CHAPTER 21

Plum Creek's Central Cascades Habitat Conservation Plan and Modeling for the Northern Spotted Owl

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The northern spotted owl (*Strix occidentalis caurina*) is the largest of the three subspecies of spotted owl inhabiting western North America (Gutiérrez et al. 1995). The species was listed as threatened by the U.S. Fish and Wildlife Service (1990) under the Endangered Species Act (ESA) in 1990 based on three findings by the agency: (1) suitable forest habitat was declining throughout its range; (2) populations showed declining trends; and (3) existing regulatory mechanisms were not adequate to protect the owl.

Following the federal listing of the spotted owl, confusion ensued regarding the regulatory impact of listing on state and private lands within the range of the species (Dietrich 1992). Not only were the numbers of spotted owl sites on nonfederal lands poorly known due to lack of adequate surveys, but the amount and configuration of suitable habitat needed to support each site were the subject of vigorous public debate (Yaffee 1994). This confusion was especially true for private forest landowners who found themselves caught on two separate playing fields as both state and federal agencies sought to impose conflicting regulations protecting the spotted owl on nonfederal lands. Eventually, what emerged in Washington state was a "circles and survey" regulatory strategy whereby landowners were required to conduct protocol surveys in suitable habitat for spotted owls and verify reproductive status for each pair found. Moreover, for each pair located, a circle with a radius approximating the mean annual home range was designated. In the central Cascades, a 2.9 km radius circle totaling 2,695 ha was designated, within which 40% (1,078 ha) must be maintained as suitable spotted owl habitat. The size of the regulatory circle varied, depending on spotted owl home range and habitat use studies conducted in various regional provinces such as the Olympic Peninsula, Cascades, Oregon Coast, or Northern California (U.S. Fish and Wildlife Service 1989, Lemkuhl and Raphael 1993, Bart 1995, Meyer et al. 1998). Within a few years of listing, landowners within the range of the spotted owl found themselves with both expensive survey requirements and significant acres of timber assets encompassed in regulatory circles. Within Washington's Interstate-90 corridor in the Central Cascades, 107 regulatory circles affected thousands of acres of Plum Creek property (Fig. 21-1). It is important to note that these circles moved as spotted pairs moved, requiring constant surveys and monitoring of spotted owl pairs, as well as dispersing offspring forming new pairs, creating yet more regulatory circles. This regulatory scenario not only was problematic for forest managers, but was not a desirable biological approach to managing spotted owls and their habitat across landscapes. Management circles did not incorporate landscape variability such as

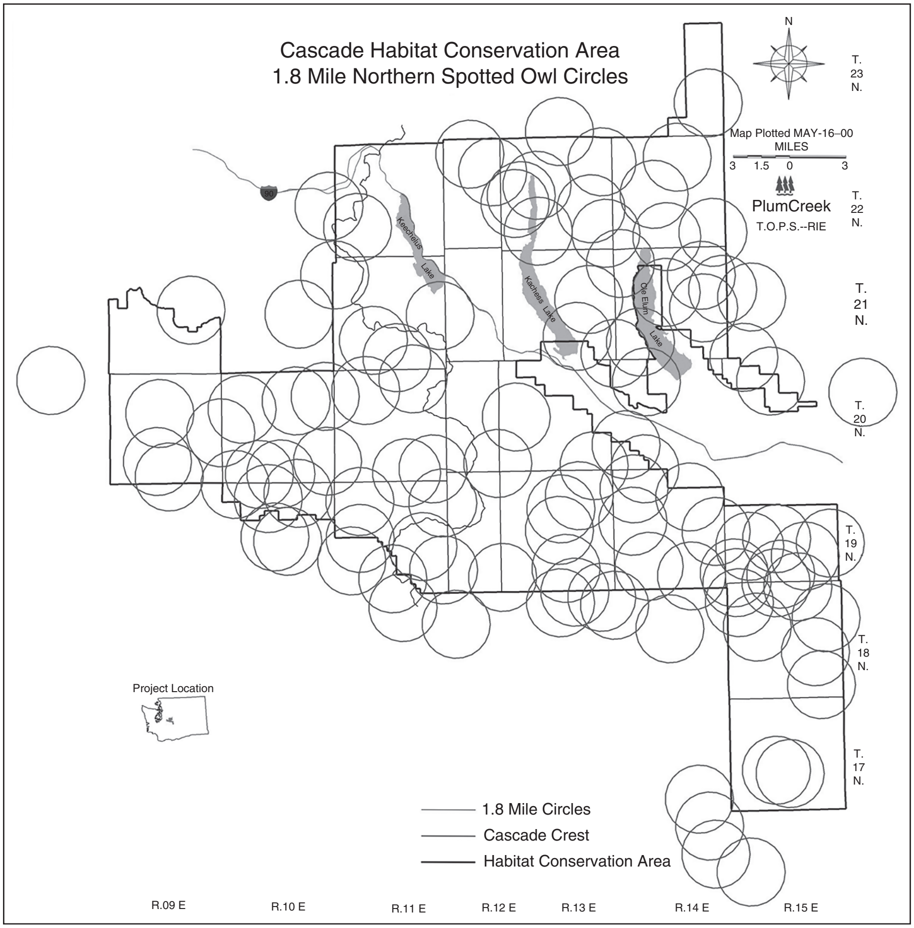

FIG. 21-1

Circles represent 2.9 km radius spotted owl activity centers (nest sites or locations of multiple owl observations) in the 170,000 ha Cascades Habitat Conservation Plan Area, central Cascades Mountain Range, Washington, USA.

topography, water bodies, and habitat juxtaposition, which are important factors affecting spotted owl use. In areas of high spotted owl density, regulatory circles often overlapped, including habitat for multiple pairs that logically would only be used by one pair of nesting owls. Additionally, regulatory circles and habitat within could be removed as spotted owl sites became vacant over time.

In addition to the northern spotted owl, other species in the region were subsequently listed or proposed for listing, such as stocks of Pacific salmon (*Oncorhynchus* spp.), marbled murrelet (*Brachyramphus marmoratus*), bull trout (*Salvelinus confluentus*), and Canada lynx (*Lynx canadensis*). Combined with species that were federally listed prior to the northern spotted owl, such as the grizzly bear (*Ursus arctos horribilis*), gray wolf (*Canis lupus*), bald eagle (*Haliaeetus leucocephalus*), and peregrine falcon (*Falco peregrinus*), wildlife management in the Pacific Northwest became exceedingly contentious and complex. The threat of additional species listings further eroded the regulatory predictability desired by federal, state, and private forest landowners.

In the early 1990s, several conservation strategies were proposed for lands managed by the U.S. Forest Service and Bureau of Land Management (Thomas et al. 1990, Lujan et al. 1992), culminating in the Northwest Forest Plan, which is presently guiding federal land management activities in Oregon, Washington, and northern California (Forest Ecosystem Management Assessment Team 1993). All these strategies sought to avoid the pitfalls of single-species management by addressing multiple species at the landscape scale.

The voluntary habitat conservation planning process, added to the ESA in 1982, provided the opportunity for private forest landowners such as Plum Creek to develop a landscape-scale long-term management plan in cooperation with the federal agencies to address the needs of listed species like the spotted owl, as well as other wildlife species that could be federally listed in the future. Several industrial timber companies in the Pacific Northwest initiated landscape-scale, multispecies conservation plans during the 1990s under either federal or state regulations with varying outcomes (Loehle et al. 2002).

In this chapter, we describe how Plum Creek's Central Cascades Habitat Conservation Plan (HCP) was developed to embrace a multispecies approach to habitat management at the landscape level. We discuss how the HCP incorporated models to both quantify habitat relationships and provide a means to develop alternatives and evaluate impacts of HCP implementation on associated resources. Finally, we offer some insights into HCP effectiveness, based on the first 10 years of plan implementation.

THE HABITAT CONSERVATION PLAN PROCESS

Section 10 of the ESA provides nonfederal land managers with the ability to apply for an incidental take permit when their otherwise lawful management activities may affect listed species in such a way as to harass or harm them, which is considered to be "incidental take." Such incidental take can be the result of habitat modification or destruction. An application for an incidental take permit must be accompanied by a conservation plan which specifies the impacts anticipated to result from that incidental take; the methods the land managers will use to minimize, mitigate, and monitor the incidental take; alternatives considered; and other measures that may be necessary.

These conservation plans are often called Habitat Conservation Plans (or HCPs), as they usually focus on providing habitat for the species in question (Beatley 1994). These plans may address unlisted species in addition to listed species. Habitat Conservation Plans form the basis for agreements between the land manager and the federal agencies (U.S. Fish and Wildlife Service and National Marine Fisheries Service; hereafter referred to as the Services), and are often long-term agreements with assurances on both sides. The HCP also describes the current status of the environment, the status of the various species in question, and the relevant science and stressors surrounding them.

A comparison between the species and habitat conditions that would be expected to result from permit issuance through the HCP and the conditions that would be expected to result from the status quo without permit issuance is normally a part of an HCP as well, including discussion of alternate scenarios. Estimating species and habitat conditions through various action and no-action scenarios over long periods of time can be a challenge. This is especially true for forest ecosystems because the permutations and consequences of management may last for decades. Moreover, there are large uncertainties about outcomes under both the "action" (e.g., HCP) and "no-action" (circles and surveys) scenarios. For instance, if owl sites were to become vacant and regulatory circles removed, less habitat would be available under the "no-action" scenario than if owls had persisted at those sites.

In landscape planning of this nature, various actions of the HCP applicant must be considered in context with actions by adjacent landowners, such as the U.S. Forest Service. Additionally, species considered in the HCP may be affected by factors completely outside the planning area, such as ocean conditions for salmon and marbled murrelet populations. Compliance with the National Environmental Policy Act often requires projections of effects for various management alternatives, thereby necessitating modeling or other projection analyses to understand long-term plans such as an HCP. Because of this uncertainty and lack of complete managerial control, HCPs generally focus on habitat provided by the applicant and avoid population metrics as a measure of plan success.

When processing an application for an incidental take permit, the federal agencies must determine that the action will not jeopardize any listed species nor destroy critical habitat for any listed species. This requirement for the federal action of permit issuance is the same as the requirements for any project that is conducted, funded, or authorized by a federal agency, and is addressed by completion of a Biological Opinion under section 7 of the ESA. In addition, Section 10 specifies a number of specific issuance criteria that must be met in order for such an incidental take permit to be issued. For instance, one of these criteria is that the impacts associated with the taking of the species must be minimized and mitigated to the maximum extent practicable. The federal agencies generally document the fulfillment of the issuance criteria in a document known as a Statement of Findings. When an HCP is properly prepared, it will provide the information needed by the public to understand how the federal agencies may be capable of making their independent determinations that will be contained within the Biological Opinion and Statement of Findings.

Since its inception in 1982, the incidental take permit program under the ESA has grown considerably to include many applicants and a substantial land area. As of 2007, the U.S. Fish and Wildlife Service (USFWS) approved 537 HCPs covering >18.2 million hectares (U.S. Fish and Wildlife Service 2007). These HCPs include plans for single species and plans that seek to address the needs of multiple species within the planning area. Multispecies HCPs have been encouraged by agencies and conservation interests because it is thought to improve the potential for an effective management program and reserve system. Additionally, permittees have incentives to cover as many species as possible in the incidental take permit to protect themselves against future listings. Consequently, including more species in an HCP would seem to serve both interests, providing more certainty for the permittee and increasing overall conservation value. However, multispecies HCPs have been criticized as inadequate and ineffective. Critics have claimed that many HCPs lacked the supporting data to justify conservation measures offered in the plans, and that few HCPs were designed to include adequate monitoring to inform future decisions (Kareiva et al. 1999). For instance, Rahn et al. (2006) cited three deficiencies in 22 multispecies HCP reviewed. Shortcomings that could limit conservation value were too broad and considered species for which there was no localized scientific information. Second, most unconfirmed species did not have specific conservation actions. Finally, the degree of justification was quite variable for included species and the extent the plans offered species-specific conservation actions.

As will be discussed later, the Plum Creek Cascades HCP incorporated a combination of general habitat-related conservation measures (e.g., forest structure stage diversity, talus slopes, ponderosa pine habitat, springs and seeps, etc.) and species-specific conservation actions (e.g., northern spotted owl, marbled murrelet, grizzly bear, and gray wolf). Even though some vertebrate species were not confirmed to be present in the planning area at the time of HCP development, subsequent surveys confirmed presence and that general habitat-related conservation measures were effective. For instance, the Larch Mountain salamander (*Plethodon larselli*) was suspected to occur in the planning area but was not confirmed until the HCP had been implemented for three years. The species was found to occur in areas where talus slope conservation measures were implemented to minimize ground disturbance and maintain conifer cover and moss for micro-site moist climate conditions that this species prefers.

Another shortcoming of HCPs is that they are expensive to develop and have become more difficult to complete in the last 10 years. The Services have made planning funds available, but there is no certainty that an applicant beginning an HCP process will be successful. Many applicants are drawn to HCPs out of necessity in the short term to mitigate an ESA-related conflict (e.g., a land development project) and others by the desire for long-term certainty (e.g., forest landowners with 50-year timber rotations).

The "no surprises" rule (50 CFR 17.22, 17.32) provides that HCP permittees will not be required to provide more money or land for conservation efforts once an HCP has been approved, except under extraordinary circumstances. The "no surprises" policy was installed by the Department of Interior in 1994 to address uncertainty inherent in the HCP process that was leading to very low HCP participation levels. The "no surprises" policy, including the subsequent rule promulgated in 1998, was very effective in providing an incentive for landowners to develop HCPs, particularly multispecies HCPs that include both listed and unlisted species (Slingerland 1999). Conversely, the "no surprises" rule has been criticized as effectively precluding adaptive management and changes needed to inform and improve HCPs over time (Wilhere 2002, Rahn et al. 2006).

Adaptive management is necessary where substantial risk exists and can also be used where agreement could not otherwise be reached. In the realm of HCPs, adaptive management may mean that a land manager may need to operate differently in the future to accommodate changing or unexpected conditions, or to accommodate the development of new information. Operating differently might involve additional land or water encumbrances, or other expenses. However, because this added conservation was part of and contemplated in the HCP Implementation Agreement, it does not conflict with the "no surprises" rule. Therefore, adaptive management must be carefully considered prior to entering into such an agreement. Modeling is an important component of examining various management scenarios through time and assessing the ecologic, economic, and social ramifications of a conservation plan. The relationship between the "no surprises" policy and adaptive management in the Plum Creek Cascades HCP is explored later in this chapter.

CASCADES HABITAT CONSERVATION PLAN

The Cascades Habitat Conservation Plan area is located in the central Cascade Mountain Range of Washington. The 170,000 ha planning area lies between 100 and 160 km east of the city of Seattle along the Interstate-90 corridor (Fig. 21-2). Because of the "checkerboard" configuration of land ownership, the HCP planning area included 69,000 ha of Plum Creek ownership and about

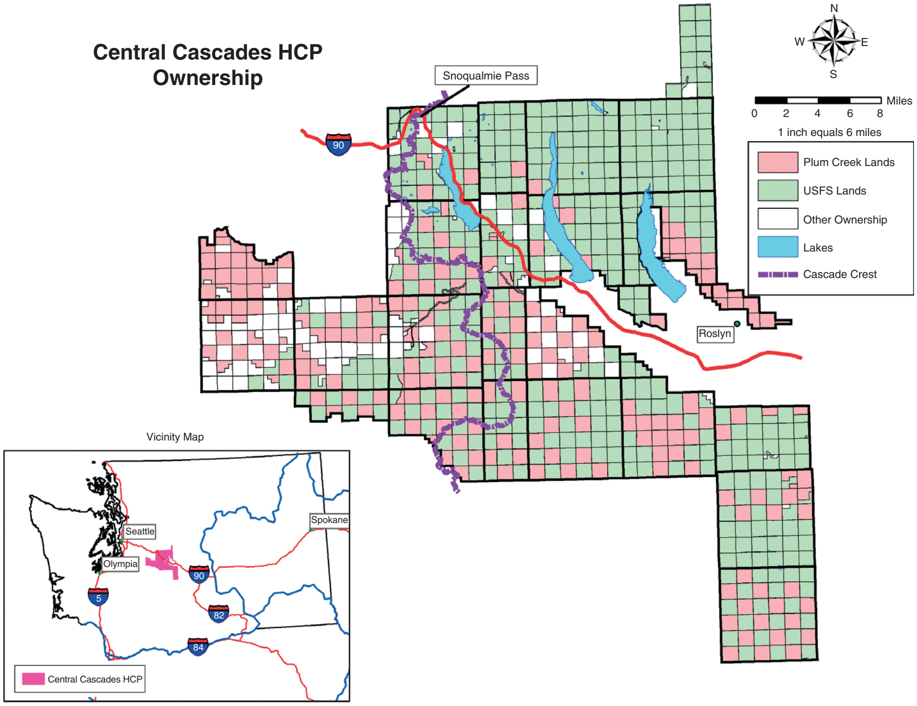

FIG. 21-2

Land ownership pattern in the 170,000 ha Cascades Habitat Conservation Plan Area, central Cascades Mountain Range, Washington, USA.

101,000 ha of other ownership intermingled and surrounding the Plum Creek lands (Fig. 21-2). Other major ownerships include the U.S. Forest Service, Washington State Department of Natural Resources, and the City of Tacoma. The checkerboard configuration is a result of land grants provided to private railroad companies by the federal government in the 1800s as an incentive to build rail lines into largely unsettled territories and provide U.S. military transport. The railroad companies were typically granted alternating 2.5 km^2 sections of land for 32 km on both sides of the rail line. Plum Creek purchased these lands from the railroad in 1989.

The HCP planning area straddles the Cascades mountain range crest and includes the varying climatic conditions and resulting forest conditions of two physiographic provinces: the western Washington Cascades and eastern Washington Cascades (Bailey 1988, Thomas et al. 1990). The western portions of the project area are dominated by humid forests composed primarily of Douglas fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) at middle and lower elevations and noble fir (*Abies procera*), Pacific silver fir (*A. amabilis*), and mountain hemlock (*T. mertensiana*) at higher elevations.

Westside forests are generally represented by only one or two tree species and greater uniformity in tree size within stands. Climatic conditions in this region are relatively mild with moist winters.

The eastern portions of the planning area are dominated by mixed-conifer (grand fir [*A. grandis*], Douglas fir, western larch [*Larix occidentalis*], ponderosa pine [*Pinus ponderosa*], western white pine [*P. monticola*], lodgepole pine [*P. contorta*]) forests at middle and lower elevations. Forests east of the Cascade crest are typically composed of a greater diversity of tree species (i.e., typically five or more species per stand) and greater diversity of tree sizes within stands than the forests west of the Cascade crest. Higher elevations in the eastern Cascades are dominated by subalpine fir (*A. lasiocarpa*) and Engelmann spruce (*Picea englemannii*). The interior climate east of the Cascade crest produces less precipitation overall, which usually occurs in the form of snow during the winter. Forests in this eastern region are fragmented due to poor soils, high fire frequencies, alpine meadows, and timber harvesting.

Multispecies Approach

Early in the negotiation process between Plum Creek and the Services, fundamental points of agreement were documented in the form of a "term sheet" that facilitated development of the HCP. The term sheet identified objectives and expectations for the HCP such as provisions for spotted owl dispersal habitat, coordination with the Northwest Forest Plan on intermingled U.S. Forest Service land, and attention to issues threatening forest health on Plum Creek land. Based on conversations with the Services, and interaction of a Plum Creek science team made up of staff and outside consulting experts, a more refined list of HCP components emerged, which influenced the selection of models, tools, and techniques to construct the HCP. These components include a riparian strategy, adaptive management, habitat "futuring," and a reserve network designed to complement and augment conservation measures implemented on federal land.

Several alternative management scenarios were developed early in the Cascade HCP process. These included a riparian alternative, whereby most of the habitat for federally listed species would be concentrated along major fish-bearing streams. Another alternative was termed the "dispersal strategy" where Plum Creek's contribution to spotted owl habitat would be restricted to middle-successional forests that could support dispersing juveniles to nesting habitat on public land. Although we used models and analysis techniques described later in this chapter to analyze these alternatives, the advent of the "no surprises" policy described earlier provided the impetus to expand the scope of the Cascades HCP to include multiple species and a wider variety of habitat conservation measures (Slingerland 1999).

Due to the substantial number of species that are currently listed or may be listed in the future on and adjacent to Plum Creek's lands in the planning area, we believed that a multispecies, ecosystem-based conservation plan was the most effective way to plan for ongoing forest management within the laws governing and protecting wildlife species (Noon et al., this volume). By attempting to address the habitat requirements of multiple species in conjunction with planning efforts by federal, state, and other private landowners, the HCP could contribute to proactive conservation. By maintaining healthy populations, these conservation plans may possibly negate the need for formal ESA protection for certain species in the future, protecting Plum Creek from potential ESA-related regulatory constraints.

The Plum Creek Cascades HCP addresses the biological needs of 315 species of fish and wildlife known to occur in the planning area and other vertebrate species across all taxa that depend on similar habitats and are suspected to occur in the planning area. The multispecies approach can help to reduce conflicts over resource management by providing a mechanism for consideration of overall ecosystem health, habitat availability, and the needs of multiple species. To achieve this broad goal, the HCP focuses on ecosystems and habitats rather than species, addresses impacts not only at the site scale but also on an ecosystem scale, and concentrates on potential long-term or future impacts rather than on intermediate or short-term impacts. Further discussion of an ecosystem diversity focus in private land planning is explored by Haufler and Kernohan (this volume).

Because of the intermingled land ownership in the HCP planning area, we designed the HCP to be consistent with the goals and objectives of management efforts on federal lands by the U.S. Forest Service. The multispecies approach in the HCP tiers to the multispecies approach in the Northwest Forest Plan. In concert, these two landscape plans protect forest habitat, provide management options for the protection of stream corridors to enhance conditions for associated aquatic and terrestrial species, and provide forest connectivity among patches of various forest structure stages.

The primary objectives of the HCP are:

1. To comply with the requirements of Section 10 of the ESA, including, to the maximum extent practicable, minimizing and mitigating impacts of any "take" incidental to lawful timber harvest and related forest management activities;

2. To provide Plum Creek with predictability and flexibility to manage its timberlands economically while contributing in a meaningful way to the conservation of the listed species and numerous other unlisted species; and

3. To provide habitat conditions to conserve the ecosystem upon which all species depend in the planning area.

The components of the HCP help to avoid, reduce, or eliminate potentially adverse environmental impacts resulting from Plum Creek's forest management activities. The components include measures to maintain and protect riparian habitat areas, spotted owl habitat management, a watershed protection program, retention of green trees and snags, and protection of special habitats for all vertebrate species of wildlife known or suspected to occur in the project area, in addition to monitoring to ensure effective implementation and guide potential changes.

HABITAT CONSERVATION PLAN MODELING

Forest Stand Classification

A primary focus of the ecosystem management approach in the HCP planning area is to link the biological needs of forest wildlife to the physical and vegetative characteristics of the forest environment. This approach requires:

1. A system to classify the diverse forest stands over a large landscape;
2. An alignment of the biological requirements of resident wildlife species with the forest stand classification system; and
3. A modeling capability to predict the amount and location of the various forest classes in the future as a result of forest growth and management across the intermingled land ownership.

To develop the HCP, we evaluated the planning area using geographic information systems (GIS) to describe attributes including elevation, slope, aspect, annual precipitation, soil type, vegetation, and ownership. A hierarchical ecological classification system identified seven levels and included both abiotic and biotic parameters: Ecoregion, Geologic District, Landtype Association, Landtype, Valley-bottom Type, Landform, and Vegetation Type. Combined with existing timber inventories, we used this information to establish a forest stand structural classification system for wildlife, following Oliver and Larson (1990) and further described in Oliver et al. (1995). Important features of the classification system include the use of common timber inventory parameters that are often already measured by foresters and exist in a format which, due to the intermingled land ownership, was compatible with U.S. Forest Service timber inventory data. We refined the system using a stand visualization program (McGaughey 2002) that constructed visual plots of the structure stages from actual data. From this process, we identified eight forest stand structure stages: stand initiation, shrub/sapling, young forest, pole timber, dispersal forest, mature forest, managed old growth, and old growth.

The structural stages are defined by tree diameter ranges. Stand age is used in part to identify old-growth stands. Classification criteria differed between the westside and eastside Cascade mountain range portions of the HCP project area to account for the climatic and tree species composition differences in the two ecological provinces. We developed two structure stages—dispersal forest and managed old growth—for special conditions and needs of the HCP. Dispersal forest encompasses the "entry level" stand conditions favorable to dispersal of spotted owls by providing minimal conditions for roosting and foraging, allowing owls to move between more favored habitats. Managed old-growth stands contain large diameter trees, are generally <200 years old, and typically have a history of selective timber harvest. Managed old growth was developed from experimentation in structural retention as discussed by Lindenmayer and Franklin (2002) and Franklin et al. (1997). For managed old-growth stands to be included in further calculations of spotted owl habitat, sufficient forest structure had to be retained to maintain conditions favorable to spotted owls as nesting, roosting, and foraging habitat (Hicks 1991). Our specifications for spotted owl foraging/dispersal habitat and nesting, roosting, and foraging habitat used in the HCP were based on over 1,000 vegetation plots collected on locations of radio-tagged spotted owls throughout the planning area from 1988 to 1995 (Hicks and Stabins 1995, Hicks et al. 1995, Herter et al. 2003).

Lifeforms and Wildlife Habitat Analyses

To evaluate, model, and plan for a variety of habitat conditions to benefit the multiple wildlife species found in the HCP project area, we developed a wildlife habitat relationship matrix following Thomas (1979) and Brown (1985). The "lifeform" approach developed and described by Thomas (1979) for the Blue Mountains of Oregon and Washington and by Brown (1985) for western Washington and Oregon were the state-of-the art compendiums for multispecies habitat relationship data at the stand and landscape level when work on the HCP began. Moreover, the format was familiar to our peers and reviewers and was applicable to other ownerships in the HCP planning area. We consulted with local experts to refine and adjust the matrix accounts for the known or suspected occurrences of vertebrate wildlife species across the array of forest types, forest stand structural stages, and special habitats that occur in the planning area, which allowed quantitative assessments of wildlife habitat across the landscape (Lundquist and Hicks 1995). Further analyses using the matrix allowed the comparison of various outcomes from alternative management scenarios or changes to the plan's assumptions on wildlife habitat distribution and amounts over the HCP's 50-year planning period.

We grouped over 300 wildlife species into 16 guilds, or lifeforms, that describe their breeding and feeding strategies (Table 21-1). We assumed that habitat conditions are the primary determinants of the number of wildlife species and numbers of individuals in a given area. We then assigned forest stand structure stages developed for the forest classification system, and special habitat types such as wetlands or talus slopes, to each of the lifeforms. We designated stand structures as nonhabitat, primary habitat, and secondary habitat. Primary habitats were those on which the species relied, while secondary

Table 21-1 Lifeform Descriptions Used in Plum Creek's Cascades Habitat Conservation Plan, Washington, USA

No.	Lifeform Type	Search Area	No. Spp.	Reproduces	Feeds	Habitat
1	Fish	RHA	34	in water	in water	Primary: Water
2	Frogs, salamanders	RHA	10	in water	on the ground, in bushes, and/or in trees	Primary: DF/MF/MOG/OG Secondary: SI/SS/YF/PT
3	Turtles, ducks	RHA	36	on the ground around water	on the ground, and in bushes, trees, and water	Primary: DF/MF/MOG/OG Secondary: SI/SS/YF/PT
4	Falcons, goats	Rocks & talus	17	in cliffs, caves, rimrock, and/or talus	on the ground or in the air	Primary: PT/DF/MF/MOG/OG Secondary: SI/SS/YF
5	Grouse, hares, elk/deer (gray wolf)	0.5 mile window	33	on the ground without specific water, cliff, rimrock, or talus association	on the ground	Forage: SI/SS/YF Cover: PT/DF/MF/MOG/OG
6	Warblers, porcupines	RHA	8	on the ground	in bushes, trees, or in the air	Primary: SI/SS/YF Secondary: PT/DF/MF/MOG/OG
7	Sparrows, blackbirds, thrushes	RHA	19	in bushes	on the ground, in water, or in the air	Primary: SS/YF/PT/DF Secondary: MF/MOG/OG
8	Warblers, flycatchers	HCP	7	in bushes	in trees, bushes, or in the air	Primary: SS/YF/PT/DF Secondary: MF/MOG/OG
9	Waxwings, grosbeaks	RHA	5	primarily in deciduous trees	in trees, bushes, or in the air	Primary: YF/PT/DF Secondary: MF/MOG/OG
10	Squirrels, tanagers, warblers	HCP	12	primarily in conifers	in trees, bushes, or in the air	Primary: PT/DF/MF/MOG/OG Secondary: SS/YF

11	Vireos, hawks	HCP	28	in conifers or deciduous trees	in trees, bushes, on the ground, or in the air	Primary: PT/DF/MF/MOG/OG Secondary: SI/SS/YF
12	Herons, osprey, great horned owl	RHA	6	on very thick branches	on the ground or in the water	Primary: DF/MF/MOG/OG Secondary: PT
13 13a	Woodpeckers: Lewis' woodpecker, white-headed woodpecker, pileated woodpecker	HCP HCP	14	in own holes excavated in trees	in trees, bushes, on the ground, or in the air	Primary: DF/MF/MOG/OG Secondary: YF/PT Primary: MF/MOG/OG Secondary: SI/SS after 10 yrs. YF/PT after 20 yrs. DF every year
14 14a	Bats, owls, bluebirds Flammulated owl, Vaux's swift, fisher	HCP HCP	43	in a hole made by another species or a natural hole	on the ground, in water, or in the air	Primary: DF/MF/MOG/OG Secondary: SI/SS/YF/PT Primary: MF/MOG/OG Secondary: DF
15	Shrews, bears voles	HCP	36	in a burrow underground	on the ground or underground	Young Aged: SI/SS/YF Mid-Aged: PT/DF Late Aged: MF/MOG/OG
16	Kingfishers, otters, beavers	RHA	7	in a burrow underground	in the air or in the water	Primary: DF/MF/MOG/OG Secondary: SI/SS/YF/PT

Search Area: RHA—Riparian Habitat Areas; HCP—Habitat Conservation Plan Area; 0.5 mile window—scanning radius which provides a basis for sampling edge habitat (i.e., the area between forage and cover habitats) in the HCP planning area.
Habitat: Primary—habitats which the Lifeform species rely on; Secondary—habitats also used by the Lifeform species. DF—Dispersal Forest; MF—Mature Forest; MOG—Managed Old Growth; OG—Old Growth; SI—Stand Initiation; SS—Shrub/Sapling; YF—Young Forest.

habitats also were used by the species. Primary habitat was emphasized during evaluations of the HCP to ensure the most important habitats would not be reduced to undesirable levels. Secondary habitat was allotted only half the weight of primary habitat during assessments of total suitable habitat (Table 21-1).

Because the forest stand classification system was tied to a GIS polygonal database, analyses resulted in describing the distribution and amount of wildlife habitat for all 16 lifeforms across the project area. Spatial analyses varied among the lifeforms and were tailored to the life history requirements of the species. In some cases, we used the entire planning area for the analysis and for some lifeforms, a more restricted analysis area focused on habitats such as streams, wetlands, talus, or forest edges (Table 21-1). For instance, lifeform 4 included species that are associated with cliffs, talus, and rocky outcroppings. Species in this lifeform included the Larch Mountain salamander and Townsend's big-eared bat (*Plecotus townsendii*). Primary habitat for these species was pole timber and older forests found in the vicinity of these rock features.

Several methods were used to refine and improve the lifeform matrix during the development and modeling process. First, the lifeform matrix was peer-reviewed by biologists from government and private organizations with local knowledge of wildlife species in the HCP planning area and familiarity with forest wildlife habitat relationship matrices. Second, as a result of peer review comments, we delineated subgroups within the primary cavity-excavator and secondary cavity-user lifeforms (13/13a and 14/14a, Table 21-1) for those species that are more associated with late successional structural stages (e.g., pileated woodpecker [*Dryocopus pileatus*], flammulated owl [*Otus flammeolus*], fisher [*Martes pennanti*]). Finally, we did not count recently harvested areas as habitat for some lifeforms (e.g., cavity-excavators) until 10 or 20 years into the HCP period, since some wildlife conservation measures (e.g., snag and green wildlife tree retention) were not implemented historically and, therefore, may not provide adequate structural elements for these lifeforms at the time of HCP inception (Table 21-1). These modifications to the habitat relationship model provided opportunities for hypothesis testing under the HCP's adaptive management program, discussed later in this chapter.

Wildlife Habitat Futuring

Because the HCP is a 50-year agreement, we used the strategic planning program OPTIONS (Reimer 2007) to model the forest structure stages through time. The OPTIONS model is a state-of-the-art forest estate planning model that plays a central role in the maintenance of the Central Cascades HCP. Inputs to the model include tabular forest inventory information (tree species, diameter, height, etc.), spatial forest inventory information (stand polygon locations), spatial landscape information (sensitive sites, view sheds, etc.), and localized growth-and-yield information. OPTIONS uses both existing forest inventory data

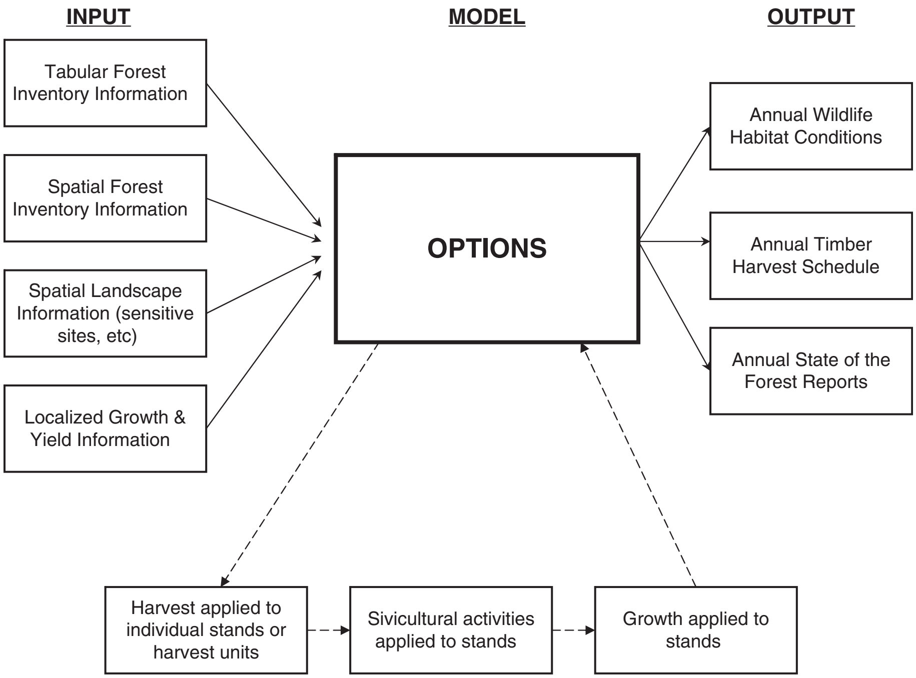

FIG. 21-3

Input and output parameters of the forest growth and modeling software OPTIONS used to project forest structural stage and wildlife habitat amounts and trends over a 50-year planning period in the 170,000 ha Central Cascades Habitat Conservation Plan area, Washington, USA.

and regionally calibrated growth algorithms to project forest stands into the future (Fig. 21-3). With the given inputs, the model provides reliable forecasts of stand attributes such as stand height, diameter, age, canopy stratification, and tree species richness. Management activities are reported for each stand for each year of the planning horizon. Based on the necessary condition and relative importance of various stand-level attributes, habitat suitability and capability for numerous special species, lifeforms, or habitat type can be assessed, forecast, and planned.

Finally, with the OPTIONS model, the abundance and spatial arrangement of individual stands of habitat that influence overall wildlife habitat conditions can be evaluated. Forest-level analysis of stand-level habitat classifications facilitates the assessment of broad-level habitat conditions. Landscape attributes such as fragmentation, isolation, and connectivity can be modeled and forecast so that long-term management prescriptions can be assessed. We used OPTIONS to assess the amounts of primary and total suitable habitat for each lifeform at 10-year intervals over the 50-year life of the HCP, accounting for forest growth and timber management. The modeling results were instrumental in projecting wildlife habitat conditions and the potential impacts of various HCP planning alternatives. The analysis also assessed timber resources, such as long-term supply, growth-and-yield, and timberland management strategies. We obtained stand inventory data from other land owners in the HCP planning area and assessed habitat conditions across the entire 170,000 ha planning area. Assumptions about rates of timber harvest were made for other landowners to inform future habitat projections.

Results of the lifeform habitat modeling during early iterations led to changes in the conservation plan design. Initial modeling results indicated a marked decrease in late successional habitat during the first decades of the plan period under conventional timber harvest strategies. We established harvest deferrals at key locations in the project area for 20 years to maintain the amount of late successional habitat during these low points (see Spotted Owl discussion). In addition, initial OPTIONS output indicated large amounts of the dispersal forest type across the planning area. This led to changes in the timber harvest schedule to direct harvest toward mid-successional stands, allowing for a more balanced diversity of young, middle, and late successional forest structural stages across the planning area.

As stated earlier, a key feature of OPTIONS is its use of input data that are common to most forest inventory systems. Consequently, we modeled both the future of habitat on Plum Creek lands under the HCP for 50 years as well as habitat availability on federal lands under harvest scenarios developed in the Northwest Forest Plan. Inventory data were acquired from the Wenatchee and Mt. Baker-Snoqualmie National Forests and from timber stand classification (phototyping) completed by outside contractors. We cross-checked proposed harvest levels with U.S. Forest Service staff for accuracy. In the 10 years of the HCP operation, it has been evident that harvest levels on U.S. Forest Service land in the HCP planning area have been significantly less than proposed under the Northwest Forest Plan, and less than originally modeled under OPTIONS for habitat supply projections. Thus, the modeling constraints on the U.S. Forest Service lands have been modified. Consequently, U.S. Forest Service lands are currently providing more late-successional habitat than estimated 10 years ago during HCP development.

The modeling output also allowed land managers, scientists, and the public to communicate, understand, and make decisions regarding habitat trade-offs in the HCP. For example, lifeform modeling quantified the future decrease in habitat for early successional and edge-associated species (lifeform 5) such as elk (*Cervus canadensis*) and deer (*Odocoileus* spp.) (Fig. 21-4) and for species reliant on early successional and shrubby habitats in wetland and riparian areas (lifeform 6). The decrease is due to the focus of the HCP on meeting the biological needs of the spotted owl, retention of buffers adjacent to streams for aquatic species protection, and the relatively low levels of timber harvest on federal lands in the Northwest Forest Plan. This example describes how an analysis outcome was useful in understanding and communicating the response of wildlife use to changing habitat conditions across the HCP project area through time.

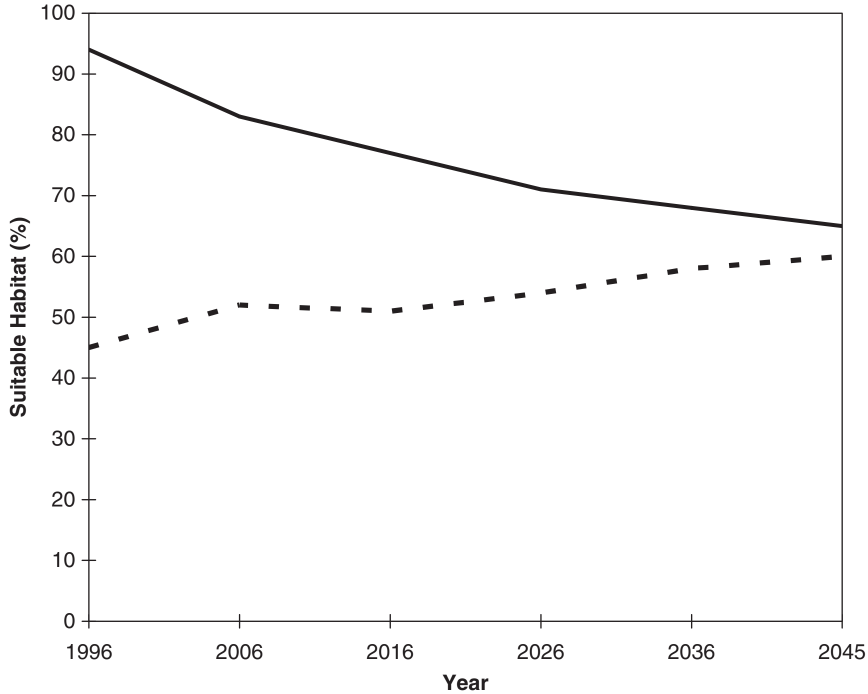

FIG. 21-4

Wildlife habitat futuring over a 50-year planning period identifies trade-offs in the amount and trend of suitable habitat between early successional forest species like deer and elk (solid line) and late successional forest species such as the spotted owl (dashed line) across multiple ownerships in a 170,000 ha Habitat Conservation Plan area in the Central Cascades Mountain Range, Washington, USA.

The wildlife habitat relationship matrix and habitat modeling in the HCP were aids to developing a set of working hypotheses of the expected use patterns of wildlife species across the vegetation types, structural stages, and special habitats in the project area. Although the wildlife habitat matrix did not represent a detailed, site-specific inventory of wildlife occurrence across the diverse habitats of the planning area, the matrix provided information on potential or likely wildlife use patterns based on the available literature. Habitat futuring under various management alternatives also allowed assessment of potential future risks due to fuel loading and fires, as well as susceptibility to pathogens such as the western spruce budworm (*Choristoneura occidentalis*). The habitat futuring exercise allowed land managers, regulators, and the public to evaluate how the proposed HCP and alternate land management plans might affect wildlife species and other aspects of the environment.

Spotted Owls and a Resource Selection Probability Function

Studies of habitat use have indicated that northern spotted owls generally use mature and old-growth forest as much or more than expected, and early seral stage forest less than expected (Forsman 1980; Forsman et al. 1984; Carey et al. 1990, 1992; Sisco 1990; Solis and Gutiérrez 1990; Meyer et al. 1998). A resource selection function (RSF) analysis was carried out in the HCP to better quantify these and other aspects of the use of habitat by spotted owls. Initially, spotted owl activity centers were located in the HCP planning area using standard and extensive survey protocols (Herter and Hicks 2000), likely locating nearly all the regularly occupied owl sites. The selection of a 1.1 km radius circle around these sites as the unit for describing the habitat followed the process described by Irwin and Hicks (1995), with similar methods used later by Meyer et al. (1998), Swindle et al. (1999) and Franklin et al. (2000). This size analysis circle describes the core area of an owl territory and does not analyze the entire area used on an annual basis. Forest habitat designations followed the protocol established by Oliver et al. (1995) and are described further in the HCP (Plum Creek Timber Company 1996).

While information was available to quantify owl nesting habitat, there was a dearth of information to define foraging habitat. Radio telemetry was used to monitor adult nonnesting owls. Daytime roost sites were located and vegetative analyses were conducted surrounding these roost sites. This information helped inform the definition of foraging/dispersal habitat for spotted owls. Separate definitions were developed for nesting habitat and foraging/dispersal habitat, and these each were dependent on the ecological zone (east side or west side of the Cascades mountain range). Definitions included factors available from standard timber inventories including size, density, and species composition of overstory trees.

The RSF model fulfills two important functions in the HCP. The first is to provide a method to assess the likelihood that habitat retained in the plan or projected to grow over the 50-year life of the plan would have a low, medium, or high probability of occupancy by spotted owls. The second was to use the RSF to provide estimates of the spotted owl carrying capacity under different management scenarios, with the carrying capacity defined to be the most reasonable maximum number of spotted owl activity centers that could be accommodated in the planning area with implementation of both the Northwest Forest Plan on federal lands and the HCP on Plum Creek lands. This latter feature of the RSF is an important monitoring component of the HCP because it makes it possible to evaluate the effectiveness of the plan after years of implementation. The RSF was initially developed in 1995 as the HCP was in its formative stage, but was revised in 2001, making use of extensive data then available in the GIS database for the HCP planning area.

The original RSF was used in the evaluation of the HCP. Using logistic regression analysis, we estimated RSFs for an array of 1.1 km "moving windows" across the HCP planning area (Irwin and Hicks 1995) because this distance provided the greatest level of discrimination between occupied and unoccupied sites. Analysis of the RSF values indicated that spotted owls were distributed nonrandomly across the planning area and distributions varied with respect to available nesting habitat, topographic variation, and fire-management activity zones (reflective of ecologically significant moisture and species composition gradients).

At the inception of the HCP in 1997, there were known to be 104 spotted owl activity centers in the HCP planning area, although only a subset of these sites were active in any one year. The revised RSF was estimated from a comparison between 92 sites known to have been actively used by spotted owls, and 51 randomly selected unused sites. Because the original 104 spotted owl sites included many sites where only a single spotted owl used the habitat temporarily, we compared only 92 used sites in which we could document multiyear use by one or more spotted owls. Later the number of unused randomly selected sites was increased to 170 to improve the accuracy of the estimated function. In order to ensure that unused sites really were unused, their circles were not permitted to overlap more than 50% with the 1.1 km radius circles for any sites in the used sample. It is also important to note that not all known activity centers are occupied by spotted owls in any given year. As discussed later, occupancy may be affected by factors other than habitat, such as the presence of predators or competitors of the spotted owl.

The major difficulty with determining the RSF was in the choice of the variables to include in the function. There were over 100 variables available in the GIS, and it was thought from the onset that no more than 10 of these should be used. Looking at all possible combinations of the 100 variables was not realistic because the number of possible models is overwhelming (Burnham and Anderson 1998). Furthermore, we combined the variables into 13 groups (e.g., slope, habitat type, stand structure, riparian/upland land status), where in some cases all the variables in a group should either be in or out of the equation. This made automatic stepwise selection procedures difficult to apply. For these reasons, we decided that an initial screening process was necessary to select biologically meaningful variables. This screening process is described in detail by Hicks et al. (2003*b*) and involved multivariate tests on the 13 groups of variables to see whether there were significant differences between unused and used sites. Following the initial screening, an RSF was fitted separately for each group of variables using logistic regression (Manly et al. 2002). In addition to the 13 groups of variables, 14 other equations with various changes and combinations of variables were fitted by logistic regression (see Hicks et al. 2003*b*). Consistency with the data for each of the 27 equations was assessed using Akaike's Information Criterion (AIC) with small values of this criterion being preferred to large values in terms of the compromise between keeping the number of variables in the equation as small as possible and fitting the data well (Burnham and Anderson 1998).

The logistic regression RSF was converted to a resource selection probability function (RSPF) using a procedure described in Hicks et al. (2003*b*) and Manly et al. (2002). For the Cascades HCP, the estimated RSPF is

$$w^* = \exp(z^*)/\{1 + \exp(z^*)\},$$

where

$$z^* = -6.369 + 0.002550XMF + 0.002531XMOG + 0.002942XOG + 0.006225XRIP + 0.001676XELEV + 0.03286XSI$$

XMF = the number of mature forest acres, XMOG = the number of managed old-growth acres managed as spotted owl habitat, XOG = the number of old-growth acres, XRIP = the total riparian acres, XELEV = the maximum – minimum elevation in meters, and XSI = the minimum 50-year site index in feet.

We used the RSPF to calculate an expected number of spotted owl sites in the HCP project area (Hicks et al. 2003*b*). One of the most useful aspects of the analysis is that it can be extended using the habitat distribution that is expected to exist in the future as a result of timber harvest, forest regrowth, and habitat protection resulting from implementation of the HCP on Plum Creek lands and the Northwest Forest Plan on adjacent checkerboard federal lands. Management actions contemplated under these plans can be modeled in the GIS and then the carrying capacity can be predicted at different times in the future (Fig. 21-5). The carrying capacity of spotted owl sites in the HCP planning area is projected to increase over the 50-year planning period, based on habitat availability, with forest management measures implemented under the HCP and Northwest Forest Plan.

Using the RSPF to predict changes in the carrying capacity of the study area based on forest management actions is an application recommended by Boyce and McDonald (1999), with some controversy resulting (Mysterud and Ims 1999, Boyce et al. 1999). At issue is the question of whether it can be assumed that the RSPF remains constant when the amounts of different types of habitat changes. In general, it can be expected that large changes in the availability of different types of habitat are likely to result in changes in the way that animals select the habitat, and hence in the RSPF. However, with the HCP application, the nature of the habitat in the planning area is not expected to change substantially in the near future (Fig. 21-5). Therefore, the assumption of a constant RSPF seems reasonable.

When the carrying capacity of the area remains constant or increases, this does not mean that the number of animals will also necessarily increase. In fact, we have evidence that the number of spotted owls in the HCP planning area has declined in the last 10 years while the available habitat has changed little. This decrease in spotted owls coincides with an increase in the number of barred owls (*Strix varia*) in the region (Anthony et al. 2006).

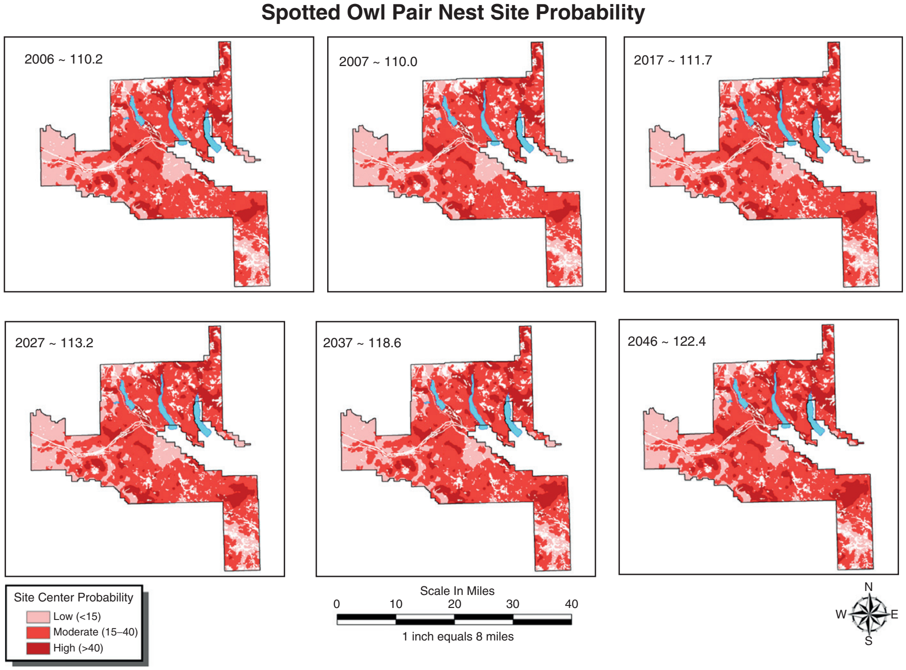

FIG. 21-5

Map of estimated values from the resource selection probability function (RSPF) for the Central Cascades Habitat Conservation Plan area, Washington, USA, for the present (2006) and as projected for 2045. The value of the RSPF for every pixel in the geographic information system was evaluated and plotted using a gradient from nonforested areas (white) to areas with the highest probabilities of spotted owl use (maroon). Map headings are the year, followed by the estimated carrying capacity of owl pairs in that year.

It seems likely that predation, interspecific territoriality, and competition for habitat with barred owls is largely responsible for the decline in spotted owl numbers. The RSPF was revised at a time when barred owl sites were approximately equal to spotted owl sites in number (Herter and Hicks 2000), but prior to a consecutive sequence of poor spotted owl reproductive years. While the HCP was written to anticipate some effects of stochastic weather events and barred owl competition, we were nonetheless surprised by the combined effects of these two factors on resident spotted owl populations in the planning area. Conversely, this development points to one of the strengths of the multispecies HCP approach. Without the HCP, habitat in regulatory circles vacated by spotted owls would have been harvested. Under the HCP, Plum Creek continues to maintain vacated spotted owl habitat to the benefit of other species associated with late-successional forests.

ADAPTIVE MANAGEMENT AND MONITORING

Although a significant body of scientific information and expertise was used to develop Plum Creek's Cascades HCP, not all the questions about the long-term effects of HCP implementation on fish and wildlife species and their habitats can be answered with total certainty today. This is particularly pertinent to the use of models in the development of the HCP. However, uncertainty can be addressed by implementation of an adaptive management approach, which incorporates research and monitoring into a responsive program to evaluate the HCP as a "management experiment" that may be modified as necessary to meet objectives.

Adaptive management is a process that can improve management practices incrementally by implementing plans in ways that maximize opportunities to learn from experience. Adaptive management (Holling 1978; Romesburg 1981; MacNab 1983, 1985; Walters 1986; Eberhardt 1988; Thomas et al. 1990; Wilhere 2002) can provide a reliable means for assessing the HCP, producing better ecological knowledge, and developing appropriate modifications to improve forest management. The primary challenge for using an adaptive management approach is to demonstrate simply and clearly why a change in management would be worthwhile.

Plum Creek's Cascades HCP was the first HCP to openly include adaptive management in the sense that the permittees acknowledged that in certain situations they may need to modify their actions so that additional expense, in the form of additional land, water, or other resources, may need to be provided as mitigation. This voluntary "partial set-a-side" of assurances under the "no surprises" policy was a significant step for Plum Creek. Plum Creek's HCP included adaptive management concepts throughout, but explicitly for several topics including whether spotted owl populations were following the model results and involved the use of deferral habitat. Another explicit topical area included whether riparian buffers were functioning adequately regarding aquatic resource values and processes.

The concept of adaptive management was soon incorporated into additional HCPs such as the Washington Department of Natural Resources HCP, Plum Creek's Native Fish HCP, and the Green Diamond Resources (formally Simpson Timber) HCP in Washington. With the development of each subsequent HCP, the concepts behind adaptive management within the "no surprises" framework of regulatory assurances was refined and cultured. Eventually, adaptive management became a common tool in HCPs across the nation.

Not only does adaptive management make sense for a long-term landscape management plan like an HCP, but recent USFWS policy (U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration 2000) addressed incorporation of adaptive management into HCPs where significant uncertainty exists. Not all HCPs require an adaptive management approach. However, adaptive management can be essential for HCPs that otherwise would pose a substantial risk as a result of information gaps regarding the species biology, the impacts likely to result from HCP actions, or the response of the species to minimization and mitigation features of the HCP. Adaptive management is also helpful in guiding plan amendments in response to changed circumstances. Through the Cascades HCP, it was determined that adaptive management in HCPs could be stringent with specific monitoring thresholds for initiating changes and active experimentation, but that adaptive management could also include observational monitoring and incorporation of outside research findings. Through these early HCPs, the Services came to understand how adaptive management could be selectively limited in scope or could be constructed with landowner involvement into cooperative and beneficial approaches.

Adaptive management is incorporated into many elements of the Cascades HCP, but most relevant to this discussion is the use of adaptive management in the development of thresholds for initiating corrective action. As stated in the HCP (Plum Creek Timber Company 1996, Sec. 5.4.2.2, pg 328): "A key element of adaptive management is the establishment of testable hypotheses tied to management objectives. Should resultant monitoring determine that biological conditions are outside the 'bounds' estimated in the HCP, Plum Creek and the Services will review assumptions, refine models and modify management to protect public resources." These thresholds "for triggering corrective action must be linked to key elements of the HCP by being related to statistically significant, biologically relevant elements and obtainable through monitoring data collected during the permit period."

To that end, model outputs contribute significantly to the future direction of the HCP. For instance, a variance of more than 20% between the projected and actual habitat condition for any lifeform creates a need to consult with the Services on causative factors and potential remedial actions. Additionally, a finding of actual spotted owl populations (as determined by spotted owl monitoring in the planning area and outside peer review) that are less than 80% of the carrying capacity estimated in the RSPF model will also trigger possible corrective action, such as retention of more habitat deferrals, extension of nesting habitat deferrals for longer time periods, or habitat deferrals may be moved to more effective locations. Key questions regarding the tripping of these threshold triggers are "Is the observed deficiency a result of HCP management?" and "Will modification of the HCP remedy conditions in a substantive way?"

In the 10 years of HCP implementation and management, model outputs have triggered thresholds and caused further evaluation of causative actions. The distribution of the eight stand structure types has deviated more than 20% from that predicted by the OPTIONS model. This occurred as the actual percentage of early successional stand structure types (stand initiation, shrub sapling, and young forest) dropped below that predicted by OPTIONS for the first decade (year 2006) of the plan. It was determined to be a result of HCP management because the deficiency was caused by a reduction in timber harvest activity in the HCP compared to levels initially estimated on Plum Creek lands during HCP development.

However, the biological consequences of less early successional habitat on the landscape than predicted was judged to be minimal, because none of the 315 species covered in the HCP would be jeopardized by less early successional habitat on Plum Creek property. The Services determined that species dependent on early successional habitats in the central Cascades are generally able to use other habitats or have evolved with such scarcity of habitats and compensated by developing good dispersal abilities. Additionally, early successional habitats still occur at near historic levels within the planning area.

As stated earlier, populations of spotted owls within the HCP project area have dropped significantly during the first decade of HCP implementation, based on spotted owl site monitoring in the HCP and demographic monitoring of owl populations mandated under the Northwest Forest Plan. Current estimates of active spotted owl sites within the HCP planning area are approximately 40% of the number when the HCP was implemented in 1997 (Raedeke Associates 2006), comparable to trends observed in the majority of other populations in the region (Anthony et al. 2006). Habitat amounts have remained relatively static within the HCP planning area over the last decade (Hicks et al. 2003*a*). Barred owls have been studied in Washington for over 20 years and were known to be present in the HCP planning areas when surveys were initiated in 1990 (Hamer 1988, Herter and Hicks 2000). However, barred owls have significantly increased within the HCP planning area within the last 10 years and now threaten the persistence of the northern spotted owl through much of its extant range (Anthony et al. 2006). The barred owl threat has extended across all types of landscapes, from industrial forest lands to national parks where no significant timber harvest has occurred in recent decades (Herter and Hicks 2000, Pearson and Livezey 2003, Gremel 2005, Livezey 2007). In this application of model output and trigger thresholds, the answer to the first question—"Is the observed deficiency a result of HCP management?"—is clearly that barred owl range expansion and competition with spotted owls has not been caused by the implementation of the HCP. However, the answer to the second question—"Will modification of the HCP remedy conditions in a substantive way?"—remains a significant and problematic management challenge for agencies and landowners within the HCP area as well as throughout the range of the spotted owl in the Pacific Northwest (Gremel 2005, Livezey 2007). The USFWS Recovery Plan for the spotted owl identifies the barred owl range expansion as a major impediment to the recovery of the spotted owl and describes an aggressive program for barred owl control through direct reduction (U.S. Fish and Wildlife Service 2008).

POLICY AND MANAGEMENT IMPLICATIONS

The Cascades HCP was a major achievement in furthering the concept of multi-species conservation planning at the landscape scale. The significance of the Cascades HCP was enhanced by the fact that it was completed within a checkerboard ownership pattern of public and private land in a controversial area of Washington known as the Interstate-90 corridor (Hicks 1997). Although the HCP did resolve ESA-related land management concerns, other issues such as back-country recreation, aesthetics, and road access were not addressed by the HCP and remained to be resolved in the Interstate-90 Corridor. Following inception of the HCP, the Interstate-90 Land Exchange between Plum Creek and the U.S. Forest Service was completed in 2000 to consolidate checkerboard ownership in the Interstate-90 Corridor and address these and other non-ESA-related public issues.

The Cascades HCP was instrumental in facilitating the land exchange. Plum Creek land could be effectively appraised for its value to the U.S. Forest Service because specific ESA-related constraints could be more accurately quantified. Conversely, U.S. Forest Service land with ESA-related habitat values could be exchanged to Plum Creek and incorporated into the multispecies HCP. The Cascades HCP was concurrently amended to reflect ownership changes resulting from the land exchange. In addition to the Interstate-90 Land Exchange, the HCP provided the framework for other conservation transactions, including conservation land sales to the U.S. Forest Service, and sales to private/public conservation groups, including the Mountains to Sound Greenway, Northwest Ecosystem Alliance, and the Cascade Coalition Partnership.

The science-based foundation of the Cascades HCP provided the platform for other research investigations during the first decade of its existence. These research projects have provided information to assess and refine models used in the HCP such as investigations in use of midsuccessional forests by avian species, which helped evaluate the lifeform modeling and "guilding" of vertebrate species to forest structure stages (Manuwal and Gergen 2001). Additionally, the lifeform guilding and structure stage classification framework used in the HCP provided the format for a research project to evaluate habitat managed under the HCP as biodiversity "hot spots" (Hanson et al. 2006).

The use of models developed by HCP applicants can be helpful in assessing impacts, but blind reliance by U.S. Fish and Wildlife Service staff upon applicant-developed models is not appropriate or in the best interest of the species, trust responsibilities, or the general public. The RSPF model for spotted owls was subjected to such scrutiny. The U.S. Fish and Wildlife Service worked with the Washington Department of Fish and Wildlife to develop a test for the Plum Creek model. Agency biologists were concerned that the model might not adequately account for habitat fragmentation. A test was developed that included equal amounts of habitat; but, under one scenario, the habitat patches were smaller and less contiguous. The agencies wanted to see if the RSPF model would predict the same number of spotted owls for both scenarios. The RSPF model successfully predicted a lower carrying capacity for spotted owls in the more fragmented test landscape (Irwin and Hicks 1995: Appendix 2), which was consistent with what was known about spotted owl habitat use. Also, in conducting its analyses under section 7 of the ESA, the U.S. Fish and Wildlife Service used a variety of analyses developed by its own staff to test or corroborate the RSPF model. The combination of independent analyses in conjunction with the RSPF model allowed the U.S. Fish and Wildlife Service to explore different scenarios and develop its own independent analysis that was vastly better than the analysis that could have been conducted in the absence of the modeling and supportive work undertaken by Plum Creek. The experiences that the U.S. Fish and Wildlife Service obtained from examining the models and participating in the analyses with Plum Creek provided a preparatory education to help the Services deal with future applicants. The Services had a better understanding of informational needs, availability of surrogate information, logistical limitations, and alternate solutions.

Most of the modeling and analytical work to prepare the Cascades HCP was completed between 1993 and 1996. There have been major improvements in the tools and techniques we used to build the HCP that could facilitate a similar effort if attempted today. The data available to explore landscape planning for wildlife have been improved substantially for the Pacific Northwest by the publication of the Wildlife-Habitats Relationships in Oregon and Washington compendium, which now includes digital databases for improved access and timely updates. The early versions of the Stand Visualization software we used to illustrate silvicultural experiments and spotted owl habitat have been significantly improved and now include the ability to display and analyze data at the landscape level. The OPTIONS program has also been improved to include the ability to incorporate more treatments and greater storage of stand-level data in the analysis of growth and harvest scenarios. Finally, the advancement of GIS now allows even more sophisticated analysis of complex biotic and physical landscape data than was available a decade ago. As we have seen with the revision of the RSPF model described earlier, GIS capabilities to analyze and compute data at the landscape level have transcended the limitations of early systems to simply make maps. Although the tools and techniques have improved since we initially developed the HCP, we have not seen other approaches or processes that we would use in their place today.

In 2007, Plum Creek and the Services completed a major 10-year review of the Cascades HCP. During that review, we assessed the quantity and quality of information obtained by monitoring and implementation of management practices mandated by the HCP. Both Plum Creek and the Services concluded that the tools and techniques used to construct and monitor the HCP have been effective and continue to provide useful information to serve both the science and management objectives of the HCP. No major changes to management practices were required as a result of the 10-year review.

However, the most disturbing development to occur during the first decade of the HCP is the reduction of the resident spotted owl population in response to the influx of barred owls. In hindsight, we underestimated the impact of the barred owl as a factor in depressing spotted owl populations within our planning area. Our modeling efforts did not incorporate the barred owl as a factor influencing habitat use by spotted owls. As we learn more about the influence of barred owls on spotted owls, it becomes evident that there are both habitat and behavioral aspects of the issue. Because little was known about barred owl and spotted owl interactions at the time of HCP development, and the dynamic nature of the issue, it is speculative that modeling could have been helpful in anticipating or addressing this complex challenge in the HCP. Given that the increase of barred owls is affecting spotted owl populations throughout the current range, it does seem plausible that the HCP could provide an opportunity for Plum Creek and state and federal agencies to collaboratively investigate biological dynamics between the two species in the planning area and develop adaptive management responses that might have value and applicability over a larger area.

Despite disappointments and challenges regarding the future of spotted owls in our planning area, the other components of the HCP continue to perform at or above expectations. The riparian strategy has been successful in maintaining water quality and habitat diversity within streams; habitat targets for maintaining the eight forest structure stages across ownerships have largely been met; and protection of special habitats such as microclimates on talus slopes, seeps and springs, late-successional ponderosa pine stands, and wildlife trees for cavity-nesting species has been achieved. One advantage to developing a multispecies HCP is that other species can benefit even if challenges develop for some target species.

FUTURE DIRECTIONS

The Cascades HCP recently completed its first decade in the 50-year life of the plan. The use of modeling to evaluate biological relationships, quantify forest harvest and growth effects on habitat, and "future out" the biological consequences of HCP implementation and management has been instrumental to the plan. Monitoring requirements in the HCP and the HCP Implementation Agreement mandate major reviews of the plan at 5- and 10-year intervals. During these reviews, new information regarding forest inventory updates and management activities are brought to the Services. Additionally, all terrestrial and aquatic monitoring data are summarized and reviewed to determine if threshold "triggers" are tripped or if mitigation measures and management activities mandated by the HCP are ineffective. In this way, adaptive management is achieved using information acquired within the HCP and applied to models and analyses developed for the HCP.

The emerging issue of barred owl and spotted owl interactions may form the basis of additional monitoring and modeling in the HCP. This would be completed in conjunction with other agencies and entities, since this is a situation affecting spotted owl recovery throughout the species range.

The HCP was designed to build upon conservation strategies used on federal lands in the Northwest Forest Plan. The HCP has undergone a major amendment to incorporate changing land ownership arising from the Interstate-90 Land Exchange. Subsequent conservation land sales have increased the probability that what is now a single-landowner HCP may become a multilandowner HCP as other forest interests (private or conservation-based) acquire ownership within the HCP project area and assume conservation responsibilities under the plan. If that scenario develops, analytical models such as lifeform/structure stage guilding and the OPTIONS model will likely be refined and applied to the new ownerships to coordinate the continued achievement of the HCP landscape conservation objectives.

SUMMARY

Plum Creek Timber Company is one of the largest private owners of forested habitat occupied by the northern spotted owl *(Strix occidentalis caurina)* in the United States. At the time of federal listing in 1990, 107 spotted owl territories had been located near the company's property intermingled with other lands in the Central Cascade Mountains of Washington. To facilitate the management of the spotted owls and address the economic impacts that the federal listing of the species had created, Plum Creek, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service (the Services) began the development of a Habitat Conservation Plan (HCP), a process under the Endangered Species Act, which allows private landowners to obtain a federal permit to incidentally "take" a listed species or its habitat under otherwise lawful activities in accordance with an approved plan that specifies actions to mitigate and minimize the anticipated impact on the listed species. The HCP area is 169,510 hectares in size, including 49,239 hectares of Plum Creek property. The HCP, which was approved by the Services in June 1996, is a 50-year plan which addresses the habitat needs of 315 vertebrate species, including the northern spotted owl. Modeling was an important tool to develop several key components of the HCP described in this chapter. The first is a forest stand structure classification system based on spotted owl monitoring and habitat analysis. The second is the OPTIONS™ timberland harvest and planning model used to simulate different management strategies and project spotted owl habitat through the 50-year planning period. Finally, a resource selection function was used to assess the likelihood that habitat retained in the plan, or projected to grow over the life of the plan, would have a low, medium, or high probability of occupancy by spotted owls. Adaptive management was incorporated into the Cascades HCP to address uncertainty by establishing thresholds for initiating corrective action. The tools and techniques used to construct and monitor the HCP have been effective and continue to provide useful information to serve both the science and management objectives of the HCP.

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