmentation of mature and old-growth forests on life history traits and fitness of spotted owls. In addition, Franklin's work examined the influence of climate on survival and reproduction.

In 1999, a project proposal by Anthony et al. (1998) for a 5-year study to explore predicting abundance and demographic performance of northern spotted owls from vegetative characteristics was funded by the spotted owl monitoring program. The study addressed the three questions posed above to determine if habitat quality and quantity could be used to provide reliable predictions of abundance and demographic performance of northern spotted owls. The stated objectives of the study were:

1. Summarize abundance and demographic performance of spotted owls at the home range and landscape scales.
2. Characterize landscape composition and patterns for home ranges and landscapes.
3. Develop statistical models that relate abundance and demographic performance of owls to landscape characteristics for a subset of home ranges in the demographic study areas.
4. Validate the statistical models by testing them on the remaining home ranges.
5. Use the statistical models to develop or refine existing spatially explicit models for spotted owls.

Another, separate study by Anthony et al. (2002b), not funded by the monitoring program, also explored the development of models to relate demographic performance of spotted owls to habitat characteristics at individual owl territories. In this study, they attempted to use models to evaluate the potential importance of specific habitat types to owl populations. This information will eventually be fed back into a larger project examining the development of silviculture systems for managing habitat important for sustaining spotted owl populations. It also has direct application to the owl abundance and demographic performance questions posed in the monitoring plan. By design, the model-building process employed in this work closely paralleled the work funded by the monitoring program, in part, because the projects are exploring similar questions and because the studies have many of the same principal investigators in common.

These three complementary studies form the nucleus of effort to develop models to predict spotted owl demographic parameters from habitat characteristics. Peer-reviewed results on the modeling efforts are reported by Franklin et al. (2000) and Olson et al. (2004). A summary of the findings in these two papers is provided in the "Results" section below.

Data Sources and Methods

Survival and productivity modeling—
Development of predictive models by using demographic information was initiated in four study areas under three separate studies in the range of the spotted owl. Owl population data from the northern California, Tyee (Roseburg), and H.J. Andrews demographic study areas and demographic data from the Umpqua and Rogue River National Forests and the Medford District of the Bureau of Land Management were used in the model-building work. Each of the modeling studies (Anthony et al. 2002a, 2002b; Franklin et al. 2000; Olson et al. 2004), followed the same general methods.

Franklin et al. (2000) formulated the initial analyses methods and the other investigators applied and expanded upon this pioneer work. The decision to pursue the same methods for analyses and model construction was beneficial because it allowed comparison of the results between study areas. The detailed methodologies of the respective studies can be reviewed in the individual reports (Anthony et al. 2002a, 2002b; Franklin et al. 2000; Olson et al. 2004). A general discussion of the methods used by the investigators is provided below.

General discussion of survival and reproductive output analytical approach—
The use of a priori hypotheses to describe how climate and habitat might affect owls was central to each of the predictive model development studies. These hypotheses were then expressed as models. The models used survival and reproduction as response variables, climate covariates as explanatory variables, and age and sex of the owls as individual covariates. An example hypothesis from Franklin et al. (2000) was that owl survival would be negatively affected by high precipitation and cold temperatures in both the winter and early nesting seasons. Franklin et al. (2000) pointed out the importance of the a priori model development approach in contrast to analyzing the data by iteratively searching the data for relations.

Capture-recapture data and Cormack-Jolly-Seber (Lebreton et al. 1992, Pollack et al. 1990) models were used to estimate survival rates. Owl reproductive output was estimated for each female from field counts of young fledged or by confirming via established survey protocols that no young were produced (Lint et al. 1999).

Climate was used as a time-varying covariate in the reproductive output and survival models. Three types of climate effects–seasonal, cumulative, and episodic–were considered. Franklin et al. (2000) defined five seasonal periods, which were also used, with minor variation of date sequences, by the other investigators. These periods were linked to annual life cycle of the spotted owl. The periods, as defined by Franklin et al. (2000) were:

- Winter stress period—November 15 through February 14
- Early nesting period—February 15 through May 14
- Late nesting period—May 15 through July 14
- Heat stress period—July 15 through September 14
- Dispersal period—September 15 through November 14

Daily measurements of amount of precipitation and minimum and maximum temperatures for each of the seasonal periods were obtained from National Oceanic and Atmospheric Administration National Weather Service stations in the vicinities of the respective study areas. Covariates for precipitation and temperature were derived from the weather station data.

Landscape habitat information was derived from available habitat map products ranging from aerial photo-interpreted products to satellite imagery-derived maps. Olson et al. (2004) used nested circles of varying radii (600-, 1500- and 2400-m radius; or 1,920-, 4,800- and 7,680-ft radius, respectively) around the owl nest site or primary roost area to quantify the habitat data for later analyses. Franklin et al. (2000) used a 0.71-km-radius (2,272-ft) circle around the territory centers to represent the spotted owl territory.

The a priori models were ranked by using model selection criteria following Akaike (1973) to determine which models best explained the empirical data. A multistep approach was used to model survival and productivity. The information theoretic approach (Burnham and Anderson 2002) was used to select the best model at each step in the model process. Refer to Franklin et al. (2000) and Olson et al. (2004) for details on model development and covariate analyses.

Occupancy modeling—

The development of models to predict likelihood of owl occupancy for a given habitat mosaic relied heavily upon the methodology developed by MacKenzie et al. (2002). This method estimates the proportion of sites occupied by a species at a single point in time, such as a given breeding season, when the probability of detection is less than 1. At this writing, the occupancy modeling effort is a work in progress and no peer-reviewed results are available.

Modeling was initiated in three of the demography study areas—Tyee, Oregon North Coast Range, and H.J Andrews. The interagency vegetation mapping project province maps were used for modeling in each of the study areas. In the Roseburg study area, two additional map sources were used. One was a map developed from aerial photointerpretation and the other was a satellite imagery-based map from the coastal landscape analysis and modeling study.

Habitat models were developed for both simple occupancy (occupied by any spotted owl) and pair occupancy (occupied by paired male and female spotted owl) using the parameters of initial occupancy, extinction probability, and colonization probability after MacKenzie et al. (2003). Additional models were developed in a post hoc manner by using combinations of these three parameters. The habitat variables and the radius distances around the owl activity centers were the same as those in the survival and reproduction model work explained above and detailed in Olson et al. (2004). Other covariates being explored include year, even-odd year effect, precipitation, and barred owl effect. The barred owl data are specific to the spotted owl territory, as opposed to the more general nature of the barred owl occurrence data used by Anthony et al. (2004).

Results

The survival and productivity of northern spotted owls is governed by biological and physical factors in their environment. Investigators (Franklin et al. 2000, Olson et al. 2004) examined the influence of climate, age and sex of the owls, amount of suitable habitat, and amount of unsuitable habitat to understand how these variables may affect spotted owl survival and productivity.

Survival modeling—
Franklin et al. (2000) found that annual survival was negatively affected by increased precipitation and positively affected by increased temperature during the early nesting period. Cold, wet springs had a negative effect on spotted owl survival, whereas warm, dry springs had a positive effect. Olson et al. (2004) noted that the relationship between early nesting season precipitation and survival was negative, but found that in their Oregon Coast Range province study area late nesting season precipitation had a positive effect on survival.

Franklin et al. (2000) discovered that apparent survival increased with increasing amounts of spotted owl habitat, increasing edge between spotted owl habitat and other habitats, and increasing mean nearest neighbor distance between patches of spotted owl habitat up to about 400 m (1,280 ft). As distance between patches increased above 400 m, survival declined with increasing distance. Similarly, Olson et al. (2004) stated that, in general, increases in late-seral forest had a positive effect on survival, whereas increases in early-seral and nonforest area had a negative effect. Their best model indicated a nonlinear relationship between late- and midseral forest and survival, with a slight decrease in survival when proportions of these cover types in the 1500-m-radius (4,800-ft) circle around the owl activity center were high.

Reproductive output modeling—
Franklin et al. (2000) pointed out that reproductive output was:

- Negatively associated with female age class (1- and 2-year-old owls fledged fewer young than >2-year-old owls).
- Negatively associated with the amount of core spotted owl habitat (nonlinearly).
- Positively associated with the amount of edge between spotted owl habitat and other habitats (nonlinearly).
- Associated with the number of patches of spotted owl habitat by an inverse quadratic relationship in which reproductive output was highest when the number of patches was either few or many and lowest when the number was intermediate.
- The changes in reproductive output were most sensitive to changes in edge between spotted owl habitat and other habitats.

They also determined that late-season precipitation was an important covariate in explaining reproductive output and provided support to the a priori hypothesis that predicted a negative relationship between reproductive output and precipitation during the late nesting period.

Olson et al. (2004) found the following relationships in the Oregon Coast Range study area:

- Age, in general, had a positive effect on productivity, and productivity of all owls was greater in even than odd years.
- There was a positive relation between precipitation in late nesting season and reproduction—opposite of Franklin et al. (2000).
- The presence of barred owls had a negative effect on productivity.
- Although there was a significant relation noted between habitat and productivity, the nature of the relation was unexpected. Productivity was apparently declining with increases in mid- and late-seral forest and was increasing with increases in early seral and nonforest area.
- The model with the greatest Akaike weight had a positive linear relationship between productivity and the amount of edge between early seral and nonforest and other classes combined.

Olson et al. (2004) offered the following summary findings on the relationship of habitat to spotted owl survival and productivity.

- For both survival and productivity, a mixture of early seral and nonforest with mid- and late-seral forest seemed to provide better habitat conditions for spotted owls.

- Owl survival was highest at about 70 percent of the forest in mid- and late-seral condition with productivity increasing linearly as the amount of edge between these forest types and other habitats increased (within 1500-m-radius [4,800-ft] circles).
- Maximum fitness potential was realized in territories where both factors were optimal; simply increasing the amount of mid- and late-seral forest could not achieve the goal. The pattern of forest type within territories is important.
- Large expanses of mid- and late-seral forests may not be optimal for owls, but neither are forests with small amounts of these forest types.
- Although there was a positive relationship between the amount of edge and productivity of spotted owls, the importance of edge for spotted owls is not well understood.

Franklin et al. (2000) discussed several hypotheses, first advanced by Gutierrez (1985), as potential mechanisms for their results, many of which Olson et al. (2004) also observed. Under the predation hypothesis, owls use older forests as cover to avoid predation by avian predators such as the great horned owl (*Bubo virginianus*). They explained that great horned owls are not as well adapted to hunt in older forest, and thus spotted owls could use these mature and old-growth forests that were not useable by great horned owls. In reference to the thermoregulation hypothesis, they pointed out that mature and old-growth forests provide a more stable microclimate and protection from inclement weather, which would promote use by the spotted owls. And finally, they offered that under the prey hypothesis, ecotones between older forests and early seral stages, at least in California, may be areas within the owl's home range where prey species such as the woodrat (*Neotoma* spp.) are both abundant and accessible to the owl as prey. They suggested that "sufficient core area" interspersed with other vegetation types may provide a source of large, accessible prey. Franklin et al. (2000) stated that there was a plausible link between the arrangement of habitat on individual owl territories, and survival and reproductive output.

Both of the studies provided measures of habitat fitness potential for individual owl territories. Franklin et al. (2000) noted from their habitat fitness potential analysis that spotted owl territories where survival is maximized had relatively large core areas of habitat with some edge. They found that those territories where fecundity was maximized had minimized core area habitat and maximized edge between spotted owl habitat and other habitats either by minimizing or maximizing the discrete patches of spotted owl habitat. Franklin et al. (2000) determined that in territories where the habitat fitness potential was high, it appeared that both survival and fecundity were high, while in those areas with low or medium fitness potential, either survival or fecundity were high, but never both. See figure 10, page 573 in Franklin et al. (2000) for examples of high, medium, and low fitness territories.

Occupancy modeling—
There were no peer-reviewed results available from the occupancy modeling efforts. Research work has focused on assessing the effects of barred owl presence on spotted owl occupancy and exploring the methods described by MacKenzie et al. (2002). Initial results should be available in late 2005.

What Did We Learn from the Model Work?

The original reason for embarking on predictive modeling was to explore the possibility of being able to shift from mark-recapture studies to increased reliance on predictive models to indirectly estimate the occurrence and demographic performance of spotted owls (Lint et al. 1999). Phase I involved conducting the research and building the models. Before moving to phase II where the models would be put into practice, it was envisioned we would have answers to the following questions.

- Can the status and trends in spotted owl abundance and demographic performance be inferred from the distribution and abundance of habitat?
- Can the relation between owl occurrence and demographic performance be reliably predicted given a set of habitat characteristics at the landscape scale?

- How well do habitat-based models predict occurrence and demographic performance in different land allocations?

Olson et al. (2004) concluded that although one study, such as theirs, could not definitively address the second question, the answer to the demographic performance portion of the question may be "no." Work is ongoing on the prediction of occupancy (abundance), so no answers are available on that portion of the questions. From these results we are not in a position, now or in the foreseeable future, to move to Phase II where the models would be substituted for mark-recapture studies.

We learned from Franklin et al. (2000) and Olson et al. (2004) that numerous sources of variation affect survival and productivity. Climate, primarily precipitation, can have a noticeable influence on survival and productivity depending upon when it occurs. Olson et al. (2004) and Franklin et al. (2000) suggested that survival and productivity of resident owls are more affected by precipitation during spring than other times of the year. Franklin et al. (2000) pointed out that their climate models do not demonstrate cause and effect, and testing of the models or their described effects cannot be tested with experiments because we have no control over climatic variation. The climate models have made us aware that understanding the influence of more than the amount and arrangement of habitat is important in predictive modeling.

We also learned that survival and productivity may be affected differently by habitat and climate. Franklin et al. (2000) stated that most of the variation in survival was based on habitat variation, and variation in reproductive output was equally based on climate and habitat variation. Olson et al. (2004) noted that climate variables accounted for less variability in productivity in their study than in Franklin et al. (2000) (38 percent vs. 55 percent). Also notable was the 43 percent of the variability explained by habitat in the Franklin et al. (2000) model compared to less than 3 percent in the best model of Olson et al. (2004). Olson et al. (2004) noted that it would require further study to determine whether these differences reflect different relative importance of habitat between the two study areas or are due to different methodologies and habitat classifications. Olson et al. (2004) noted that 59 percent of the model variability was explained by factors other than climate or habitat, which explained <2 percent.

Olson et al. (2004) stated, in summary, that their results indicate we have a lot to learn about how habitat affects spotted owl demography, but that they thought examination of habitat influences on fitness parameters represents the best way to learn. Franklin et al. (2000) offered "that understanding the magnitude, strength and relative importance of different factors under varying conditions provides a deeper understanding of population dynamics." The results of these two studies, although they did not produce operational models, follow the rationale of needing to try and to learn expressed by Lint et al. (1999).

This learning process continues with the exploration of models to predict occupancy for a given habitat mosaic. Initial results from the occupancy modeling will be available in late 2005.

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Joe Lint

Chapter 6: Emerging Issues and Monitoring Program Needs

Joseph Lint[1]

Emerging Issues

There are two emerging issues with potential to negatively affect the conservation and recovery of the spotted owl. Neither is directly related to the management of habitat under the Plan, but both may affect the Plan. The two issues are the interspecific interaction and competition between the barred owl and the spotted owl, and the potential threat of West Nile virus (*Flavivirus* spp.) infections in the spotted owl population.

The barred owl currently constitutes a significantly greater threat to the northern spotted owl than originally thought at the time of listing (Courtney et al. 2004). There are many ideas as to the cause of the barred owl invasion ranging from climate change to forest management practices. However, there are no data to support or refute any of these hypotheses (Kelly et al. 2003) and it is unclear if forest management has an effect on the outcome of interactions between barred and spotted owls (Courtney et al. 2004). It is known that barred owls appear to be habitat generalists that can occupy a broad range of forest conditions (Courtney et al. 2004). The continuing range expansion, increasing numbers, and possible negative influence on spotted owl occupancy make the barred owl a concern for the future.

The West Nile virus is a threat to the spotted owl because it has the potential to reduce the population numbers beyond the projected decline under the Plan. The magnitude of the potential effect is unknown. So far, no mortality in wild, northern spotted owls has been recorded, but the first cases of the virus in other species were only recently recorded in the range of the owl.

The barred owl and West Nile virus are potential stressors to the spotted owl. These stressors may have a direct effect on the success of the Plan in arresting the downward trend in the spotted owl population.

These two stressors clearly add a dimension to spotted owl management that is not a part of the habitat-based strategy of the Plan. The barred owl and West Nile virus are best addressed in the broader species conservation arena where all affected parties are involved. If and when strategies are developed to address these stressors, we will be better able to judge what role, new or continued, the Plan may have in managing the stressors.

For additional discussion of these two stressors, particularly barred owls, and other threats to the spotted owl refer to Gutierrez et al. (2004) and Courtney and Guiterrez (2004).

Monitoring Program Needs

The conclusion of the first 10 years of monitoring of spotted owls and their habitat under the Plan affords the opportunity for partner agencies to examine the spotted owl monitoring program and make adjustments as needed. In recent years, program managers from the partner agencies have reviewed and discussed the monitoring program to gain understanding and to inform decisionmakers about the program. The chapter on "Information Needs" by Courtney and Franklin (2004) in the larger report prepared by Sustainable Ecosystems Institute (SEI) provides additional information for consideration during the continued review of spotted owl monitoring program. Topic areas in Courtney and Franklin (2004) that may be germane to the review of the monitoring program are:

- Interaction with prey and prey biology
- Habitat associations
- Habitat trends
- Barred owls
- West Nile virus
- Demography

Copies of the SEI report are available at www.sei.org.

As Plan monitoring enters its second decade, discussions on the future of monitoring need to address the continuation of existing monitoring and research efforts, to include modifications to the scope and effort of these activities and the initiation of new activities. Foremost among the activities in the continuation discussion are

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the demographic studies. The data from these study areas have proven invaluable in assessing the status and trend of spotted owl populations. The data sets from years of demographic study are recognized as the best information on any raptor species anywhere in the world. Careful consideration of the consequences versus the benefits will need to be given to any proposal to continue, reduce, or expand the demographic study areas.

Initial efforts into the realm of predictive modeling to link landscape habitat characteristics with owl survival, productivity, and occupancy will be concluding in the next year. This will present a decision point on the future of this research. It will be time for managers to assess the results of these efforts and determine what next steps in predictive modeling, if any, might warrant investment and exploration.

The habitat status and trend information assembled for this 10-year monitoring report provided a good foundation for continued monitoring of the maintenance and restoration of owl habitat under the Plan. The tangible measures of success of the habitat-based Plan lie in the maintenance and restoration of habitat. Tracking habitat conditions over time will require attention to all the components involved. This includes the refinement of methods to identify habitat conditions, the characterization of change to those conditions, and the recruitment of those conditions through forest succession. Attention should also be given to solving the information management problems encountered during the preparation of this report.

There are several opportunities for initiating new monitoring and research. In the forefront is the need to explore cause-and-effect relations through formal experimentation for several of the correlative relations noted. Lack of information on several fronts precluded the authors of the 10-year report from offering much in the way of cause-and-effect relations for the population status and trend information presented. We are getting a handle on what happened, and now we must press to understand why and how particular things happened, recognizing that we must be selective in what we pursue. Inherent in deciding what to study is some idea of what we might do in response to confirmation of specific cause-and-effect relations. Candidate topics for understanding cause and effect include, but are not limited to, studies on spotted owl and barred owl interactions, effect of small-mammal abundance on owl demography, impacts of West Nile virus on owls, and effects of forest thinning on owls and their prey. Specific examples include controlled experiments of the effects of barred owl removal on spotted owl occupancy and productivity and the study of prey ecology at forest ecotones.

Of utmost importance to the future of the effectiveness monitoring program is for the agency managers to be proactive and decisive on both the continuation and initiation fronts. Courtney and Franklin (2004) pointed out that without continued monitoring and research efforts, subsequent reviews of the status of the owl will put us in the position of knowing less than we know now. Identifying the information needed for informed decisionmaking, and following up with direction and commitment to obtain that information are all essential steps to setting the course for spotted owl monitoring and research under the Plan in future decades.

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters (cm)
Feet (ft)	.305	Meters (m)
Miles (mi)	1.609	Kilometers (km)
Square miles (mi^2)	2.59	Square kilometers (km^2)
Acres (ac)	.405	Hectares (ha)

Glossary

adaptive management areas—Landscape units designated for development and testing of technical and social approaches to achieving desired ecological, economic, and other social objectives.

adaptive management reserve—adaptive management areas that occur within the boundaries of late-successional reserves (see late-successional reserves).

algorithm—A procedure used to solve a mathematical or computational problem or to address a data processing issue. In the latter sense, an algorithm is a set of step-by-step commands or instructions designed to reach a particular goal.

associated species—A species found to be numerically more abundant in a particular forest successional stage or type compared to other areas.

attribute—Information about a geographic feature (grid-cell or polygon) in a geographic information system, usually stored in a table.

autocorrelation—The lack of independence between pairs of observations at given distances in time or space as is commonly found in ecological data.

baseline—The starting point for analysis of environmental consequences. This may be the conditions at a point in time (for example, when inventory data are collected) or may be the average of a set of data collected over a specified period.

blowdown—Trees felled by high winds.

correlation matrix—A table showing the intercorrelations among all variables.

covariance matrix—A square matrix that contains all of the variances and covariances among variables.

DEM—Digital elevation model. Grid-based geographic information system data that contains x, y, and z (east, north, and elevation) coordinates for each grid cell. Developed by the U.S. Geological Survey for geographical and topographical data.

demography—The quantitative analysis of population structure and trends; population dynamics.

diameter at breast height—The diameter of a tree measured 4.5 feet above the ground on the uphill side of the tree.

digital orthophoto—An aerial photo or satellite scene that has been transformed by the orthogonal projection, yielding an image that is free of most significant geometric distortions.

dispersal—The movement, usually one way and on any time scale, of plants or animals from their point of origin to another location where they subsequently produce offspring.

dispersal habitat—Forest stands with average tree diameters >11 inches and conifer overstory trees with closed canopies (>40 percent canopy closure) and with open space beneath the canopy to allow the owls to fly (Thomas et al. 1990).

distribution (of a species)—The spatial arrangement of a species within its range.

edge—Where plant communities meet or where successional stages or vegetative conditions with plant communities come together.

Eigenvalue—Column sum of squared loadings for a factor; also referred to as the latent root. It conceptually represents that amount of variance accounted for by a factor.

factor—Linear combination (variate) of the original variables. Factors also represent the underlying dimensions (constructs) that summarize or account for the original set of observed variables.

fecundity—A measure of animal (in this case, spotted owl) productivity expressed as the number of female young per adult female.

final environmental impact statement (FEIS)—The final report of environmental effects of proposed action on an area of land. This is required for major federal actions under Section 102 of the National Environmental Policy Act. It is a revision of the draft environmental impact statement that includes public and agency responses to the draft.

Forest Ecosystem Management Assessment Team (FEMAT)—As assigned by President Clinton, the team of scientists, researchers, and technicians from seven federal agencies who created the Forest Ecosystem Management Assessment Team report (1993).

fuzzy accuracy classification—A widely accepted technique in remote sensing that permits greater flexibility in interpretation of map predictions of what is actually on the ground. It works by degrees of membership, whereas traditional techniques are discrete (right or wrong).

fuzzy-set—Using conventional logic, individual values or items either are, or are not, members of a set. In contrast, fuzzy sets attempt to model imprecision, approximation, or vagueness. In fuzzy logic, a fuzzy set is a set of values or items whose individual degree of membership in the set may range from 0 to 1.

geographic information system (GIS)—A computer system capable of storing, manipulating, and displaying spatial (that is, mapped) data.

grid cell—A single element in a grid or raster-based GIS, similar to the individual cell of a spreadsheet. The cell, also called a pixel, contains two types of information, its geographic (x,y) coordinates and a thematic attribute value. Grid size or scale can usually be defined by the user.

guideline—A policy statement that is not a mandatory requirement (as opposed to a standard, which is mandatory).

habitat— The resources and conditions present in an area that produce occupancy—including survival and reproduction—by a given organism.

habitat diversity—The number of different types of habitat within a given area.

habitat fragmentation—A landscape-scale process of breaking up habitat into smaller, and sometimes more isolated, patches through modification or conversion of habitat by natural processes or human land use activities.

histogram—A graphical way of showing the characteristics of the distribution of values in a given population or sample. A bar graph that shows the frequency of data in intervals.

Interagency Scientific Committee (ISC)—A committee of scientists that was established by the Forest Service, Bureau of Land Management, Fish and Wildlife Service, and National Park Service to develop a conservation strategy for northern spotted owls.

land use allocation—The specification in forest plans of where activities, including timber harvest, can occur on a national forest or Bureau of Land Management district.

landscape—A heterogeneous land area with interacting ecosystems that are repeated in similar form throughout.

late-successional old-growth habitat—A forest in its mature or old-growth stages.

late-successional reserve—A forest in its mature or old-growth stages that has been reserved under a management option (see “old-growth forest” and “succession”).

management activity—An activity undertaken for the purpose of harvesting, traversing, transporting, protecting, changing, replenishing, or otherwise using resources.

map unit—A discretely mapped entity, also called mapping unit (see “pixel”).

matrix—Federal lands outside of reserves, withdrawn areas, and managed late-successional areas.

model—An idealized representation of reality developed to describe, analyze, or understand the behavior of some aspect of it; a mathematical representation of the relations under study. The term “model” is applicable to a broad class of representations, ranging from a relatively simple qualitative description of a system or organization to a highly abstract set of mathematical equations.

monitoring—The process of collecting information to evaluate if objective and anticipated or assumed results of a management plan are being realized or if implementation is proceeding as planned.

monitoring program—The administrative program used for monitoring.

neighborhood functions—Geographic information system analytical functions (such as mean, maximum, or variety of values) that assign a value to each grid cell by taking its surrounding pixels into consideration.

niche—A region in a multidimensional space of environmental factors that affect the welfare of a species (Hutchinson 1957).

normal distribution—A symmetrical data distribution that can be expressed in terms of the mean and standard deviation of the data. The normal distribution is the most widely encountered model for probability and is characterized by the "bell curve." Also called "Gaussian distribution."

northern spotted owl—One (*Strix occidentalis caurina*) of three subspecies of the spotted owl that ranges from southern British Columbia, Canada, through western Washington and Oregon, and into northwestern California. Listed as a threatened species by the U.S. Fish and Wildlife Service.

old growth—This successional stage constitutes the potential plant community capable of existing on a site given the frequency of natural disturbance events. For forest communities, this stage exists from about age 200 until stand replacement occurs and secondary succession begins again. Depending on fire frequency and intensity, older forests may have different structures, species composition, and age distributions. In forests with longer periods between natural disturbance, the forest structure will be more even-aged at late mature or early old-growth stages.

old-growth forest—A forest stand usually at least 180 to 220 years old with moderate to high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; high incidence of large trees, some with broken tops and other indications of old and decaying wood (decadence); many large snags; and heavy accumulations of wood, including large logs on the ground.

old-growth stand—A mappable area of old-growth forest.

overstory—Trees that provide the uppermost layer of foliage in a forest with more than one roughly horizontal layer of foliage.

physiographic province—A geographic area having a similar set of biophysical characteristics and processes because of the effects of climate and geology that result in patterns of soils and broad-scale plant communities. Habitat patterns, wildlife distributions, and historical land use patterns may differ significantly from those of adjacent provinces.

pixel—See grid cell.

pixel noise—The "speckled" or "salt and pepper" appearance in a grid map caused by pixels in close proximity to each other having a wide variation of values.

polygon—A graphic figure that represents an area in a geographic information system.

population—A collection of individual organisms of the same species that potentially interbreed and share a common gene pool. Population density refers to the number of individuals of a species per unit area, population persistence to the capacity of the population to maintain sufficient density to persist, well distributed, over time.

process—Change in state of an entity.

range (of a species)—The area or region over which an organism occurs.

record of decision—A document separate from but associated with an environmental impact statement that states the management decision, identifies all alternatives including both the environmentally preferable and preferred alternatives, states whether all practicable means to avoid environmental harm from the preferred alternative have been adopted, and if not, why not.

recovery—Action that is necessary to reduce or resolve the threats that caused a species to be listed as threatened or endangered.

sensitivity analysis—An investigation of how the outcome might change with different input data.

species—(1) A group of individuals that have their major characteristics in common and are potentially interfertile. (2) The Endangered Species Act defines species as including any species or subspecies of plant or animal. Distinct populations of vertebrates also are considered to be species under the act.

stand (tree stand)—An aggregation of trees occupying a specific area and sufficiently uniform in composition, age, arrangement, and condition so that it is distinguishable from the forest in adjoining areas.

stand condition—A description of the physical properties of a stand such as crown closure or diameters.

stand-replacing event—A disturbance that is severe enough over a large enough area (for example, 10 acres) to virtually eliminate an existing stand of trees and initiate a new stand.

standards and guidelines—The primary instructions for land managers. Standards address mandatory actions, whereas guidelines are recommended actions necessary to a land management decision.

stationary population—A population of owls where estimates of the annual rate of population change are not significantly different from 1.0 suggesting that the population is neither increasing or decreasing.

stochastic—Random, uncertain; involving a random variable.

successional stage—A stage or recognizable condition of a plant community that occurs during its development from bare ground to climax. For example, coniferous forests in the Blue Mountains progress through six recognized stages: grass-forb, shrub-seedling, pole-sapling, young, mature, and old growth.

structure—The various horizontal and vertical physical elements of the forest.

succession—A series of dynamic changes by which one group of organisms succeeds another through stages leading to potential natural community or climax. An example is the development of a series of plant communities (called seral stages) following a major disturbance.

threatened species—Those plant or animal species likely to become endangered species throughout all or a significant portion of their range within the foreseeable future. A plant or animal identified and defined in accordance with the 1973 Endangered Species Act and published in the Federal Register.

training data set—Data points used to construct a model.

wildfire—Any wildland fire that is not a prescribed fire.

windthrow—Synonymous with windfall, blowdown.

young stands—Forest stands not yet mature, generally less than 50 years old; typically 20 to 40 years old.

Continue to Appendixes A through D