Conservation implications of coarse-scale versus fine-scale management of forest ecosystems: Are reserves still relevant?

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EXECUTIVE SUMMARY

The Northwest Forest Plan was among the first efforts globally to address a comprehensive suite of conservation goals using a planning strategy integrating conservation of terrestrial and aquatic species at fine and coarse spatial scales. Although old-growth forest was recognized in the plan as a key habitat and source of ecosystem services, the plan was broader than a strategy to protect old forest stands. We review here the efficacy of this strategy given recent research findings and emerging threats to biodiversity.

KEY FINDINGS

Coarse-scale planning is crucial to maintaining biodiversity on public forestlands. Any major revisions to the Northwest Forest Plan, including expansion of thinning projects, should be tiered to a strong and coherent coarse-scale conservation strategy. Incorporating fine-scale (stand-level) management within a broad contextual framework allows assessment of factors such as reserve area, distribution, and connectivity that are emergent properties of landscape pattern. Coarse-scale planning enhances coordination across ownerships and thus lessens threats to imperiled species arising from inadequate regulatory mechanisms.

Reserves, or zones of low-intensity management, are a key element of such a management strategy which afford practical benefits that are hard to achieve by other means. Reserves function as control treatments that aid assessment of unanticipated long-term management impacts. Reserves also function as practical guarantees that land-management agencies will address coarse-scale planning issues despite a variety of potentially conflicting societal demands.

Intensive management such as thinning has the potential to result in a variety of both positive and negative effects on biodiversity and ecosystem services. Limiting such thinning to previously-managed or younger stands, while sensible, does not avoid the necessity to evaluate and mitigate cumulative impacts such as soil erosion and compaction by means of coarse-scale management guidelines and zoning strategies.

Current proposals that primarily address fine-scale conservation issues, such as expanded protection of older forest stands and thinning of young trees and forests, would be more effective in achieving conservation goals if integrated within a comprehensive and rigorous multi-scale evaluation of the Northwest Forest Plan that addresses emerging threats to biodiversity such as climate change and invasive species. The NWFP was conceived a dynamic strategy that would be updated based on monitoring results and advances in ecosystem science. This aspect of the plan was abandoned during a federal administration that was generally hostile to the goals of the original plan. Monitoring efforts in the first decade of the NWFP provide support for such a review but are not in themselves sufficient. The current debate over proposed legislation can in this way provide an opportunity to address emerging challenges to conservation of forest ecosystems of the Pacific Northwest.

INTRODUCTION

The field of conservation planning originates, in part, from the observation that where conservation actions are implemented on the landscape may be as important as what those actions are (Noss and Cooperrider 1994). This principle in turn derives from recognition of the importance of spatial and temporal scale in ecology (Levin 1992, Holling 1992). We now know that the size, location, context, and spatial adjacency patterns of vegetation communities significantly affects landscape-scale patterns of biodiversity (Lindenmayer et al. 2008). However, the need to plan at both local and broad spatial scales has not always been recognized in public lands management. Initial enabling legislation and subsequent regulations for agencies such as the USDA Forest Service focused on establishing general standards to remedy abuses such as extensive clear-cutting and attendant damage to soils and streams (Yaffee 1994). For example, after the passage of the 1976 National Forest Management Act, timber harvest units on public lands were limited to about 16 ha without sufficient consideration of the effects of the resultant checkerboard harvest pattern on forest biota (Forman and Wilson 1995).

By 1990, it became apparent that a primary focus on fine-scale planning (here defined as ranging from projects of several hundred hectares to individual forest stands) had led to a lack of coordination among management units. Broad-scale cumulative impacts on both terrestrial and aquatic species and ecosystems, which had not been considered in the planning process, reached unacceptable levels (Thomas et al. 2006). In 1990, the Northern Spotted Owl (*Strix occidentalis caurina*, henceforth "the owl") was listed as threatened under the U.S. Endangered Species Act (ESA) due to declining population trends related to the loss of older coniferous forest habitat to logging (Noon and Blakesley 2006). In the Pacific Northwest, the majority of stocks of anadromous fish species were in decline or threatened with extirpation (Reeves et al. 2006a). These developments led to extensive public debate and litigation over the future of forest management on public lands in the region (Yaffee 1994).

THE NORTHWEST FOREST PLAN AS A MODEL FOR MULTI-SCALE CONSERVATION PLANNING

To remedy these problems and resolve the legal impasse caused by ESA listing of the owl and other species, a new planning framework was implemented in 1994 (USDA and USDI 1994). The Northwest Forest Plan (NWFP) sought to ensure viable populations of the owl and other old-growth-associated species by coordinating regional habitat management across multiple ownerships encompassing the range of the owl within the United States (western Washington, western Oregon, and northwestern California)(Thomas et al. 2006). Thus, fine-scale project-level management was embedded within a coarse-scale planning framework (defined here as encompassing areas ranging in size from sixth field watersheds of 4,000-16,000 ha in size to entire regions such as the 23 million ha region encompassing the NWFP).

However, the multi-scale and multi-species nature of the NWFP arose late in the planning process. Due to historical reasons, the NWFP was a product of a single-species reserve design paradigm for conservation of the owl, with all the other elements that eventually became part of the plan "add-ons" addressed by additional teams of scientists. The degree to which lands set aside for owls (and to some extent salmonids) would provide for the habitat needs of other species was secondary in terms of the policy debate and litigation that was the focus of attention during that time.

Late-successional and old-growth forest (LSOG) in the Pacific Northwest is typified by the presence of old live trees (e.g., > 150 years; Strittholt et al. 2006), abundant large snags and downed logs, and complex stand structure (FEMAT 1993). This type of forest, which is heavily reduced from its pre-settlement extent due to past timber harvest, was identified as a key conservation target of the NWFP (FEMAT 1993, Strittholt et al. 2006). In this respect the plan marked a major departure from timber-dominated management of federal lands to an emphasis on biodiversity and ecosystem management where timber production was secondary (USDA and USDI 1994). In particular, remnant areas of LSOG were recognized as a key habitat for a large proportion of the native biota as well as a source of ecosystem services such as maintenance of clean water and carbon sequestration.

However, the NWFP sought to place conservation of fine-scale elements of forest structure such as live old-growth trees and large snags within the context of preserving broad-scale forest ecosystem processes and disturbance dynamics (Table 2, FEMAT 1993). Similarly for terrestrial fauna, "fine-filter" strategies to conserve narrowly-distributed endemics were combined with broader-scale strategies for conservation of wide-ranging (widely-distributed, with large territories and dispersal distances) focal species such as the owl (Table 2). A similar fine and coarse-scale strategy was applied to freshwater aquatic species and systems. By integrating both coarse- and fine-scale targets, the NWFP represents an early example of the type of multi-track conservation plan that has since been widely applied in other contexts (Lindenmayer and Franklin 2002, Noss et al. 1999, 2002). By focusing on species, structures, and ecosystem processes at multiple scales, such plans seek to develop a comprehensive biodiversity strategy that is more effective and cost-efficient than a combination of disparate conservation strategies for individual species. However, due to its historical context, the multi-scale nature of the NWFP was not fully explicated in as coherent a manner as is typical of more recent efforts.

The NWFP placed 9.8 million ha of federal lands in Washington, Oregon, and northern California into different land-use categories, including late-successional reserves (LSRs, 2.97 million ha) that emphasize retention and restoration of older forest conditions, adaptive management areas (609,000 ha) where new approaches to forestry would be developed, managed late-successional reserves (40,900 ha) where clearcuts would be restored to older forests, and the matrix (1.59 million ha) where most timber management would occur. The NWFP also includes a conservation element complementary to terrestrially-defined reserves, the Aquatic Conservation Strategy (ACS), to drive protection and restoration of water quality, aquatic biological diversity, and sensitive freshwater species. The ACS included two land allocations with special planning requirements: stream-adjacent zones termed Riparian Management Areas or riparian reserves (1.05 million ha), and larger refugia termed Key Watersheds (3.70 million ha) where aquatic biological values are particularly prominent (USDA and USDI 1994).

Despite acknowledging the ecological importance of older forest, the NWFP did not protect all remnant LSOG stands. The large blocks of land in reserves were embedded within a intensively-managed matrix from which the majority of timber would be supplied. In the NWFP planning process, Alternative 1, which would have protected all LSOG, was passed over in favor of Alternative 9, which left 37.5% (1,370,000 ha) of LSOG within the matrix in order to increase timber production (Strittholt et al. 2006). Although large portions of the LSR network were not composed of LSOG at the time of the NWFP, it was assumed they would become dominated by older forest over time if the plan was maintained. The plan's network of LSR and congressional reserves (e.g., wilderness areas), combined with measures to ensure retention of habitat connectivity on matrix lands, were considered sufficient to insure viability of species such as the owl despite continued harvest of LSOG within the matrix (Noon and McKelvey 1996).

PROPOSALS TO TRANSFORM NORTHWEST FOREST PLANNING

The NWFP’s multi-scale planning framework and reserve/matrix paradigm were controversial. Shortly after the NWFP’s initiation, the authors of the regional conservation plan for the Interior Columbia Basin Ecosystem Management Project (ICBEMP) proposed a non-reserve strategy described as a “landscape without lines” that they judged to retain more management flexibility than the LSR design for the NWFP (Everett and Lehmkuhl 1996; see DellaSala et al. 1996 for a rebuttal). Criticism of the NWFP was motivated in part by a decreased emphasis on timber harvest and the apparent loss of discretion by local land managers. This was aggravated by the failure to meet timber harvest goals projected under the NWFP (Baker et al. 2005). However, there was also fundamental disagreement over the necessity of intensive management of the entire landscape for other goals besides timber production. In particular, fire regimes altered by past forest management (fire suppression, grazing, logging) were believed to pose a threat to conservation goals, requiring intensive management of the entire landscape to restore conditions similar to those produced by historic fire regimes (Spies et al. 2006).

From 2000 through 2008, the federal administration sought to revise or eliminate several key elements of the NWFP, resulting in protracted legal conflicts. In addition, several administrative and legislative proposals emerged that attempted to substantially revise the plan. Legislative proposals to modify the NWFP currently being considered by the U.S. Congress include the Pacific Northwest Forest Legacy Act (PNWFLA; available at defazio.house.gov) proposed by Congressman Peter DeFazio (D-OR) and the Forest Restoration and Old Growth Protection Act proposed by Senator Ron Wyden (D-OR)(OFROGPA; available at wyden.senate.gov). These acts propose to increase protection of older trees and LSOG stands in the matrix with elimination or weakening of the role of the LSRs and exemption of timber projects from planning requirements (Table 1). For example, PNWFLA proposes elimination of LSRs as a management designation. In contrast, OFROGPA retains LSRs but exempts thinning within LSRs by affording such projects "categorical exclusions" from regulatory processes.

Proponents argue that LSRs would no longer be necessary because the entire landscape would be managed to achieve conservation goals. Based on a goal of forest restoration, both legislative proposals limit timber harvest to thinning of younger stands. This type of logging is advocated as restorative (accelerating restoration of LSOG condition) and consistent with returning forest structure that existed prior to high levels of

Table 1. Matrix describing key aspects of alternative proposals for management of public forest lands in the Pacific Northwest. Abbreviations: NWFP; Northwest Forest Plan (Alternatives 1 and 9), PNWFLA; Pacific Northwest Forest Legacy Act, OFROGPA; Oregon Forest Restoration and Old Growth Protection Act, OWL PLAN; USFWS Northern Spotted Owl recovery Plan of 2008, IRA; inventoried roadless area, ACS; Aquatic Conservation Strategy, Y, N, P; component is present, absent, or partially mandated.

ALTERNATIVE	**NWFP-ALT.9**	**NWFP-ALT.1**	**PNWFLA**	**OFROGPA**	**OWL PLAN**
POLICY COMPONENT					
<u>LARGE RESERVES</u>					
Large reserves in westside ecoprovinces	Y	Y	N	Y	P
Large reserves in eastside ecoprovinces	Y	Y	N	N	N
<u>ROADS</u>					
No entry into IRA	N	N	N	Y	N
No net increase in road density	P	P	Y	P	N
<u>STAND-LEVEL PROTECTION</u>					
Matrix old-growth stands protected	N	Y	Y	Y	P
Matrix late-mature stands protected	N	N	Y	N	N
<u>AQUATIC CONSERVATION STRATEGY (ACS)</u>					
ACS on westside ecoprovinces	Y	Y	Y	P	N
ACS on eastside ecoprovinces	N	N	Y	P	N
<u>FUELS MANAGEMENT</u>					
Thinning projects exempt from some regulatory processes	N	N	Y	Y	Y

understory recruitment following logging, grazing and fire suppression.

The Northern Spotted Owl recovery plan speaks of creating patches of open forest over 65-70 percent of the landscape which could recover to owl habitat by ingrowth if needed (USFWS 2008). Similarly, elements of both legislative strategies expand thinning of dry forests east of the Cascades in an effort to reduce fire extent and severity. OFROGPA proposes extending protection from logging to old-growth stands within the current NWFP matrix whereas PNWFLA also protects matrix late-mature stands (Table 1). Because of the difficulty of delineating stand boundaries and estimating stand age, it is uncertain what would be protected in areas composed of a mosaic of older and younger trees as is especially the case in dry forests where fire regimes most often result in mixed stands of old and young trees and widely scattered legacy trees. Given these contrasts, the NWFP and the alternative legislative and administrative proposals can be placed on a spectrum which varies in terms of: 1) levels of retention of NWFP reserves, 2) level of protection afforded to old-growth and mature stands within the matrix, and 3) contrast between management in mesic and more xeric ecoprovinces (Table 1).

Conservation planning is by its nature an iterative process, which must respond to increasing knowledge, changing landscapes, and shifting societal values. However, none of the proposed legislation has been subjected to the level of scientific scrutiny applied to the original NWFP (FEMAT 1993), and the potential long-term impacts of the proposed landscape management on conservation goals has received little consideration. In this report, we review published research and conduct new analyses to evaluate and compare expected conservation outcomes under the NWFP with those anticipated under proposed legislation. Because both legislative proposals are in flux, we do not evaluate specific language but rather focus on their key elements to explore the contrasts between the coarse-scale and fine-scale planning. The monitoring mandates of the NWFP have resulted in unprecedented body of biological data that can be used to evaluate the conservation implications of alternative strategies and explore the tradeoffs between coarse-scale and fine-scale planning on the specific conservation targets identified in the NWFP: 1. old-growth forest structural elements, 2. old forest stands and forest ecosystem processes, 3. Northern Spotted Owls and other terrestrial wide-ranging species, 4. localized rare and endemic species, and 5. freshwater aquatic species and 6. freshwater aquatic systems (Table 2). We seek in this review to use the short-term debate over legislative proposals as an opportunity to re-evaluate and strengthen long-term forest conservation policy in the Pacific Northwest and other regions where the integration of fine- and coarse-scale planning is the subject of policy debate.

MANAGEMENT IMPLICATIONS OF COARSE-SCALE PLANNING

Proponents of NWFP revision emphasize that the reserves (LSR) established under the plan were not intended to resemble parks and wilderness areas. Activities such as thinning and burning are allowed in LSRs, but the NWFP requires prior consideration of the net effects of stand treatments on conservation values. LSRs do not necessarily provide protection against intensive harvesting activities, which have been permitted, for example, within Middle Cow LSR and several LSR within the Biscuit fire area (Oregon)(Donato et al 2004, Thompson et al. 2007). In practice, however, the procedural

Table 2. Conservation targets and strategies incorporated within the Northwest Forest Plan and their role within the multi-scale conservation framework implicit in the plan. Number in parentheses reference conservation targets as numbered in text.

BROAD GOAL	FINE-SCALE ELEMENT	COARSE-SCALE ELEMENT
Vegetation		
Target	Old-growth trees and snags (1)	Old-forest landscapes, processes (2)
Strategy	Silvicultural standards	Late-Successional Reserves
Terrestrial fauna		
Target	Localized species (4)	Northern Spotted Owl (3)
Strategy	"Survey and Manage" Program	Late-Successional Reserves
Aquatic species and systems		
Target	Localized species (5)	Aquatic systems (6)
Strategy	Riparian Reserves	Key Watersheds

requirements of LSR projects usually appear to have limited such projects. Proposals to eliminate LSRs, either *in toto* or in the drier eastside and Klamath regions (Table 1), are intended to facilitate more intensive, landscape-level thinning and consequently increase timber production.

Few data are available to assess the claim that LSR designations deter thinning projects. LSRs may be lower priority for thinning because LSOG has lower fire risk, or because LSR are more remote and generally unroaded. Published monitoring data have limited ability to inform this debate as they generally cannot be spatially referenced to specific management zones (LSR or matrix) that received thinning or regeneration harvest (Baker et al. 2005). Because of the reduced extent of older forest and increased protection of non-timber resources, the NWFP forecasted that timber production from federal lands would drop by about 80% from levels achieved in the 1980s (USDA and USDI 1994). Total timber production on USFS and BLM lands in the first nine years of the NWFP was 54.9% of the reduced levels initially anticipated under the plan and 63.0% of subsequently revised forecasts (Baker et al. 2005). 84% of the 133,141 ha logged in the first decade of the NWFP was treated by partial harvest, with the remainder generally clearcut. About 2% of the area of riparian reserves (20,743 ha) was logged within in the first decade of the NWFP, with 81% of that area thinned and the remainder clearcut (Reeves et al. 2006a). Thus, the majority of recent timber harvest on federal lands can be characterized as some form of thinning which has been insufficient to meet the plan's initial timber volume forecasts. From these data, it is impossible to discern which specific procedural or zoning elements of the NWFP (e.g., LSR, ACS, Survey and Manage program) have most affected timber harvest volume.

Although not originally envisioned as restrictive reserves, it appears that LSRs have become *de facto* reserves with low-intensity management. Increased harvest within LSRs would likely occur with the increase in timber volume projected under both legislative proposals. This could occur by explicitly abandoning the reserve framework or alternately exempting thinning projects from procedural requirements. Because we cannot predict the areal footprint of future thinning projects under either the NWFP or alternative proposals, we instead compare areas subject to thinning. If the NWFP is maintained, we assume that LSRs will continue to experience relatively low-intensity management.

COARSE-SCALE PLANNING AND CONSERVATION OF FOREST ECOSYSTEMS

Adoption of a coarse-scale reserve strategy has several consequences that potentially enhance conservation of a broad spectrum of biodiversity targets. The NWFP's regional reserve network mandated coordinated planning across large spatial scales (i.e., the range of the owl) and long temporal scales (sufficient for regeneration of LSOG within portions of the reserves that currently held younger forest). For species whose viability is dependent on processes (e.g., long-distance dispersal) that occur at such scales, broad-scale planning reduces threats from "inadequate regulatory mechanisms," one of the five factors by which a species' conservation status is evaluated under the US Endangered Species Act (ESA; 16 USC 1531–1540 [1988]).

The biodiversity-enhancing aspects of reserves that emerge at coarser scales derive from three factors: reserve *area*, *connectivity*, and *distribution* (Noss and Cooperrider 1994). The same area of habitat can more effectively support wide-ranging species such as the owl when it is aggregated in a large cluster than when it is fragmented into many small areas (Lamberson et al. 1994). Similarly, a watershed with undisturbed (e.g., roadless) areas aggregated in one or few catchments may retain sensitive aquatic species longer than a watershed where all catchments are at the same median level of disturbance. Late-successional forest aggregated in large patches has a lower edge/area ratio than when fragmented into many smaller patches, and thus has higher habitat value for species that avoid edge habitat or suffer negative edge effects. Coarse-scale reserves also provide benchmark conditions (Stoddard et al. 2006) to guide management and restoration actions in other portions of the landscape. Restrictions on road-building are an important attribute of reserves and form one aspect of their value as control areas. Roads cause disturbance of ground cover and soil which increases exotic invasions and erosion (Trombulak and Frissell 2000). Many studies show the detrimental effects of roads and, as a corollary, the value of roadless reserves (Trombulak and Frissell 2000, Strittholt and DellaSala 2001). Road densities on public forestlands in the Pacific Northwest are high in relation to known thresholds for impacts on conservation targets. Mean road density of the region's sixth-field watersheds with at least 25% federal ownership is 1.54 km/km^2 (USFS unpublished data). Road densities above 0.6 km/km^2 reduce habitat suitability for both wide-ranging carnivore species such as the gray wolf (*Canis lupus*; Fuller 1989) and sensitive aquatic species such as salmonids (Frissell and Carnefix 2007). 80.0 % (1104 of 1381) of the sixth-field watersheds summarized above exceed this threshold.

The major expansion in the area subject to thinning contained in proposals to revise the NWFP would produce an overall increase in landscape-level road density despite components in some proposals to restrict the net increase in permanent forest roads. Implementation of landscape-level thinning to reduce fire effects without increasing road density may be unattainable, albeit rigorous analysis of this connection is lacking. Roadless approaches to logging are expensive, which could lead to pressure to remove more timber volume to offset costs and slow restoration of LSOG condition. Additionally, fuel produced with roadless thinning may be more difficult to treat (Agee and Skinner 2005). Potential road density increases, and consequent biological effects, is even greater under the Northern Spotted Owl Recovery Plan, a strategy that implements thinning within inventoried roadless areas (Table 1).

Other proposals maintain existing protections on inventoried roadless areas with the stated intention of focusing thinning and any associated road construction on previously harvested areas, with no net increase in permanent roads. Limiting thinning to the existing road networks probably results in the lowest potential for self-defeating tradeoffs (e.g., fuel production and loss of LSOG characteristics). However, this strategy could still expand the area of disturbed soil by re-opening revegetated roads and creating new temporary roads and landing areas. Landings typically occupy about 2% of the project area and thus could have more significant cumulative aquatic impacts than associated roads (Beschta et al. 2004, Karr et al. 2004, Bloemers and Winter 2008).

Coarse-scale conservation planning considers not only the size of reserves, but also their distribution and number, i.e., where they should be placed for greatest benefit to biodiversity. This allows planners to consider factors that emerge at the broadest scale, that of a region such as the Pacific Northwest. Reserves may be distributed following coarse-filter guidelines so as to represent all major types of a biodiversity feature such as forest vegetation or ecosystem types (Groves et al. 2002). Wide distribution of reserves also spreads the risk to species viability from factors such as catastrophic disturbance or disease, increasing the probability of retaining well-distributed populations (Den Boer 1968). Planning on a regional scale can also identify and protect areas of high importance to connectivity of wildlife populations (Crooks and Sanjayan 2006). For example, we describe below analysis that identifies "pinch points" where regional-scale habitat connectivity for the owl is at risk. Another recent analysis identified areas as either refugia or habitat corridors that may increase persistence in the face of climate change for 131 of the NWFP's species of conservation concern (Carroll et al. in press). These priorities would not have been evident in finer-scale planning efforts.

In following sections, we assess the implications of the contrast between coarse-scale and fine-scale planning paradigms on each of the NWFP's key conservation targets (fine-scale forest structure and coarse-scale forest pattern and process, localized and wide-ranging terrestrial species, and aquatic species and systems; Table 2). First, we assess the biological effects of a landscape-scale strategy involving large reserves embedded within a matrix that is more intensively managed for timber production. Second, we assess the ability of a given conservation target to withstand the loss of LSOG within the matrix consequent on such a strategy. Third, we briefly review the potential fine-scale (stand-level) effects of proposed silvicultural treatments (e.g., thinning) on the respective conservation targets (Table 2).

CONSERVATION TARGET 1: ELEMENTS OF FOREST STRUCTURE ASSOCIATED WITH LATE-SUCCESSIONAL STANDS

Late-successional forest enhances biodiversity at spatial scales ranging from an individual large live tree or snag, to old forest stands, to watersheds composed of a mosaic of stand ages. Silviculture also affects forest ecosystems at several scales by altering forest composition, abundance and spatial distribution of structural attributes, and spatial patterns of vegetation types and stand age classes, and by dissecting the landscape with a road network (Lindenmayer and Franklin 2002, Lindenmayer et al. 2008). The dominant silvicultural methods on public lands in the Pacific Northwest during the period 1950-1990 reduced both the extent of older forest and the ability of remnant LSOG stands to contribute to biodiversity conservation (FEMAT 1993). As a consequence, the NWFP focused on LSOG conservation at several scales, coordinated as a multi-scale conservation strategy.

The NWFP reserve strategy did not comprehensively protect LSOG stands. At its core, the NWFP is an owl conservation strategy in which the number, size, and spacing of reserves took precedence over the objective of maximizing LSOG protection (Murphy and Noon 2002). Approximately 40% of LSOG stands were excluded from NWFP reserves (Strittholt et al. 2006). Legislative proposals for NWFP revision are motivated in part by the belief that the amount of LSOG protected within reserves may be insufficient to achieve the plan's conservation objectives. To help inform this debate and assess the current and potential ecological role of LSOG stands, we evaluated the amount, configuration, and degree of fragmentation of LSOG within NWFP reserves and matrix.

The proportion of LSOG within the current landscape varies widely by region (Strittholt et al. 2006). Based on data from Strittholt et al. (2006), 37.5% (1,367,130 ha) of old-growth forest on federal lands and 48.6% (1,160,126 ha) of mature forest on federal lands is within the NWFP matrix. This LSOG is currently being cut at a low rate compared to historic levels. About 0.2% of the older forest on federal lands was logged during the period 1994-2004 (Moeur et al. 2005). This loss is counterbalanced by an increase in LSOG in other areas due to forest succession (Moeur et al. 2005). This rate of harvest may increase due to shifts in policy, for example the recent administrative actions intended to weaken the plan's provisions. The current rate of LSOG logging within the matrix, although low compared to historic rates, may be of conservation concern at a regional scale for wide-ranging species such as the owl and in ecoprovinces such as the Oregon Coast Range where little LSOG remains (Noss 1993).

The Northern Spotted Owl recovery plan recommends thinning treatments to reduce tree density on the majority of the landscape, e.g. 65-70% of eastside and California Cascades provinces (USFWS 2008). However, tree recruitment that is often cited as a cause of fire concerns is generally not a feature of undisturbed old-growth stands (van Mantgem et al. 2009). In contrast, legislative proposals emphasize thinning in plantations and other previously harvested areas (Table 1). Even if old trees are retained, however, the expansion of thinning may impact emergent aspects of forest condition by increasing edge effects. Where LSOG patches are highly fragmented, shifting from a reserve design to a LSOG protection strategy has the potential to increase edge effects, loss of connectivity, and other landscape-scale impacts. Thus, it may be beneficial to retain a broad-scale strategy that assesses restoration needs of larger planning units, some of which would be reserves protected from thinning and other anthropogenic disturbances.

Recent proposals for landscape-wide silvicultural treatments (e.g., growth release and pre-fire stand manipulation to influence fire outcome) have characterized reserve strategies such as the NWFP as anachronistic, in part because current stand-level treatments, unlike those in use historically, are believed to be compatible with biodiversity conservation. Even when confined to previously harvested stands, however, thinning treatments must be evaluated carefully and, if deemed necessary for ecological restoration, implemented in such a way as to avoid negative impacts. Ground-based methods and associated machine piling, burning of activity fuels, construction and increased use of roads and landings can increase soil erosion, compact soils, and elevate surface runoff. Other aspects of potential concern about soils include loss of soil fertility associated with burning slash piles. Cumulatively this can often affect 15% or more of forest surface area after 2-3 thinning entries. Cumulative or chronic reduction or depletion of soil organic matter can occur under repeated-entry thinning regimes, as opposed to the more episodic reduction that occurs with natural fire processes. We do not suggest that thinning projects are invariably detrimental to biodiversity. In some cases, fuel-reduction treatments and increased species protection can be compatible if designed and implemented intelligently (Prather et al. 2008). Nevertheless, thinning projects always should be evaluated case by case and designed to further ecological goals.

Effects of thinning on landscape connectivity, spread of invasive species and other spatial processes need to be considered in the context of the configuration and degree of fragmentation of remnant LSOG stands. Historic checkerboard harvest patterns led to fragmentation of LSOG patches and reduced their ability to contribute to conservation goals. LSOG stands may function as islands of habitat for old-forest associated understory species. Island biogeography and metapopulation theory suggest that if a LSOG-associated species is unable to disperse easily through other forest age classes, patch level extinction rates can exceed recolonization rates, triggering local, and perhaps ultimately regional, extinctions (MacArthur and Wilson 1967, Hanski 1998). Dispersal and establishment of some plants may be especially limited among old-growth stands because edges of old-growth patches may be unsuitable for many plants due to altered microclimate (drying) and increased seed predation (Jules et al. 1999, Jules and Rathcke 1999, Talmon et al. 2003, Jules and Shahini 2003). Strong edge effects also subject remnant LSOG patches to increased propagule pressure from non-native species, making them more at risk for invasion by diseases such as Port-Orford Cedar root rot (Hansen et al. 2000, Kaufmann and Jules 2006), as well as exotic flora that grow into the forest canopy (e.g., cape ivy (*Delairea odorata*)) or dominate understories (e.g. Himalaya blackberry (*Rubus discolor*))(Merriam et al. 2006, Keeley 2006). Thinning or prescribed burning can increase grass vegetation, including cheatgrass (*Bromus tectorum*), increasing fire risk and rate of spread (Kerns et al. 2007). However, even where the role of remnant LSOG stands is heavily compromised by edge effects, they retain biological value, e.g., as a source for propagules of understory species associated with old forests.

We analyzed the landscape pattern of existing LSOG stands as a whole and by management category. Edge effects have been documented to commonly penetrate 100 m into a forest stand (Chen et al. 1992). Even when edge is

Table 3. Comparison by ecoprovince within the Northwest Forest Plan area, of the percentage of area of old-growth and old-growth/mature stands considered edge habitat. Edge is defined here as that zone within a 60 meter distance from the patch boundary.

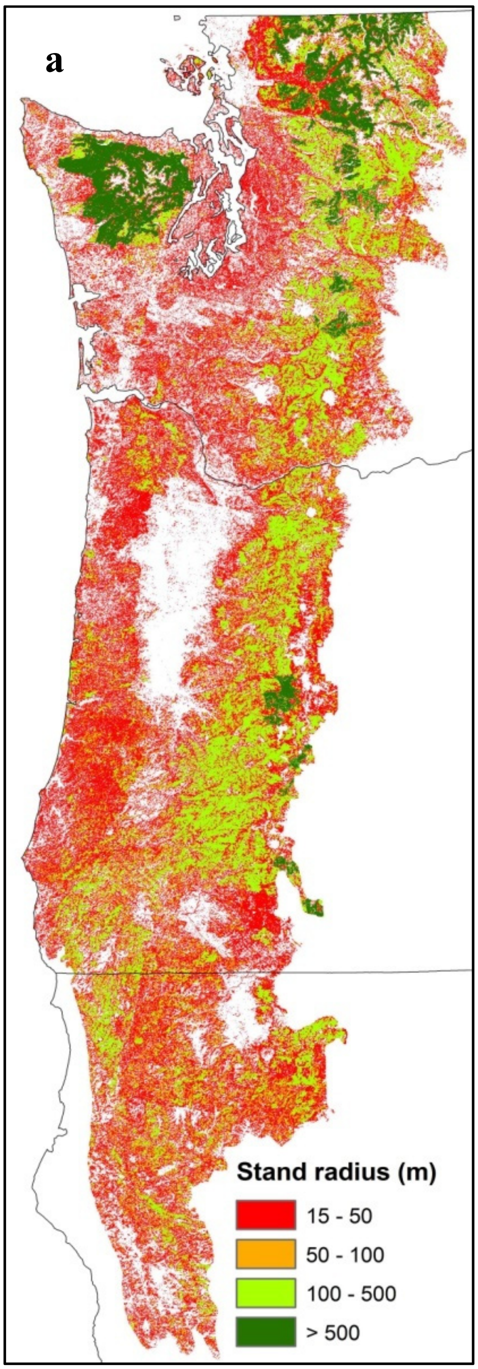
PROVINCE NAME	OLD-GROWTH	OLD-GROWTH/MATURE
California Cascades	81.75	62.64
Eastern Oregon Cascades	70.03	56.77
Western Oregon Cascades	64.82	45.96
California Coast	87.92	67.59
Oregon Coast Range	86.51	63.13
Eastern Washington Cascades	64.99	45.19
California Klamath	82.04	60.71
Oregon Klamath	78.22	51.75
Olympic Peninsula	38.81	36.23
Western Washington Cascades	53.66	38.28
Western Washington Lowlands	88.62	68.18
Willamette Valley	90.89	65.01
TOTAL	67.34	51.65

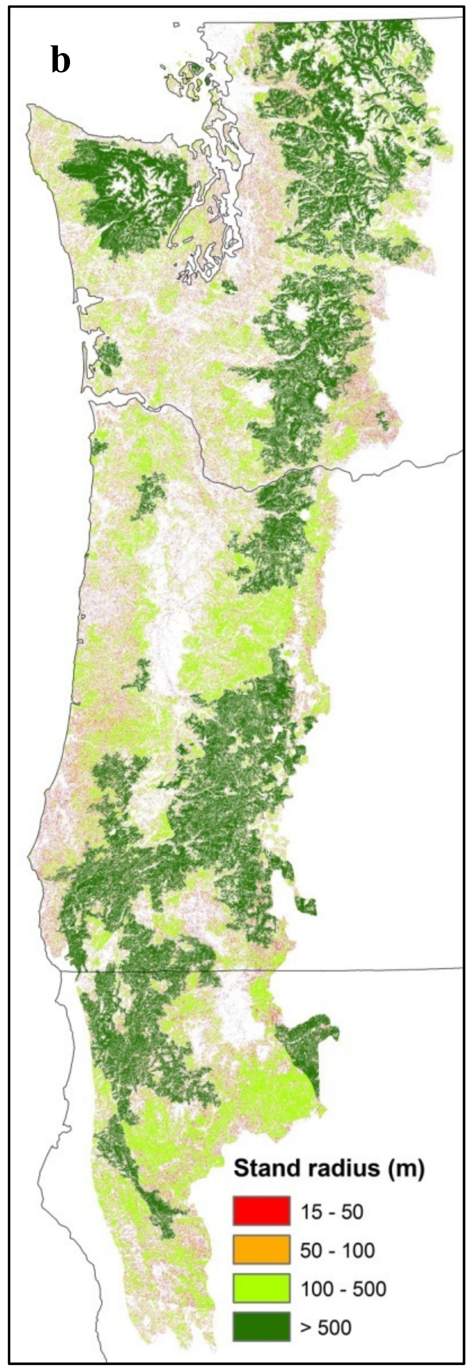
Table 4. Comparison by Northwest Forest Plan management category of the proportion of old-growth and old-growth/mature stands considered edge habitat. Edge is defined here as that zone within a 60 meter distance from the patch boundary.

MANAGEMENT CATEGORY	OLD-GROWTH	OLD-GROWTH/MATURE
CR/AW	52.58	39.37
LSR/AMR	63.39	44.08
LSR/AMR/AMA	64.40	44.98
AMA	70.74	49.86
Matrix	71.87	51.55
Federal lands overall	62.47	45.78

Abbreviations: CR; congressional reserves, AW; administratively-withdrawn areas, LSR; late-successional reserves, AMR; adaptive-management reserves, AMA; adaptive-management areas.

Figure 1. Maximum radius (depth) of old forest stands in the Pacific Northwest. Stands were delineated based on the forest age data from Strittholt et al. (2006). Figure 1a shows the radius of old-growth stands (> 150 years). Figure 1b shows the radius of stands delineated by combining old-growth and late mature stands (>50 years). The depth to which edge effect penetrates into and influences old forest stands varies depending on the site, forest type, and biological characteristic of interest. However, a variety of biologically-important effects are commonly recorded up to 100 meters from the stand edge. Therefore, subject to the spatial resolution (here 30 m) and classification system of the data, a stand with maximum radius of 100 m would be considered entirely edge habitat in some respects, although the type of edge effect would vary depending of what other cover type bordered the old forest stand.





conservatively defined based on a 60 m zone, a high proportion of existing old-growth stands are largely edge habitat and would be subject to indirect effects of thinning of adjacent stands (Table 3, Figure 1). When old-growth and mature age classes are considered together as an ecological unit, a much greater proportion of stands is composed of core (non-edge) habitat.

When the configuration of stands is assessed by management category, old-growth stands within current reserves (congressional reserves and LSR) have a lower proportion of edge habitat than do old-growth stands within adaptive management areas (AMA) and matrix (Table 4). These results suggest that 1) the median condition and conservation value of remnant LSOG varies greatly among regions, 2) matrix old-growth stands are more fragmented and ecologically compromised than is old-growth within reserves, and 3) matrix old-growth and mature stands should be considered together in any proposal to expand stand-level protection in order to reduce edge effects.

CONSERVATION TARGET 2: FOREST ECOSYSTEM PROCESSES AND DISTURBANCE DYNAMICS

The NWFP also addressed maintenance and restoration of elements of landscape-level biodiversity that had been compromised by historic timber harvest patterns. To restore landscape-level patterns and processes, the plan sought guidance from research on the pre-settlement disturbance dynamics of the region. First, it was thought that wildlife may be better adapted to human-induced landscape change if the spatial extent of individual reserves or timber harvest units approximates that of natural disturbance-recovery processes (e.g., Hansen et al. 1991, Hunter 1993, Cissel et al. 1999). Second, the concept of "minimum dynamic area" proposes that any single reserve should be several times larger than the typical extent of a single natural disturbance event if it is to retain habitat types over time (Pickett and Thompson 1978). The NWFP reserve strategy was designed to mimic spatial patterns of natural disturbances in forests west of the Cascade crest, characterized by infrequent large events, consistent with understanding of fire regimes in the Coast Ranges of Oregon and Washington (Agee 1993).

At the time of the NWFP, it was believed that fire regimes at the dry end of the forest gradient in the Pacific Northwest (Eastern Cascades and Klamath regions) were typically characterized by frequent, low-severity surface fires. Consequently, a model of forest dynamics associated with surface fire regimes was thought to apply to these areas (Hessburg et al. 2007). The NWFP applied a similar reserve strategy to both coastal and dry interior regions, a decision subsequently criticized as inconsistent with historic disturbance patterns (Spies et al. 2006). Proposed revisions to the NWFP diverge most strongly from that plan in the dry forest types, because of their contrasting characterization of historic disturbance regimes. The recently revised Northern Spotted Owl Recovery Plan states that "ongoing loss" of habitat to fire is a primary threat to spotted owls and that "no reserves are identified in these Provinces [Dry Forest Provinces], given the assumption that the severe natural disturbance regime precludes long-term persistence of any static habitat management areas" (USFWS 2008).

Nevertheless, a recent review of long-term fire history data across the northwestern USA, particularly the Klamath Region, concluded that large stand-replacing fires have historically been part of the natural fire regime in many interior areas (Whitlock et al. 2008). Even in the drier eastside forests where surface fire is considered most characteristic, mixed-severity fire regimes created more complex fire and vegetation patterns in some areas than was previously assumed (Hessburg et al. 2007, Klenner et al. 2008). Thus, recent research suggests that the NWFP's coarse-scale zoning strategy, rather than homogeneous management standards, may also be relevant for drier forest types. Similarly, the concept of minimum dynamic area may be relevant across the region's wet and dry forest types. Infrequent Coast Range fires have been at the spatial scale of LSRs—however, the replication of LSRs across the region, helps ensure that only a modest proportion of LSR habitat would be in early or mid-successional stages at any one time as a result of fire (Wimberly et al. 2000). Reserves of similar size in dry forests will exhibit more fine-grained spatial patterns of disturbance and recovery. However, they may best retain conservation value in the face of disturbance if the size of disturbances is substantially smaller than the size of a single reserve (i.e., each reserve constitutes a minimum dynamic area). Thus, the concept of minimum dynamic area (Pickett and Thompson 1978) can be applied at two spatial scales dependent on the scale of historic fire events. In dry forests, undisturbed area will exist within a reserve at any given time to provide for late-successional species and to serve as source areas for dispersal back into disturbed areas. In wet forests, this dynamic will occur across the system of reserves.

The perception that Pacific Northwest forests are at high risk from excess fire disturbance has been largely driven by media attention to the impact of large fires on human communities, rather than by reliable data on fire effects. A recent review critiques the NWFP's fixed reserve strategy (SEI 2008); p. 96-97) by citing a 69 year rotation interval for high severity fire in the dry Cascades provinces, relying largely on the undocumented effect of one large, recent fire. To evaluate the extent of ongoing loss of old forest due to fire within the NWFP region, we used a recent assessment of fire risk in dry provinces based on remote sensing and GIS data (TWS 2008, Hanson et al. in review). Fire-severity data from 1994-2002 (Oregon Eastern Cascades), 1994 and 1996-2002 (Washington Eastern Cascades), and 1994-2003 (California Cascades) were from Mouer et al. (2005). Fire severity data from 2003 in the Oregon Eastern Cascades were from USDA (2004, 2005). This analysis found that ongoing fire rotation intervals are an order of magnitude longer than 69 years, and that the slowest forest recruitment rates greatly exceed high severity fire rates, resulting in a net gain rather than a loss of old-forest with ongoing rates of fire. Although one decade is far too short to analyze trends that fluctuate over much longer time scales, this has been the approach used by administrative and legislative proposals to justify elimination of reserves (USFWS 2008). These results suggest that existing data do not support claims of rapid loss of old forest at the ecoprovince scale.

Studies of the ecological impacts of fire have often found largely beneficial effects of fire, including high-severity fire, especially when such fires are “characteristic” or within the historic range of variability for the ecosystem type concerned (Baker 1994, Kotliar et al. 2003, Turner et al. 2003, Fulé et al. 2004, Smucker et al. 2005, Noss et al. 2006, Odion and Hanson 2006, Hutto 2008). In the drier forests in the NWFP area targeted for extensive thinning, disturbance by fire is occurring at rates that appear consistent with ecological goals (Hessburg et al. 2007), and generally well-suited for biodiversity maintenance (Odion and Sarr 2007). Fire severity remains mostly low, and there is no trend in severity since 1984 (Schwind et al. 2008). When high-severity fire does occur, relatively little biomass (mostly litter and fine wood) is removed from forests (Agee 1993), and the dead and dying trees that remain serve as essential habitat for many bird species and other organisms dependent on such structures (Smucker et al. 2005, Hutto 2008). Disturbance magnitude, as measured by biological legacies that remain, generally does not prevent the pre-disturbance community from playing an important role in succession (White and Jentsch 2001).

Proposals to revise the NWFP and eliminate LSR in the drier eastside and Klamath forests assume not only that excess fire effects are occurring, but that they can be effectively reduced. The ongoing rates of high-severity fire, however, yield a very low mean probability that forest treatments will intersect high-severity fire events. Assuming the current return intervals for fire and 20 years between treatments, it will take 36 cycles of treatment, on average, before thinned areas have a 50% probability of intersecting high-severity fire (Rhodes and Baker 2008). Should fire intersect treatments, the effects on fire behavior will depend upon the specific nature of the thinning. Thinning alone, without subsequent prescribed fire or other treatments to reduce fine fuels, may increase fire severity because of logging slash (small trees, branches, tree tops) left scattered on the ground and available to combustion (Raymond and Peterson 2005). Planning documents associated with thinning the NWFP area (USDA and USDI 2007) acknowledge that only 40-50% of the fuel from thinning may be burned, which may be optimistic given constraints of expense and air quality restrictions on burning. The area in the California Klamath, North Coast, and Cascades regions that has been treated with prescribed fire in the 20 years prior to 2008 is about 0.8% (California Department of Forestry and Fire Protection, unpublished data available at frap.cdf.ca.gov/data/frapgisdata/select.asp). Much of this burning is for range improvement, and may not be relevant to thinning treatments. The same limits to prescribed burning are found throughout the dry regions. Moreover, 5-10 years after being burned, treated areas need to be burned again if low fuel levels are to be maintained (Agee and Skinner 2005). These management difficulties may explain the results of Hanson and Odion (2006), who found that all areas they could identify that had been previously commercially-thinned and then burned in wildfires exhibited higher fire severity than unthinned controls. Thus, the feasibility of treating fuels produced by a greatly expanded thinning program is questionable. Thinning without proper fuel treatment can increase fire severity, flame length, and rate of spread under many conditions, which can offset much or all of the potential benefit of structural changes in fuels. With low mean probabilities that thinning will intersect high-severity fire, thinning may have relatively minor overall effects on fire regimes, especially on a regional scale.

Proposals to eliminate LSR in the eastside and Klamath regions also assume that more intensive, landscape-level thinning would be benign. Although thinning differs from conventional logging, many of the same impacts can occur to conservation targets, with magnitude proportional to disturbance intensity. Conducting regular thinning and prescribed burning will substitute management action for natural disturbance regimes. The magnitude and frequency of thinning and burning effects will determine their long-term effects, which are largely unstudied. A major pulse of tree recruitment usually follows partial harvests and associated activities (Covington 2000, Agee and Skinner 2005). Commercial thinning, which often differs from thinning conducted primarily for ecological restoration, commonly removes about a third of the basal area of trees and more biomass than the average effect of most fires (Hanson and Odion 2006). Associated activities like machine piling of slash will compound thinning disturbances. Compounded disturbances may lead to a system shift to a persistent, degraded state (Paine et al. 1998), albeit this hypothesis has not been well tested in the context of forest management.

Thinning may play a positive role in some fire-excluded forests, especially if followed by prescribed fire. Thinning can also be beneficial in increasing fine-scale heterogeneity in plantations and intensively managed forests (Hunter 1993, Carey 2003, Odion and Sarr 2007). Nevertheless, the application of thinning treatments across the broader landscape, as advocated in proposals for NWFP revisions (Table 1), cannot be justified at present. No evidence exists to support the contention that an extensive thinning program will hasten restoration of historic patterns of forest heterogeneity on a landscape scale. Hence, thinning treatments should be applied cautiously and only where ecologically warranted. Thinning should not be considered a cure-all for forests degraded by fire exclusion or other human activities.

CONSERVATION TARGET 3: THE NORTHERN SPOTTED OWL AND OTHER TERRESTRIAL WIDE-RANGING FOCAL SPECIES

Wide-ranging focal species are a key consideration in comprehensive conservation planning because they provide unique insights on the effects of reserve size and configuration on population viability on a broad scale (Noss and Cooperrider 1994, Carroll et al. 2001). The focal species element complements "coarse-filter" efforts to represent ecosystem types and "fine-filter" efforts to capture important sites for localized species (Noss and Cooperrider 1994). Although the NWFP's planning focus eventually broadened to a suite of old-growth associated conservation targets, the owl continued to serve as the *de facto* focal species (Noon and Blakesley 2006). We focus on the owl in this section because of extensive data on the its biology and habitat needs. Nevertheless, similar coarse-scale planning issues are relevant to recovery of other wide-ranging species of concern in the region such as the Pacific fisher (*Martes pennanti pennanti*)(Carroll et al. 1999, Aubry and Lewis 2003).

Planning for owl conservation was not initially viewed as a reserve design question. Primarily, the initial focus was on fine-grain habitat requirements at the scale of individual owl pairs and their home ranges (e.g., canopy closure, mean age and dbh of overstory trees, and dead and down wood). Thus prescriptions and restrictions on harvest activities at the project scale were a primary focus. The reserve design approach (i.e., viewing the owl's distribution as a collection of metapopulations) arose near the end of the Interagency Scientific Committee (ISC) process which preceded the NWFP (Thomas et al. 1990).

Conservation planning efforts for the owl were among the first to use spatial simulation models to assess the potential effects of reserve size and spacing on population viability. Because of the owl's strong association with older forest, the forest landscape of the Pacific Northwest was modeled as a binary map of suitable (old) and unsuitable (young) stands. Initially, Lande (1987, 1991) used a non-spatial model to demonstrate that a territorial species such as the owl could reach an extinction threshold while habitat still remained, thus highlighting the importance of suitable but unoccupied habitat to persistence. Lamberson et al. (1994) then developed a dynamic spatial model, which analyzed owl viability on idealized landscapes with territory clusters of varying size and spacing. This model suggested general rules for the size and spacing of habitat blocks that informed early reserve design proposals for the owl (Thomas et al. 1990). A pair of owls required a block of old forest of sufficient size to establish a territory and successfully reproduce. At a coarser scale, suitable habitat aggregated into clusters of 10-20 territories ensured that dispersing juvenile owls could encounter and colonize vacant territories without having to disperse through the forest matrix where mortality risk was high. Based on the model, if such habitat clusters were spaced within 20 km of each other, dispersing owls might be expected to occasionally make a successful crossing between clusters, thus ensuring continued genetic and demographic interchange (Lamberson et al. 1994).

In the end the ISC strategy, which formed the foundation of the NWFP owl conservation strategy, adopted an explicitly multi-scale approach: 1) nest tree requirements measured in terms of tree size and age; 2) local habitat and area requirements measured at the scale of the individual territory, 3) meso-scale requirements measured in terms of collections of neighboring territories that collectively formed local populations, and 4) landscape-scale requirements which adopted a metapopulation perspective and viewed the adequacy of the conservation strategy in terms of persistence likelihoods driven by factors such as local population stability and rates of colonization and extinction among local populations (Murphy and Noon 1992).

As computational power and data on landscape composition improved, these early efforts were refined to model the relative viability of owl populations on detailed representations of real landscapes. Input data now included the location and boundaries of proposed reserves and spatial data on variation in habitat quality across the landscape (Raphael et al. 1994, Schumaker et al. 2004). When owl viability was simulated on realistic landscapes, the earlier reserve design based on idealized landscapes was found to pose higher risks to owl viability than anticipated (Raphael et al. 1994).

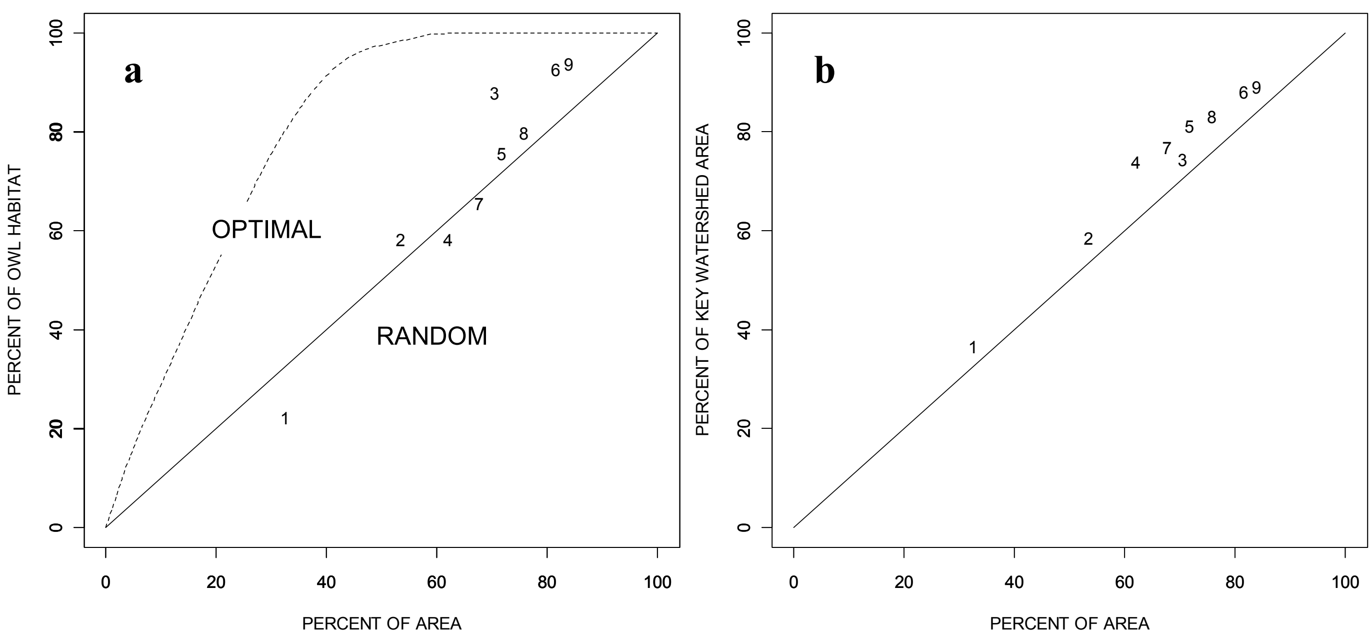
Several threats to the owl have emerged or strengthened since creation of the NWFP: 1) continued loss of old forest, primarily on private lands, 2) spread of the congeneric barred owl (*Strix varia*), which can competitively exclude spotted owl from otherwise suitable habitat, 3) continued decline in owl populations, 4) potential erosion of genetic variation; and 5) the potential for climate change to alter habitat suitability (Anthony et al. 2006, Funk et al. 2008, Carroll et al. in press). Although much new data has been gathered under the NWFP on owl habitat requirements, little progress has been made on updating simulations of owl viability. Due to political pressure, the recent Northern Spotted Owl recovery plan (USFWS 2008) was based on outdated simulations on idealized landscapes.

Owl populations have continued to decline at around 3% per year, although the decline is slower on lands subject to the NWFP than on private timber lands (Anthony et al. 2006). The NWFP anticipated the potential for a continued decline of owl populations during the transition period when the remaining LSOG was logged from the matrix, but the LSR had not yet been restored to their full habitat potential (Noon and Blakesley 2006). Nevertheless, the emergence of new threats merits reassessment of the plan's ability to insure owl persistence during this transition. To assess this question rigorously, we advocate development of updated simulation models that incorporate realistic scenarios of landscape change due to timber harvest, forest succession, expansion of the range of competing species, and climate change, as well as quantitative modeling of the effect of alternate reserve designs on the genetic structure of the owl metapopulation.

In the absence of a comprehensive assessment, we performed a preliminary evaluation of the ability of the NWFP and alternative plans to capture owl habitat. We overlaid alternative reserve proposals, including the NWFP, on recently-developed maps of owl habitat (Carroll and Johnson 2008). As has been noted in previous analyses, pre-NWFP congressional reserves poorly capture owl habitat (Figure 2a). The NWFP network (LSR and congressional reserves) performs better, with a similar level of success as a stand-level strategy focusing solely on old growth (stands > 150 years). A strategy focusing on both old-growth and mature (50-150 years) stands performs best by this measure. This is not surprising given that habitat modeling found owl abundance positively associated with both old-growth and mature forest (Carroll and Johnson 2008). Nevertheless, although a fine-scale reserve network based on protecting older forest stands performs best in this static habitat model, it would likely perform more poorly under dynamic simulation models that incorporate effects of reserve size and spacing as described above, due to the small size and high level of fragmentation of remnant LSOG stands in some regions (Table 3, Figure 1). Two conclusions can thus be drawn from this initial analysis: 1) mature forest, in addition to old growth, should be a core component of the owl habitat network, and 2) complex models are required to optimize design of an owl reserve network in the face of inherent tradeoffs between reserve composition and size.

Recent research has revealed strong regional-scale genetic bottlenecks in remnant owl populations, perhaps due to the recent steep population decline combined with limitations on owl dispersal through landscapes fragmented by logging (Funk et al. 2008). These bottlenecks have the potential to further lower population viability as the species enters an “extinction vortex” (Gilpin and Soulé 1986) due to multiple interacting threats. If connectivity between regional owl sub-populations is of importance for maintaining genetic viability, then regional-scale “pinch points” where habitat loss would reduce such connectivity are conservation priorities. We identified such linkage areas using the integral index of connectivity (IIC), a metric based on graph theory derived with the program Sensinode (Pascual-Hortal and Saura 2008). We created a graph network based on the grid of 24 km^2 hexagons used in the habitat analysis of Carroll and Johnson (2008). The centroid of each hexagon became a node in the graph, and flow between nodes was proportional to their habitat value in the model of Carroll and Johnson (2008). IIC value is assessed by dropping a particular node from the graph and then reevaluating the overall connectivity of the entire network to assess the node's importance. Pascual-Hortal and Saura (2008) conceptualize the connectivity role of a patch as a combination of the patch's habitat value and its location as a connector (i.e., given the same location, a good quality patch would enhance connectivity more than would a low quality patch). Here we evaluate the connectivity role of a node independent of its habitat value by mapping the residuals derived by regressing the IIC metric on the input habitat value. Based on this metric, the most important areas for maintaining range-wide connectivity for the owl are the areas connecting the Klamath region to both the Oregon Coast Range and Oregon Cascades (Figure 3). Particularly narrow and thus vulnerable habitat bottlenecks are found within southwestern Oregon where public and private

Figure 2. Efficacy of alternate terrestrial-oriented conservation proposals in capturing (overlapping) a) owl habitat as defined by the model of Carroll and Johnson (2008), and b) Northwest Forest Plan Key Watersheds. The x axis indicates the percent of lands subject to the NWFP encompassed by the proposed reserve network. The diagonal line indicates efficacy of a randomly-allocated reserve network. The dotted line in (a) indicates efficacy of a strategy focused solely on optimizing owl habitat. Conservation proposals are identified as follows: 1 - pre-NWFP congressional reserves, 2 - all old-growth stands on federal lands, 3 - all old-growth and mature stands on federal lands, 4 - current NWFP reserve system (congressional reserves, Late-Successional Reserves, and Adaptive Management Reserves) , 5 - current NWFP reserve system and matrix old-growth stands (similar to NWFP Alternative 1), 6 - current NWFP reserve system and matrix old-growth and mature stands, 7 - current NWFP reserves system and Adaptive Management Areas, 8 - current NWFP reserve system, Adaptive Management Areas, and matrix old-growth stands, and 9 - current NWFP reserve system, Adaptive Management Areas, and matrix old-growth and mature stands.



lands form a checkerboard pattern. Because graph theory is a highly idealized representation of habitat pattern, this analysis must be seen as exploratory. Nevertheless, it demonstrates that regional-scale analysis and coarse-scale planning are necessary to identify and protect key linkage areas for wide-ranging species.

In order to maintain adequate habitat connectivity within the matrix despite continued harvest of LSOG, the NWFP instituted the "50-11-40" rule (USDA and USDI 1994). This rule mandated that 50% of the landscape would be maintained in stands with dominant trees at least 11 inches (28 cm) in dbh and with canopy closure of at least 40%. Simulation models of owl viability developed under the NWFP found that retention of all LSOG in the matrix between LSRs would enhance owl connectivity and population viability, and planners developed an alternative (Alternative 1) that incorporated this strategy (Raphael et al. 1994). However, the models also forecast that the ultimately-selected Alternative 9, which opted for the less stringent 50-11-40 rule to enhance timber production within the matrix, would also maintain well-distributed, albeit smaller, owl populations. Current proposals to revise the NWFP that prohibit logging of LSOG within the matrix resemble NWFP Alternative 1 in this respect (Table 1). Simulation models updated with new data and analysis of new threat factors might assign different levels of risk to NWFP Alternatives 1 and 9 than did the analysis of Raphael et al. (1994). Until these analyses are conducted, we are limited to concluding that enhanced matrix LSOG protection would likely enhance owl viability, but by an unknown amount.

The degree to which enhancement of owl population viability and connectivity due to protection of matrix LSOG stands would be counteracted by a reduction in canopy closure due to thinning under the current legislative proposals (Table 1) is unknown. Spotted owls may abandon nests in response to intensive thinning in their vicinity (Meiman et al. 2003). Thus, the intensity and frequency of treatments needed to maintain fuels at levels that could dependably reduce fire severity and extent, as advocated under recent proposals (Table 1), could be directly in conflict with goals for maintaining and recovering owl populations. Realistic simulation models, as described above, would be necessary to assess the net effects on viability of the combination of increased stand-level protection and expanded thinning.

Proponents of NWFP revision state that the potential decline in habitat quality following thinning may be acceptable if thinning prevents greater habitat loss due to high-severity fire. High-severity fire is often considered together with logging, implying that the disturbances have similar effects on habitat. The two disturbances, however, leave behind very different resources for wildlife and differ greatly in magnitude and other properties. Disturbance magnitude can be measured by the biological legacies (trees, logs, soil, seed banks, fungi, etc.) that remain (White and Jentsch 2001, Lindenmayer and Franklin 2002). Studies of the immediate effects of fire on spotted owls are limited, but suggest that fire does not necessarily lead to owl movement. Spotted owls often use burned habitat where biological legacies remain, including snag forests, large woody debris and vegetation regenerating from the seed bank. Clark (2007), working in the Klamath Province, found that owls continued to occupy stands that were lightly or moderately burned and used severely burned stands in proportion to their availability. In a study in the Sierra Nevada four years after a fire, Bond et al. (2006) found that California Spotted Owls

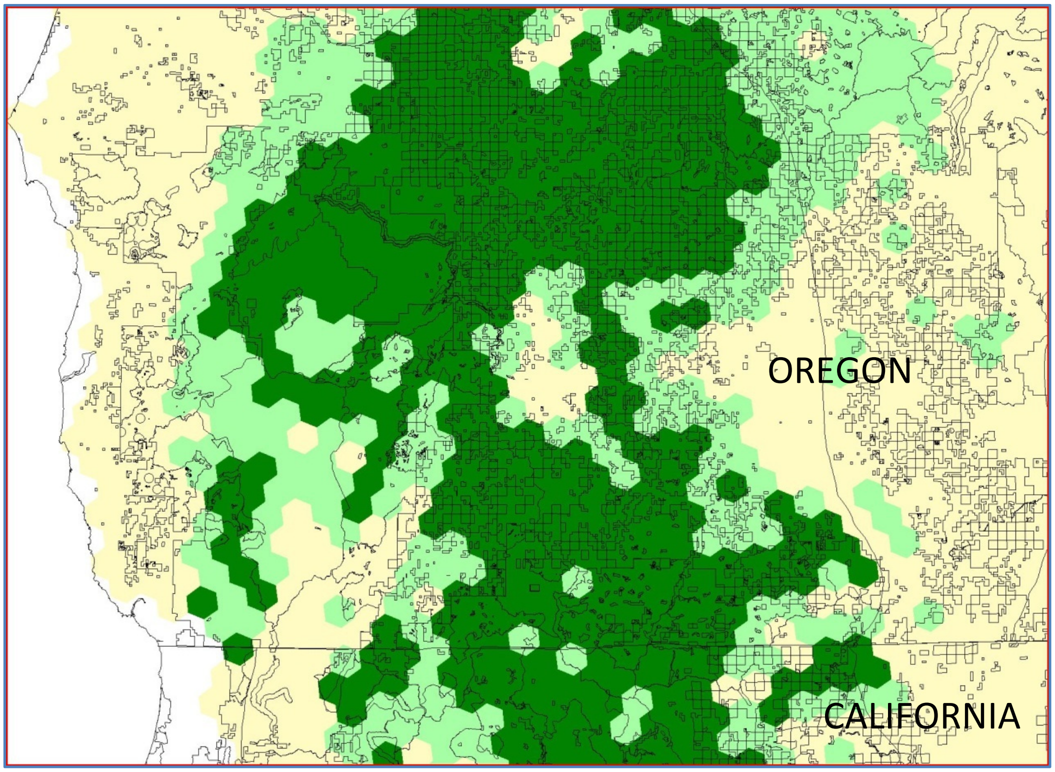


Figure 3. Regional-scale analysis to identify areas where Northern Spotted Owl habitat connectivity may be important for overall metapopulation connectivity and potentially vulnerable to habitat loss (Carroll et al. in prep.). Areas in dark green have highest connectivity value, followed by those in light green and tan. Areas were identified using the integral index of connectivity (IIC), a metric based on graph theory derived with the program Sensinode. The connectivity role of an area is described here independent of its habitat value by mapping the residuals derived by regressing the IIC metric on the input habitat value. The most important areas for maintaining range-wide connectivity for the Northern Spotted Owl based on this metric are areas connecting the Klamath region to both the Oregon coast and Oregon Cascades. Particularly narrow and thus vulnerable habitat bottlenecks are found in the region of southwestern Oregon where public and private lands form a checkerboard pattern.

preferentially used burned areas, encompassing all burn severities, over unburned areas. Further, Bond et al. (2002) provided evidence that survival of spotted owls whose territories experienced a fire event was similar to owls inhabiting territories free from fire. These studies occurred in regions that are relatively dry for owl habitat, indicating that owls may use burned areas in these regions, perhaps even preferably after a few years of understory regrowth. In addition, landscape heterogeneity created by cumulative fire events appears important to owls in the Klamath region (Franklin et al. 2000). Therefore, unlike clearcutting, fire cannot be categorized as generally detrimental to owls. In fact, lack of fire may be a risk when it causes vegetation homogenization across large areas, especially in dry regions. Considerable research is needed to reduce uncertainty about the effects of fire on spotted owl habitat and to elucidate geographic variation in responses. The temporal and spatial relationships of fire and post-fire legacy elements (snags, green trees, vegetation regeneration propagules) are among the many relationships that remain unclear.

CONSERVATION TARGET 4: LOCALIZED RARE AND ENDEMIC TERRESTRIAL SPECIES

Information on how the size and spacing of reserves might affect viability of a wide-ranging focal species (the owl) was thought to also be potentially relevant to connectivity needs of a larger suite of lesser-known species (Noon and Blakesley 2006). However, even when planned around the needs of well-selected focal species, a system of coarse-scale reserves is generally unable to capture habitat for all localized species because of contrasting scales of habitat selection among taxa (Andelman and Fagan 2000, Carroll et al. 2003). Thus, comprehensive planning efforts combine coarse-filter and fine-filter elements, augmenting the network of large reserves with site-level protection (Noss and Cooperrider 1994, Noon et al. 2009).

The NWFP acknowledged that a large group of rare and endemic species associated with older forests in the Pacific Northwest were either too little known to ensure that the new reserve system was adequate, or were too localized in distribution to be adequately conserved by a conservation plan based on large reserves (Raphael and Molina 2007). The NWFP used an expert-based screening process to identify over 400 species that were suspected of being associated with the region's old-forest ecosystems. These included primarily fungi and lichens, bryophytes, vascular plants, and mollusks, as well as amphibians, a bird, and a mammal. The NWFP mandated that distributional data would be collected for these "Survey and Manage" species before management activities (e.g., timber harvest) occurred on federal lands. Sites found to be occupied were subsequently managed to protect habitat (Molina et al. 2006).

Terrestrial taxa most sensitive to silvicultural practices are invertebrates, non-vascular plants, and fungi, which encompass the bulk of Survey and Manage species (Sarr et al. 2005). They are particularly sensitive because their abundance and diversity is correlated with large amounts of biomass, including down wood, snags, and litter. This biomass is often greatly reduced by thin and burn treatments. Although some fuel-treatment methods could have lower impacts, ground-based mechanical treatments are often employed, and these methods often have damaging effects to soil-dwelling organisms.

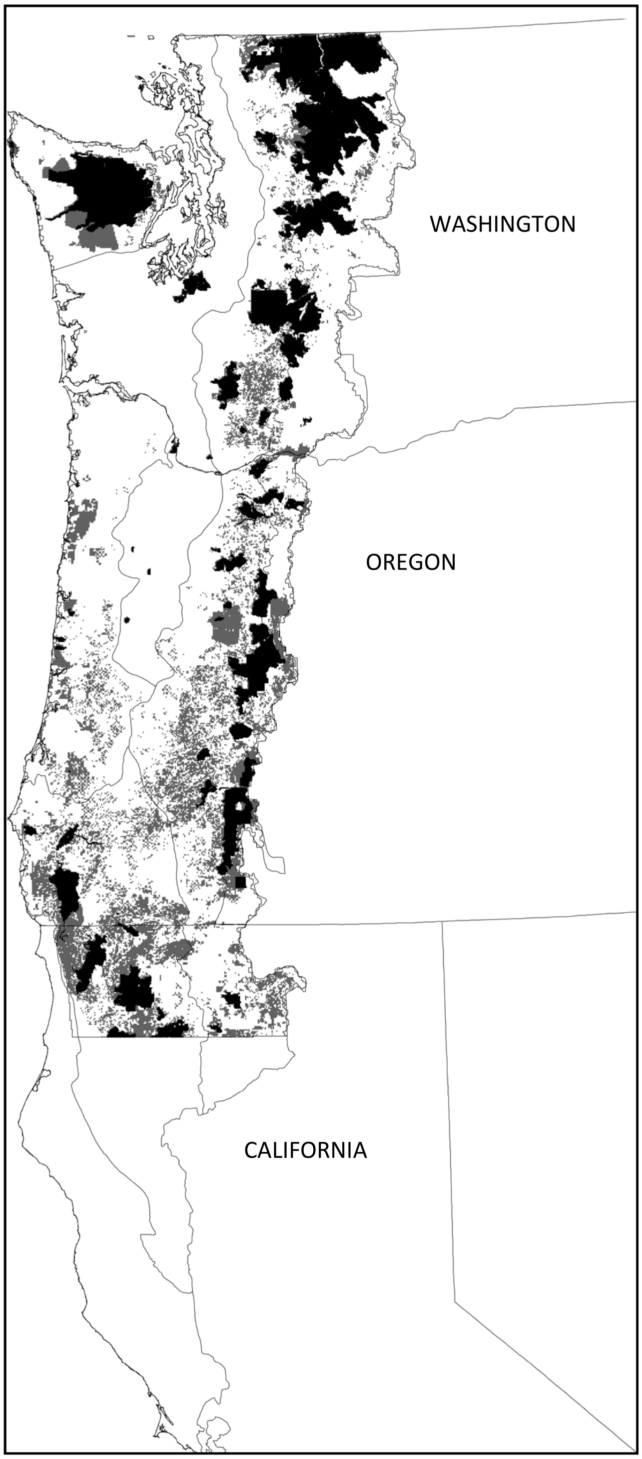
The taxonomic scope of the NWFP was unusual for public lands management in the USA. Little data on habitat associations exist for most of these Survey and Manage taxa, and research is needed to understand the long-term impacts of silviculture-related disturbances. The NWFP's fine-scale requirements have proved much more expensive than anticipated, and efforts have been made to abolish this component of the plan (Molina et al. 2006). Despite these difficulties, the program's survey mandate has produced initial data on the distribution and habitat associations of these previously little-known species,. Especially given a new federal administration anticipated to be supportive of the NWFP's conservation goals, this information may allow refinement of the NWFP fine-filter conservation strategy.

The effectiveness of any system of reserves may be compromised under climate change as habitat for various species shifts to non-reserved areas, a problem that may be compounded when wide-ranging species are used as conservation umbrellas for other taxa. In order to assess the extent of this problem, Carroll et al. (in press) developed habitat models for the owl and 130 Survey and Manage species. They then used reserve selection software to identify a system of areas that efficiently captured habitat for both the owl and localized species and prioritized refugial areas of climatic and topographic heterogeneity where current and future habitat for dispersal-limited species is in proximity. The study found a general pattern of shifting of priority areas towards either coastal areas or higher elevations. Nevertheless, certain regions (the Oregon and California Klamath and the Olympics of Washington) will be more likely to retain their importance for rare and endemic species under climate change due in part to high climatic, edaphic, and topographic heterogeneity, as has been the case in past episodes of climate change (Whittaker 1960, Noss 2001) (Figure 4). Climate change refugia for localized species showed some overlap with those for the owl, but a more efficient reserve system could be achieved by simultaneously considering the needs of both the owl and Survey and Manage species in reserve design. Resilience of narrowly-distributed species to climate change might be increased by protection of remnant matrix LSOG stands. This approach, however, poorly captures rare species priority areas when compared with a strategy explicitly based on those species' habitat needs (Carroll et al. in press). Although the proportion of the landscape within older forest is a key limiting factor for almost all of the Survey and Manage species analyzed, other factors such as climate are also important in limiting distribution (Carroll et al. in press). Thus, crafting a conservation strategy resilient to climate change requires not only conserving LSOG stands but nesting that protection within a coarse-scale framework that identifies and prioritizes areas that are documented or predicted climate-change refugia. Such refugia span a range of spatial scales, from single slopes or rock crevices to entire mountain ranges and river valleys (Noss 2001). Based on these results, protection of localized Survey and Manage species under new threats such as climate change requires a more comprehensive and explicitly multi-scale strategy than was considered at the time of the NWFP's creation or in current proposals for NWFP revision.

CONSERVATION TARGETS 5 AND 6: FRESHWATER AQUATIC SPECIES AND SYSTEMS

The NWFP's Aquatic Conservation Strategy (ACS) was developed with the recognition that conservation measures designed for terrestrial species may not sufficiently protect aquatic habitats and species (USDA and USDI 1994). The ACS's two land allocations had special planning requirements. Riparian Management Areas are stream-adjacent zones defined by default buffer widths scaled to protect and restore processes that link terrestrial and aquatic ecosystems. In RMAs, the agencies must ensure all actions are intended to protect or restore natural ecosystem functions, including stream flow, thermal regime, sediment input, and large woody debris recruitment and retention. Inclusion of intermittent streams without fish (which are important for amphibians and as sources of wood, cold water, and nutrients) as riparian reserves greatly increased the area affected by RMAs (Reeves et al. 2006a). Second, the ACS designated as Key Watersheds areas where aquatic biological values are particularly prominent. Inside Key Watersheds, which averaged 22,600 ha in size, soil and water restoration receives high priority, road density must be reduced, road construction in current inventoried roadless areas is prohibited, and a watershed analysis protocol is required to inform restoration and other management decisions. The long-term goal of the ACS was creation of a network of watersheds with an aquatic condition sufficient to support viable subpopulations of aquatic and riparian-dependent species (Reeves et al. 2006a). This coarse-scale

Figure 4. Priority areas for conservation under climate change of 130 rare and endemic species identified as “Survey and Manage” species under the Northwest Forest Plan, as well as the Northern Spotted Owl (Carroll et al. in press). Congressional reserves (parks and wilderness areas) are shown in black. Priority areas are shown in grey as identified in by the program Zonation as most efficiently capturing areas on federal lands where current and future habitat is in proximity. Extent of priority areas is equal to the area now in LSRs. Future habitat is based on projected habitat for these species under climate change scenarios for the years 2011-2040. The analysis excluded the southernmost portions of the NWFP area due to unavailability of comparable input climate projections.



strategy parallels the terrestrial strategy of concentrating protection of owl habitat within a network of coarse-scale reserves (LSR) to increase viability. However, conservation of anadromous species that migrate through stream systems presents inherent challenges to connectivity that differ from those presented by terrestrial wide-ranging species.

In their ten-year review of monitoring to assess the conservation efficacy of the NWFP ACS, Reeves et al (2006a) reported that in the NWFP's first decade, conditions improved in 64% of 250 sampled watersheds, declined in 28%, and remained relatively the same in 7%. Declining scores were associated with wildfire in some areas, while improving scores were associated with road decommissioning projects that reduced the density and impact of roads. Key watersheds had been successfully prioritized for restoration, and more road decommissioning had taken place there under NWFP than in non-key watersheds (Reeves et al. 2006a). However, Reeves et al. (2006a) concluded on the cautionary note that although "the NWFP and ACS changed the focus from small spatial scales (i.e., project areas) to larger landscapes[,] It appears that the implications of these changes have not been recognized fully or appreciated by the land-management and regulatory agencies or general public".

Debate over the value of coarse-scale reserves for aquatic conservation parallels the debate over terrestrial conservation strategies. Reserve-based strategies may be ineffective where freshwater ecosystems have been altered to such an extent that there are few or no natural processes and patterns left to maintain. In those landscapes, current ecological configuration requires active intervention of various kinds to attain a more desirable state. Even in these cases, there remains a role for concentrated spatial allocation of restoration resources for functionally the same reasons that terrestrial reserves are needed. Some have argued that because of their high physical and biological connectivity and rates of energy throughput, freshwater ecosystems cannot be conserved in the form of spatially-explicit patches. This contention, however, has been thoroughly dispatched in marine ecosystems, which are similarly dynamic and fluid, but where fixed-location reserves have been shown to benefit biological diversity and productivity both within the reserve and in surrounding waters (Roberts and Polunin 1991, Halpern and Warner 2002). We performed an initial evaluation of the efficacy of the NWFP's terrestrial reserve system and alternative proposals in capturing (overlapping) Key Watersheds. We found that none of the nine alternate reserve networks based on terrestrial conservation goals, including a stand-level LSOG protection strategy, performed substantially better than a randomly-allocated network in protecting large-block aquatic areas such as Key Watersheds (Figure 2b). This is because the large size of key watersheds or other reserves driven by the ecological scale of aquatic systems makes them difficult (although not impossible) to coordinate with a terrestrial strategy based on finer-scale targets such as LSOG stands.

Stream ecosystems are either little impacted by (Scheidt 2006) or benefit from major natural ecological disturbances such as high-severity wildfire (Gresswell 1999, Minshall et al. 1997, Minshall et al. 2005). Among other effects, wildfire triggers the "pulsed" recruitment of large woody debris that sustains complex habitat structure and increases nutrient retention in streams for many decades (Robinson et al. 2005). In addition to increases in these aquatic and terrestrial linkages, Baxter et al. (2005) have reported on the mid-term fire effects (5 years post-fire), investigating the flow of energy from aquatic to terrestrial habitats at different sites in the northern Rockies. They found that stream reaches that experienced high-severity fire had the greatest benthic insect biomass and exported the greatest fluxes of adult aquatic species, and that these supported the highest numbers of fly-catching birds and bats, as well as spiders. Burned tributaries exported larger quantities of invertebrate prey downstream, supporting larger numbers of cutthroat trout (*Oncorhynchus clarki*). In sum, wildfire may drive a pulse of productivity characterized by amplified fluxes from stream to riparian systems and downstream to support consumers there. Stream ecosystems and species appear well-adjusted to recover rapidly from occasional pulse disturbances that to humans may appear to be catastrophic (Sedell et al. 1990. Reeves et al. 1995). Human alterations of ecosystems have two important effects (Reeves et al. 1995, Frissell and Bayles 1996): first, they often increase the frequency and extent of such pulse disturbances, such as landslides and debris flows originating from logged, unstable slopes and roads (Jones et al. 2000). This can reduce the availability and persistence of refugia from which sensitive species recolonize habitat after disturbance (Sedell et al. 1990). Second, human perturbations elevate the level and spatial extent of sustained, chronic stress, also called “press" disturbances, such as by fine sediment and runoff alteration by road networks, depletion of large wood from post-fire environments by salvage logging, and mechanical ground disturbance from logging operations that increases sediment mobilization (Beschta et al. 2004). Freshwater biota do not tolerate such press disturbances well (Sedell et al. 1990, Reeves et al. 1995), and in fact many of these alterations of ecosystems directly undermine the ecological elements and processes by which watersheds and streams recover naturally from wildfire and other natural disturbances (Ebersole et al. 1997, Beschta et al. 2004).

The NWFP considered soils and erosional and edaphic processes primarily within a bootstrapping context--i.e., "Have wildlife and aquatic protections accomplished enough in enough places that no further protection for soil and erosion are needed?" The answer was a qualified yes, based on two core tenets. First, "riparian" protection for streams had been pushed well up-slope to include adjacent erosion-prone hillslopes. Second, many large blocks of land (including Key Watersheds) were to remain essentially free of new, extensive human disturbance aside from road reduction and other restoration actions. Because these areas were well-dispersed with regard to the most biologically sensitive watersheds, there was limited risk of cumulative downstream or regional effects emerging as a result of up-slope land disturbance.

That human-associated disturbance of aquatic systems is seldom benign and contrasts with natural disturbances demonstrates that coarse-scale planning such as the ACS is key to long-term conservation of these systems. The potential effect of a shift from coarse-grain to fine-grain strategies (e.g., best management practices) is to bring all watersheds to median condition with roads and disturbance spread throughout the landscape, which may lead to degradation of key refugia and decline of anadromous and other species. Proposals for revision of the NWFP retain the ACS’s provisions to varying degrees (Table 1). PNWFLA and OFROGPA would explicitly retain the spatial elements of the ACS, including Riparian Reserves and “Key Watersheds,” but how the lands within these reserves would be managed remains unclear. Concern lingers that the language of these two legislative vehicles implies a mandate to thin forests inside these areas, which could trump current direction that requires any logging practices within riparian reserves be approved strictly on the basis of clearly established net benefit to riparian-dependent species and resources. Equally important, the landscape-wide thinning mandates of PNWFLA and OFROGPA can be assumed to inexorably increase the demand to maintain or extend an extensive road network for management access. The current road network was recognized in FEMAT and other reviews to be already far larger than the land management agencies are able to properly maintain. Overlooking this concern, both legislative vehicles increase incentive to retain or expand extensive road networks without establishing direction or providing resources to reduce the environmental impact of roads.

There are very few data on the impacts and benefits of riparian thinning, and what is available is highly ambivalent or indicates net harm to water quality (Reeves et al. 2006b). This suggests that the risk of inadvertent adverse effects on water quality and aquatic biodiversity from an extensive mechanized thinning program is high (Rhodes 2007). It is likely that the increased area of disturbed soil resulting from re-opened roads, temporary roads, and landings necessary to accommodate thinning will significantly affect aquatic health (Bloemers and Winter 2008). This implies that such proposals need to be evaluated within and tiered to a coherent coarse-scale aquatic planning framework such as the NWFP ACS to prevent degradation of aquatic condition and increased risk to aquatic species of concern.

DISCUSSION

The Northwest Forest Plan (NWFP) was among the first efforts globally to address a comprehensive suite of conservation goals using a planning strategy integrated across multiple spatial scales (USDA and USDI 1994; Thomas et al. 2006). The plan marked a major departure from timber-dominated management of public forest lands by its emphasis on biodiversity and ecosystem management combined with a more sustainable approach to timber harvesting (USDA and USDI 1994). In particular, late-successional/old-growth forest (LSOG) was recognized as a key habitat for a large proportion of the native biota as well as a source of ecosystem services such as the provision of clean water and flood mitigation. Moreover, the plan was much broader than a strategy to protect LSOG stands, as it integrated goals for conservation of terrestrial flora and fauna and aquatic species at fine and coarse scales.

The coarse-scale planning elements of the NWFP marked the greatest departure from previous planning paradigms and consequently have been the most poorly-understood aspects of the plan (Reeves et al. 2006a). This problem may also stem from the political context in which the plan was initiated and implemented. Recent regional planning efforts of this scope have generally sought to involve the public in critiquing and reviewing reserve design analysis as it develops (e.g., the Great Barrier Reef conservation plan (Fernandes et al. 2005)). In contrast, the NWFP was a top-down planning process developed primarily by scientists and agency personnel. Additionally, the NWFP was ambitious in its efforts to address conservation of a broad suite of poorly-known taxa such as invertebrates. The resultant "Survey and Manage" program has proved unwieldy to implement, with a greater impact on level of timber harvest than anticipated (Molina et al. 2006).

Conservation planning is an iterative process, and initial implementation challenges should be evaluated and resolved with the same level of scientific rigor used to develop the plan. However, a hostile federal administration during the later stages of NWFP implementation (2001-2008) prevented effective science-based efforts to refine and update the plan. Politics also actively discouraged agencies from working toward the identified need to better integrate into planning for traditional resource-extractive uses the new strategic conservation building blocks created in coarse-scale design elements of the NWFP. Thus the relative lack of integration of the NWFP's coarse-scale planning principles into current legislative proposals is not surprising.

We conclude, for reasons discussed in the previous sections, that the coarse-scale planning paradigm, centered on a system of large LSOG reserves as well as matrix management, remains highly relevant to any effort to conserve forest ecosystems in the Pacific Northwest. Incorporating fine-scale (stand-level) management within a multi-scale strategy that focuses on factors such as reserve area, number, distribution, and connectivity assures an effective conservation strategy. Coarse-scale planning enhances the opportunity for coordination across ownerships and thus lessens threats to species of concern from inadequate regulatory mechanisms.

The necessity of coarse-scale planning is of broader scope than the debate over the need for reserves (zones with generally low-intensity management aimed toward maintenance of biodiversity; Noss and Cooperrider 1994). Nevertheless, reserves offer conservation benefits that can be generalized across ecosystems. Among many benefits, reserves function as control treatments that aid assessment of unanticipated long-term management impacts. Restrictions on road-building and the large size of reserves allow these areas to function as refugia for aquatic and other species sensitive to the biological impacts of roads. Reserves also function as practical guarantees that land-management agencies will address coarse-scale planning issues despite a variety of potentially conflicting societal demands.

A strategy of coarse-scale management zones and a fine-scale non-zoning will converge as management within the various zones becomes more similar. Proponents of a "landscape without lines" strategy, which broadly applies thinning and other management treatments without use of reserves, emphasize the restorative ecological effects of such management. We do not dispute that thinning, prescribed fire, and other intensive management have net ecological benefits in certain contexts. Nevertheless, the effects of roads, landings, soil disturbance, and other impacts associated with logging, as well as the consequent change in stand composition and structure, can conflict with many conservation goals. In general, potential biological impacts are expected to scale with the timber volume projected under the various proposals to revise the NWFP (Table 1). Because all proposals are regional in scope, however, they potentially have significant impacts that merit coarse-scale planning. Even in dry eastside forests, where the utility of thinning and prescribed fire to restore historic stand condition and disturbance regimes is best documented, a reserve strategy is still beneficial to manage roads and other forms of human disturbance. At a minimum, fuels reduction projects in drier forests would require careful and mandated staging over time and space to ensure that roads are decommissioned to reduce their environmental impact as soon as possible after fuels treatment has been completed. However, the recurring expense of decommissioning and re-constructing a road network is likely to be prohibitive if fuels reduction efforts need to be repeated at ca. 15-

year cycles to sustain the stand structures managers desire.

The NWFP's reserves are more ecologically meaningful than a collection of old trees; rather, they are places where certain types of human disturbance are minimized. This refuge effect benefits a host of biological elements and ecosystem processes, many but not all of which are mediated by the presence of large trees. Policy alternatives analyzed at the time of the NWFP, in particular Alternative 1 (FEMAT 1993), would have provided additional protection for LSOG within the matrix while retaining the current reserve network and minimizing risk to species sensitive to human activities. In contrast, the current proposals that focus exclusively on fine-scale protection may effectively allow disturbance associated with logging of younger trees to occur throughout the landscape--even directly adjacent to large, old trees that are individually protected. Such homogenization of the landscape does not address the habitat requirements of LSOG-associated species with large area requirements.

A broader policy question concerns what mixture of legislative and administrative direction is optimal for achieving conservation of forest ecosystems in the Pacific Northwest. Legislative language is unavoidably expressed in generalities, which the agencies then elaborate into regulations that provide details necessary for implementation. Thus, it may be too much to expect proposed legislation to contain detailed science-based standards for forest management. Nevertheless, a lack of specificity makes it difficult to gauge the full ecological effects of the proposed legislation before implementation. For example, OFROGMA appears to retain existing NWFP guidelines for logging within LSRs in mesic westside ecoprovinces, but allows categorical exclusions to procedural requirements that may permit more ecologically-harmful logging projects to occur than under the current regulatory framework. Improving NWFP implementation through legislative rather than administrative action therefore has risks (e.g., lack of scope for detailed planning and implementation) as well as benefits (e.g., consistent direction despite changes in administration).

NEW CHALLENGES TO CONSERVATION OF FOREST ECOSYSTEMS

Broad-scale reviews that apply current research findings to evaluate the NWFP are necessary to respond to threats such as climate change that were not evaluated in the original plan (Millar et al. 2007). The NWFP reserve system retains its efficacy under changing climate better than expected given that this factor was not incorporated into the initial design (Carroll et al. in press). Nevertheless, explicitly incorporating analysis of climate change impacts into planning, for example through prioritized protection of climate refugia, can improve the likelihood of retaining a large component of biological diversity in the face of climate change (Noss 2001, Carroll et al. in press). The negative impact of invasive species such as the barred owl on achievement of NWFP's goals has increased and requires new types of planning and analysis not considered in the original plan. The NWFP's broad taxonomic focus is a laudable advance over the previous focus on a small group of (primarily vertebrate) species of concern (Molina et al. 2006). New types of habitat and viability modeling, however, will be necessary to maintain protection of a range of taxa without the expensive survey mandates of the original Survey and Manage program (Raphael and Molina 2007).

Efforts to restore historical fire regimes and associated forest structure, while minimizing negative impacts to wildlife, requires attention to new conservation planning issues. Planners should identify where modification of coarse-scale fire behavior is ecologically necessary, where it is feasible and desirable through thinning or other management, and how this goal may compromise other broad-scale goals, such as metapopulation connectivity. Thus, research to support fire management (e.g., landscape succession and fire effects simulation) should be integrated with habitat and viability modeling for species of concern under a range of management alternatives (Prather et al. 2008).

Conservation planners and decision makers need to think creatively about how to maintain ecosystem function and simultaneously protect human communities so that fire can assume more of its natural role, as opposed to continuing to focus on prevention approaches in fire-suppressed forests. However, treatments using prescribed fire will be very limited in scope unless constraints (expense, liability, smoke restrictions) can be overcome. In order to reduce negative ecological impacts associated with uncharacteristic fires, managers should minimize treatments such as post-fire logging that compound disturbance effects and may lead to ecological surprises (Paine et al. 1998, Lindenmayer et al. 2004, Noss et al. 2006).

The goal of this review is not to endorse or oppose specific policy proposals but to broaden the policy debate to encompass fundamental aspects of conservation science and planning. We do not contend that the current NWFP, if seen as a static plan, is sufficient to meet emerging conservation challenges. The NWFP was conceived a dynamic strategy that would be updated based on monitoring results and advances in ecosystem science. This aspect of the plan was in part abandoned during a federal administration that was generally hostile to the goals of the original plan. Monitoring efforts in the first decade of the NWFP have resulted in extensive new data and scientific reviews (e.g., Moeur et al. 2005, Anthony et al. 2006). These products can provide support for a more comprehensive review in which the multi-scale strategy implicit in the NWFP can be made more explicit and coherent in the light of current best practice in the field of conservation planning (Pressey et al. 2007).

Current proposals that primarily address fine-scale conservation issues, such as expanded protection of older forest stands and thinning of young trees and forests, would be more effective in achieving conservation goals if integrated within such a comprehensive and rigorous evaluation of the Northwest Forest Plan that addresses emerging threats to biodiversity such as climate change and invasive species. The current debate over proposed legislation can in this way provide an opportunity to address emerging challenges to conservation of forest ecosystems of the Pacific Northwest.

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