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Options for biodiversity conservation in managed forest landscapes of multiple ownerships in Oregon and Washington, USA

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Abstract We examine existing and developing approaches to balance biodiversity conservation and timber production with the changing conservation roles of federal and nonfederal forest land ownerships in the US Pacific Northwest. At landscape scales, implementation of the reserve-matrix approach of the federal Northwest Forest Plan in 1994 was followed by proposals of alternative designs to better integrate disturbance regimes or to conserve biodiversity in landscapes of predominantly young forests through active management without reserves. At stand scales, landowners can improve habitat heterogeneity through a host of conventional and alternative silvicultural techniques. There are no state rules that explicitly require biodiversity conservation on nonfederal lands in the region. However, state forest practices rules require retention of structural legacies to enhance habitat complexity and establishment of riparian management areas to conserve aquatic ecosystems. Habitat Conservation Plans (HCPs) under the US Endangered Species Act provide regulatory incentives for nonfederal landowners to protect threatened and endangered species. A state-wide programmatic HCP has recently emerged as a multi-species conservation approach on nonfederal lands. Among voluntary incentives, the Forest Stewardship Council certification comprehensively addresses fundamental elements of biodiversity conservation; however, its tough conservation requirements may limit its coverage to relatively small land areas. Future changes in landscape management strategies on federal lands may occur without coordination with nonfederal landowners because of the differences in regulatory and voluntary incentives between ownerships. This raises concerns when potentially reduced protections on federal lands are proposed, and the capacity of the remaining landscape to compensate has been degraded.

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Abbreviations

CA	California
DBH	Diameter at Breast Height
ESA	US Endangered Species Act
FSC	Forest Stewardship Council
HCP	Habitat Conservation Plan
NWFP	Northwest Forest Plan
OR	Oregon
SFI	Sustainable Forestry Initiative
US	United States
WA	Washington

Introduction

Biodiversity conservation is a conundrum for a forested landscape, such as the temperate coniferous forests of western Oregon (OR) and Washington (WA), US, because lands are owned and managed by a mixture of federal and nonfederal ownerships that differ in goals and objectives, laws and regulations, and management practices and land use patterns. The situation becomes more complex when conservation measures of one landowner are implemented contingent upon land management decisions occurring on adjacent lands. As measures become further nested within plans and policies across adjacent landowners, the situation can become untenable if these subsequently become altered over time. We examine how biodiversity conservation is addressed in the multiple ownerships of the US Pacific Northwest, at landscape and stand scales for federal and nonfederal ownerships, and synthesize regulatory and voluntary incentives to conserve species and biodiversity for nonfederal ownerships.

Central to understanding current approaches to conserve forest biodiversity in this region is a review of relevant events over the past decade. Public concerns over conservation of rare native species associated with old-growth forests brought forest management of economically valuable conifers, largely comprised of Douglas-fir (*Pseudotsuga menziesii*), to a standstill across 9.8 million ha of federal land in the late 1980s (USDA and USDI 1993). The decision to list the northern spotted owl (*Strix occidentalis*), marbled murrelet (*Brachyramphus marmoratus*), and anadromous salmonid fishes (*Oncorhynchus* species) under the US Endangered Species Act of 1973 (ESA) in the early 1990s raised further concerns for listing 1,098 other species that were potentially associated with late-successional or old-growth forest conditions in the region (Thomas et al. 1993). Restrictions on forest management activities also were imposed on nonfederal lands where ESA-listed species and their habitats were found (Epstein 1997). As a solution to the region's forest management crisis, the Northwest Forest Plan was developed in 1993 (USDA and USDI 1993, 1994) to balance social, economic and ecological values of federal forests (Fig. 1) and to ease burden of species conservation on nonfederal lands (Thomas et al. 2006).

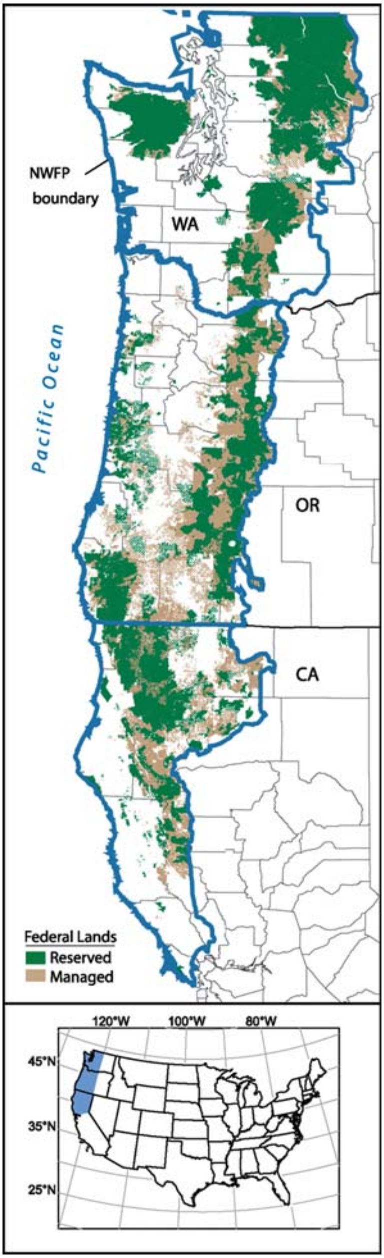

Fig. 1 Forest landscape area of the US Pacific Northwest with the range of the northern spotted owl delineated as the federal Northwest Forest Plan (NWFP) boundary. Federal forest lands in reserved and managed (i.e., planted: matrix, adaptive management area) land use allocations extend from northwestern Washington (WA), through Oregon (OR) into northwestern California (CA)

Under the Northwest Forest Plan (NWFP), a network of large reserves was established on federal lands as a coarse filter approach to conserve habitats of the northern spotted owl, marbled murrelet, and other species that were associated with late-successional and old-growth ecosystems (Fig. 1, Thomas et al. 2006). Aquatic conservation strategies were developed to restore and maintain ecological processes of aquatic and riparian habitat by establishing riparian reserves and identifying key watersheds as targets of restoration (Reeves et al. 2006). Stream networks are particularly dense in the forested landscape of western OR and WA, such that riparian reserves may offer protection not only for aquatic- and riparian-dependent species but a host of terrestrial species as well (Olson et al. 2007b; Rundio and Olson 2007; Rykken et al. 2007). These ribbons of protected federal forest may extend to ~150 m perpendicular to each side of streams, dependening on the presence of fish, stream size and hydrology (Olson et al. 2007b); hence, riparian reserves may be the key foundation element upon which biodiversity conservation rests (Figs. 2 and 3). Meanwhile, forest management for timber production on federal lands became restricted to the lands classified as matrix (16% of the federal lands; 1,609,000 ha) and Adaptive Management Areas (6% of the federal lands; 616,000 ha; Fig. 1 [USDA and USDI 1994]). Instead of simply applying conventional forest management techniques for timber production, these lands have been actively managed to enhance biodiversity by retaining components of late-successional and old-growth ecosystems, including large green trees, snags, and down wood (USDA and USDI 1994).

To further address species' concerns relative to forest management activities on matrix and Adaptive Management Areas, fine filter approaches also were applied, such as the deployment of 40-ha conservation reserves around existing spotted owl nests (Thomas et al. 2006). The survey-and-manage program was developed as an additional fine filter for ~400 rare or little-known species thought to be associated with late-successional and old-growth forests that were not well protected by reserves (Molina et al. 2006b). Under the survey-and-manage program, surveys for species presence were conducted before trees were harvested from stands. Based on the survey results, harvest plans were potentially modified or protection buffers around known species sites were established. The survey-and-manage program also collected new information on rare or little-known species (Olson

Fig. 2 A study site of the US Bureau of Land Management's density management and riparian buffer study in western Oregon (Cissel et al. 2006) showing a mix of silvicultural approaches offering benefits to native forest-dependent species, including: aggregated retention harvest or leave islands of three circular sizes (0.1, 0.2, 0.4 ha), riparian reserves of differing widths (6–70 m on each side of streams), and thinned forest where the pre-harvest managed stand of ~600 trees per ha (tph) was reduced to a range of densities, ~100–300 tph. Species' responses to these treatments suggest this was a relatively benign disturbance (Wessell 2005; Olson and Rugger 2007; Rundio and Olson 2007)

Fig. 3 Patchwork of forest types created by diverse land ownerships and forest management practices in Oregon and Washington, US, result in a landscape mosaic, where a variety of conservation measures for biodiversity are embedded. Dense stream networks in this region result in riparian reserves occurring in most managed stands, as shown by the ribbon of green trees in the central harvested patch. This specific landscape is an area of ''checkerboard'' ownership near the H.J. Andrews Experimental Forest in the western Cascade Range, Oregon. Photograph by Al Levno, July 2005, courtesy of the USDA Forest Service, Pacific Northwest Research Station and the Oregon State University Forest Science Data Bank

et al. 2007a) and developed management strategies for species persistence on federal lands (Molina et al. 2006b; Thomas et al. 2006).

The NWFP was intended to relieve the burden of species management from nonfederal lands. This has been a successful enterprise, with interesting consequences. Nonfederal lands in the region of the plan comprise 13.2 million ha of multiple ownerships, including states, native American tribes, private industry, and small woodland owners (USDA and USDI 1993). Nonfederal forests in the region are predominantly plantations and often are managed at shorter rotations, such as 40–60 years rotations (e.g., Curtis 1997; Curtis et al. 1998), in comparison to federal matrix lands (80 years rotations, USDA and USDI 1994). The trend of private landowners to favor short rotations and grow smaller and more uniform trees has been intensified since the implementation of the NWFP. This is mainly due to the closure of mills that could process large logs previously supplied by federal lands and to the decline in the export market of large logs to Asia in the mid-1990 (Barbour et al. 2006). Furthermore, 85% of the region's timber harvest has occurred on private lands between 2000 and 2005 (Bormann et al. 2006). Consequently, over the last 10 plus years, two distinct habitat patterns have developed across the US northwest forest landscape between ownerships: older forests dominate on federal lands and young forests dominate on nonfederal lands (Molina et al. 2006a).

Important biodiversity conservation issues arise from this bifurcation of forest land pattern (Fig. 3). Timber production priorities dominate management of most nonfederal forest lands in the region, while a more balanced approach for timber harvest and species conservation occurs on federal lands, as per the design of the NWFP. On nonfederal lands, there are generally fewer protective measures for biodiversity or habitats such as riparian areas relative to federal lands, except ESA-listed species receive some protection. Meanwhile, significantly, large proportions (>40%) of high quality nesting habitat for species such as the marbled murrelet and the northern spotted owl (Bormann et al. 2006) and the majority of best spawning and rearing habitats of coho salmon (*Oncorhynchus kisutch*) remain on nonfederal lands without the level of protection assured by the NWFP (Barbour et al. 2006). This adds to the conundrum for how to best provide for species by the differing yet interdependent approaches offered by federal and nonfederal lands across a mosaic of landowners.

Additionally, it needs to be pointed out that the NWFP is not a static entity. While adaptive management is a foundation element of the NWFP, its basic acceptance within the region has been tenuous, at best. There have been continuous debates and lawsuits to eliminate or modify the NWFP over the first 10 years of its implementation (Thomas et al. 2006). In particular, the survey-and-manage program has fallen under scrutiny. In 2004, this program was terminated in response to a settlement agreement for a lawsuit brought by the timber industry (Molina et al. 2006b). However, a court ruling reinstated the survey-and-manage program in 2006, in response to a counter lawsuit brought by environmental groups, citing inconsistencies and deficiencies in the analyses for termination (Molina et al. 2006b). Another current discussion has been whether to adopt an alternative forest management plan on Oregon Bureau of Land Management (BLM) lands ($\sim$1 million ha) which could potentially eliminate large reserves, survey-and-manage, and special status species considerations. This consideration arose in response to a 2003 settlement agreement to another lawsuit, contending that Oregon BLM lands were to be available for sustainable timber production under the OR and CA Revested Railroad Lands Act of 1937 (O&C Act of 1937, Public Land Foundation 2005). Elimination of large reserves and rare species provisions would increase the area of actively managed matrix lands. Hence the role and capacity of these federal lands for biodiversity conservation would be significantly altered. Changes in the NWFP to lower current conservation standards might potentially have ramifications of compensation elsewhere; as biodiversity conservation measures are reduced in one area, adjacent landowners or other stakeholders may be compelled to heighten their measures (Molina et. al 2006a; Stritthold et al. 2006).

While the NWFP's implementation and its consequences over the last 10 years provide a necessary back-drop for understanding our current situation in the US Pacific Northwest, the science and policies of biodiversity conservation are not wholly represented by this narrow focus. The following sections present and evaluate additional approaches that have been conceived or are being implemented in the region. First, we present recently developed or already existing landscape- and stand-scale approaches for forest management plans, with an example of one design that integrates elements from both scales. Second, we review a number of conservation policies and incentives that are particularly relevant to nonfederal landowners.

Forest management approaches at landscape and stand scales

Management approaches at landscape scales

The NWFP has been the most comprehensive approach for conservation of biodiversity at the regional landscape scale in the US, characterized by its reserve-matrix approach to balance conservation of biodiversity and commodity production (Spies and Turner 1999). An alternative landscape management design was proposed to better integrate natural disturbance regimes into this reserve-matrix design (Cissel et al. 1998, 1999). In their alternative, Cissel et al. (1998, 1999) modified the reserve-matrix approach by assigning matrix lands to three categories of historical fire regimes, based on fire frequency and intensity. These matrix lands were then managed according to patterns of the three fire regimes, where rotation lengths matched fire frequencies and levels of harvest (number of retained trees) matched fire intensities. The alternative design was predicted to yield less timber volume but produce more late-successional habitats with large patch sizes, higher canopy heterogeneity, and greater landscape connectivity. Thus, the landscape managed by this alternative approach could potentially contribute more to conservation of biodiversity than the original matrix-reserve approach (Cissel et al. 1998, 1999).

In dry fire-prone landscapes of the US northwest, where fire suppression has altered forest structure, large areas of forested reserves may be lost to fires over time, and a reserve-matrix approach to conservation may not be effective (Spies et al. 2006). Instead, active management of the entire landscape could restore forest stand structure to a natural state, while commodity production could support the cost of stand restoration (Spies et al. 2006). Management objectives for biodiversity conservation in fire-prone landscapes could be to restore open late-successional forests that are resistant to stand-replacement fires and to create habitat islands of dense layered forests within the fire resistant forests for rare species associated with dense forests, such as the northern spotted owl (Spies et al. 2006). For example, a combination of thinning from below and fuel treatments based on vegetation patterns and historic fire regimes would be one way to achieve desired forest stand conditions in a fire-prone landscape (Spies et al. 2006).

Conservation approaches without reserves also are inevitable in landscapes of predominantly young forests heavily focused on timber production, such as most nonfederal forest lands in the US northwest region. In such landscapes, one approach for biodiversity conservation would be to use active management to provide a landscape with full representation of forest stands in different structural stages of development. An example of such a landscape management plan, referred to as ''structure-based management,'' was developed in 2000 by the OR Department of Forestry for a landscape of predominantly young even-aged forests primarily intended for commodity production (Bordelon et al. 2000; ODF 2001). The core strategy of their structure-based management was to actively manage and maintain shifting mosaics of five structural stages of forest stands across the landscape in pre-determined proportions (Bordelon et al. 2000). Various densities of thinning were applied to create stand conditions that met target allocations and stand configurations (Bordelon et al. 2000).

Management approaches at stand scales

To conserve biodiversity at forest stand scales, recent innovative silvicultural approaches incorporate processes of natural stand development and patterns of natural disturbance that are responsible for habitat heterogeneity in natural forest stands (Hunter 1993; Franklin et al. 2002). Variable retention harvest has been proposed as a means to quickly restore function, structure, and composition of late-successional forests at stand scales by retaining key structural legacies of original stands to which various biota have strong associations, including large live trees, snags, down wood, undisturbed layers of forest floor, and understory plant communities (Franklin et al. 1997; Palik et al. 2003). Dispersed retention of dominant or co-dominant trees may provide well-distributed sources of soil energy, future snags and down wood, habitat for late-successional species as well as mitigate microclimate or hydrological processes evenly throughout a stand (Hansen et al. 1995; Franklin et al. 1997). Aggregated retention, also called patch reserves or leave islands, may be used to provide lifeboats for low-mobility species from removal of their entire habitat during stand harvest operations. Retaining leave islands of old trees, snags, down wood, or deciduous trees in conifer stands would provide habitat for some low-mobility species, such as lichens, vascular plants, arthropods, mollusks, and amphibians (Neitlich and McCune 1997; Duncan 1999; Wessell 2005).

Another approach to promote heterogeneity in managed forest stands is to create irregular distributions and densities of trees in a stand through either planting at irregular spacing or thinning at variable densities (McComb et al. 1993, Carey and Curtis 1996, Hayes et al. 1997). Thinning with varying target densities among stands could potentially be used to promote horizontal heterogeneity among stands across the landscape (Hayes et al. 1997). To enhance horizontal habitat heterogeneity within stands, sections within a forest stand would be thinned to two or more densities using a series of variable density thinning operations (Carey and Curtis 1996). Overtime, differences in tree growth among these stand sections induced by variable density thinning would increase overall vertical heterogeneity of the thinned stand (Carey and Curtis 1996). Thinning heavily to low tree densities could be used to accelerate the creation of large diameter trees and potentially be used to recruit large snags and down wood through an artificial means (Carey and Curtis 1996; Hayes et al. 1997). Depending on thinning intensities and locations of stands in a landscape, windthrow may also create snags, down wood and additional patchiness in thinned stands (Carey and Curtis 1996). Meanwhile, shade-tolerant conifers, such as western hemlock and western redcedar (*Thuja plicata*), and hardwood, such as bigleaf maple (*Acer Macrophyllum*), can be planted under canopy gaps created by heavy thinning to further enhance vertical layering of thinned stands (Carey and Curtis 1996; Cissel et al. 2006). With a series of carefully planned thinning operations, rotation age of stands between 40 and 80 years could be extended to 70–240 years (Carey and Curtis 1996; Curtis 1997; Franklin et al. 1997) to provide for species associated with late-successional forests without diminishing potential of stands for timber volume production. Alternatively, a combination of thinning operations and artificial planting or natural regeneration of seedlings would be used to convert even-aged stands to structurally diverse uneven-aged stands to enhance biodiversity (McComb et al. 1993; Cissel et al. 2006).

The Applegate Watershed Design

Management designs that are being developed for the federal lands of the Applegate Watershed integrate many of the landscape- and stand-scale themes above. This watershed occurs in a fire-prone landscape primarily in southern OR (Fig. 4), and is within the larger Klamath-Siskiyou ecoregion that has been identified for its unique diversity of species and habitats (DellaSala et al. 1999). The Applegate Watershed includes nonfederal lands that are predominantly managed as commercial plantation forests, and federal lands administered by both the US Forest Service and BLM. Federally managed forests in this area are designated as an ‘‘Adaptive Management Area,’’ a land use allocation where programmed timber harvest is allowed (federally managed lands: Fig. 4a). Much of this watershed has been logged and replanted, and current activities include planning for regeneration harvests, fuels treatments (i.e., thinning) near human communities in areas designated as Wildland-Urban Interface (Fig. 4b), and management of rare species and special habitats.

Addressing multiple species and habitat concerns has resulted in a landscape mosaic of federal and nonfederal planted forest lands interspersed with federal reserves to preserve biodiversity and ecological functions of old forests (Fig. 4a). The larger blocks of federal reserved lands in the south and southeast portion of the watershed were considered by Strittholt and DellaSala (2001) to contribute significantly to the conservation of the region's biodiversity by preserving a multitude of unique habitats and species. North of these large reserves, throughout the major portion of the watershed in the federal Adaptive Management Area is a network of linear riparian reserves along streams to protect fish and

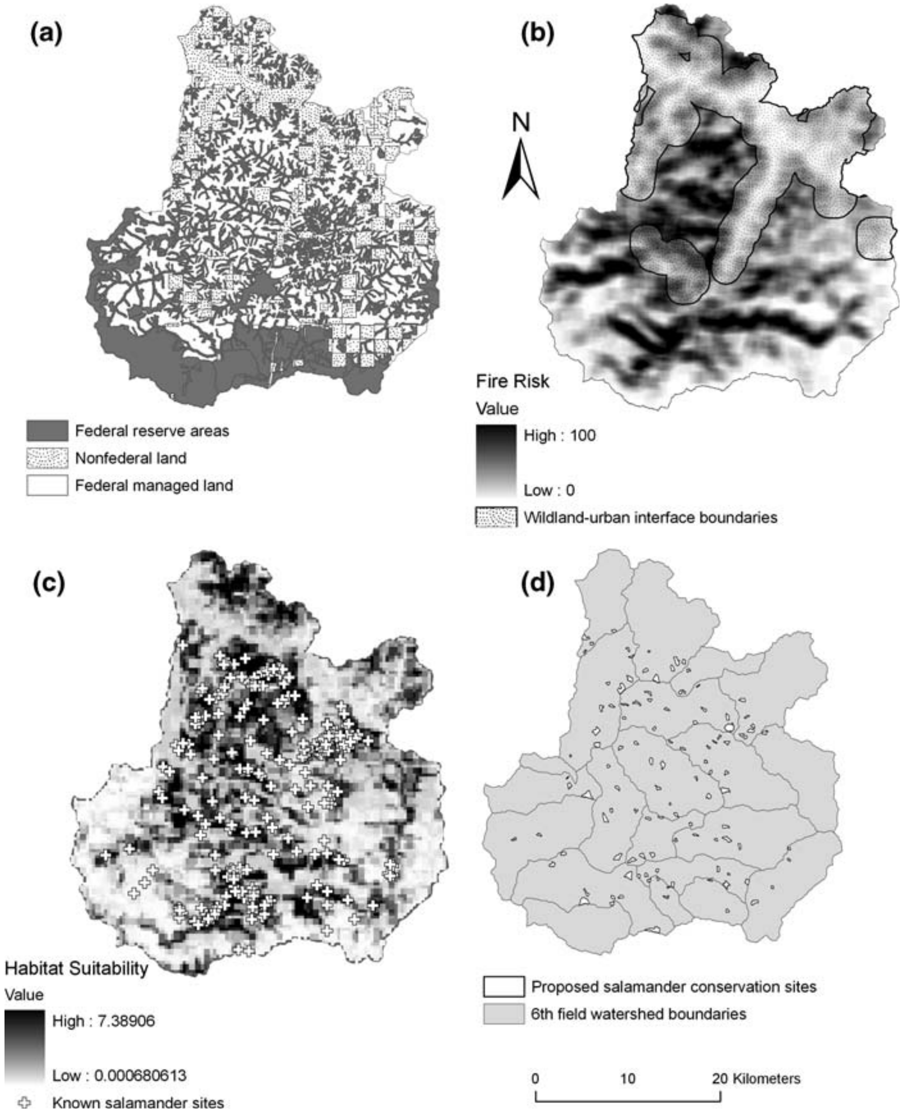

Fig. 4 Integrated approaches of joint biodiversity and planted forest management occurs in the Applegate Watershed of southern Oregon, US, depicting: a) federal and nonfederal land ownerships and federal land-use allocations, managed or reserved lands, including large block reserves to the south, linear riparian reserves and botanical and owl set-aside reserves north of these blocks; b) fire risk and Wildland-Urban Interface delineating communities at risk of fire, reflecting areas designated for fuels treatments such as forest thinning projects; c) habitat suitability and all known sites for the endemic Siskiyou Mountains salamander (*Plethodon stormi*) a species of concern in the area; and d) Siskiyou Mountains salamander sites selected as high priority for species management, to maintain well-distributed populations in the watershed

aquatic habitats. Riparian reserves are buffers at least as wide as 300 feet (91 m) or as two site-potential tree heights on each side if the stream has fish and at least as wide as 150 feet (46 m) or as one site-potential tree height on each side if the stream does not have fish (USDA and USDI 1994). After closer assessment during planning of forest management projects, these widths can be adjusted contingent upon site conditions. Forest management within the riparian reserve boundaries is possible for purposes of restoration. For example, if the previous harvest and planting conducted prior to implementation of riparian reserves has left the area in a high density young stand condition, then thinning might be used to accelerate development of large streamside trees. It should be noted that riparian buffers occur on the nonfederal lands in this landscape, but we have not mapped them in Fig. 4a, and their widths are smaller. In addition to riparian reserves, small areas of federal lands (<~40 ha) have been set aside to preserve unique botanical areas and old-growth forest-associated northern spotted owls (these small set-aside reserves are among the federal reserve areas in Fig. 4a).

A recent additional assessment of endemic salamanders associated with rocky soils in this landscape has resulted in another consideration for biodiversity conservation in the region. This region is part of a larger biogeographic zone considered to have the highest species richness of salamanders in the US Pacific Northwest (Bury and Bury 2005). The Siskiyou Mountains salamander (*Plethodon stormi*) is a rare species in the Applegate Watershed; its conservation has been of prime concern for federal land managers (Clayton et al. 2005). Habitat associations of this species have been studied (N. Suzuki, unpublished data, e.g., Welsh et al. 2007) and suitable habitat has been mapped along with all known sites (Fig. 4c). To advance combined timber and biodiversity concerns for the watershed, a subset of known sites has been proposed as ''high priority'' for species management, areas where conservation of the salamander would be of utmost importance. Selection of salamander conservation sites are intended to anchor the species within this portion of its range, to preserve the current species' distribution. It is assumed salamander occupancy is retained at some level outside these anchors for connectivity, which is supported by the prevalence of their rocky soil habitat throughout the area and knowledge that these animals can occur in suboptimal conditions.

A primary objective to the development of salamander conservation sites was to produce a pattern of well-distributed sites throughout the larger Applegate Watershed. To accomplish this, sites were evaluated within the context of an intermediate spatial scale, sixth field watersheds (i.e., regional sub-watershed hydrologic unit designations with catchment areas ranging from ~4,000 to 16,000 ha in western OR; Fig. 4d), chosen due to its existing use in forest management and aquatic resource planning in the area. Within sixth field watersheds, salamander sites were selected by a host of criteria. These included occurrence of sites within or adjacent to existing reserves (Fig. 4a), sites representing a range of fire risk areas and fire management areas (Fig. 4b), sites in or adjacent to areas thought to have optimum salamander habitat conditions (Fig. 4c), and locations both central and peripheral to the boundaries of the sixth field watersheds. Additional species were considered in this selection process, to include locations of other biota within priority salamander sites.

This Applegate Watershed design has several key elements described by Spies et al. (2006) for the dry provinces of the NWFP. The spatial extent of the large block of federal reserves at the southern boundary is reduced (it is less than the ~80% prescribed for the entire NWFP), yet may provide significant conservation benefits (Stritthold and DellaSala 2001). Fire risk has been modeled for the landscape (Fig. 4b) and can be used to integrate timber harvest priorities to reduce fuels, using approaches such shaded-fuel breaks and ladder fuel management. Furthermore, human communities at risk of fire are identified with the Wildland-Urban Interface, and are areas where higher priority fuels reduction treatments can be planned. Habitat islands for botanical, owl and salamander species have been identified throughout the area, and these may be managed. Specific management considerations include: retention of legacy forest attributes (e.g., large trees and dead wood); restoration (e.g., thinning of young stands) of late-successional and old-growth habitat conditions (i.e., for owl, salamander, and riparian areas); prescribed fire in some of the botanical zones; and retention of some canopy closure to maintain cool, moist surface microclimates and to avoid ground disturbing activities in priority salamander sites. Commodity production can be a priority in the intervening federal matrix, with commercial plantations having reduced biodiversity conservation objectives occurring on the nonfederal blocks (Fig. 4a). The outcome of these multiple priorities and concerns is a managed plantation landscape (nonfederal and federal managed lands) with small species-conservation areas anchoring habitat and species concerns throughout the landscape. While this design is conceptual, most elements are being implemented at this time. Monitoring and adaptive management is needed to advance the efficacy of such integrated matrix management to meet the diverse conservation and timber objectives of this ecosystem.

Regulatory approaches and incentives for biodiversity conservation

Habitat Conservation Plans for nonfederal lands under ESA

While a wide variety of approaches are currently available to potentially maintain or enhance biodiversity on nonfederal lands through innovative management practices (e.g., Carey and Curtis 1996; Franklin et al. 2002; Hartley 2002), landowners often are reluctant to invest for biodiversity conservation without clear economic benefit (Loehle et al. 2002). Consequently, federal and state regulations have been developed to provide minimum standards for conservation of biodiversity on forest plantations.

Under the ESA, the development of a Habitat Conservation Plan (HCP) provides regulatory incentives for nonfederal landowners to protect populations and habitats of threatened and endangered species. An important benefit of an HCP to nonfederal landowners is that they can obtain an incidental take permit for federally protected species in exchange for developing an HCP on their land (Noss et al. 1997). An incidental take permit allows a landowner to unintentionally harm individuals or modify habitats of endangered species while landowners continue forest management activities (Harding et al. 2001). Hence, this provision protects landowners from prosecution while they are attempting to balance management for species, habitats, and commodities on their lands.

Some landowners have successfully incorporated an HCP into their forest management practices at landscape scales (Loehle et al. 2002). However, without landowners' conscientious efforts to protect populations and habitats of endangered species, the HCP as a regulatory incentive presents several limitations. To enhance its effectiveness in endangered species conservation on nonfederal lands, several issues need to be remedied. First, nonfederal landowners are not required to address the recovery of endangered species in an HCP (Shilling 1997). HCPs are intended to maintain populations and habitats above the baseline conditions, which are often determined by the initial population and habitat conditions upon which the agreement was signed (Noss et al. 1997). As a result, an HCP does not particularly encourage landowners to improve habitat quality, increase populations, or to create new habitats for listed species on their land.

Second, the majority of HCPs lack monitoring programs to track population trends, and many existing monitoring programs are insufficient to evaluate the HCP's success (Kareiva et al. 1999). Although the development of an HCP is based upon the best available science, the process does not encourage landowners to incorporate adaptive management to address scientific uncertainties and modify management based on newly discovered information because a ''no surprise'' policy guarantees landowners that they would not be required to incur financial burden beyond the signed agreement (Wilhere 2002).

Third, concern is raised when an HCP is applied to the conservation of multiple species. Multi-species HCPs frequently fail to address adequate conservation measures for each species when they include species with no confirmed occurrence and distribution information in planning areas as well as little-known species (Rahn et al. 2006). Multi-species recovery plans appear to be less effective than single species recovery plans partly due to the lack of special attention to the ecological requirements of each species (Boersma et al. 2001; Taylor et al. 2005). Developing and implementing an HCP that covers a large number of species without clearly identifying species distributions, conditions of populations and habitats of species on a nonfederal property is essentially developing the plan in the absence of credible scientific information to help species recovery; such an approach might seriously jeopardize the persistence of endangered species (Noss et al. 1997; Kareiva et al. 1999; Reichhardt 1999; Rahn et al. 2006; Harding et al. 2001).

Programmatic HCP

Instead of each landowner developing an individual HCP, a state or local government can organize a group of stakeholders and develop a programmatic Habitat Conservation Plan to mitigate a group of similar management activities (e.g., forest management practices) proposed across a broad landscape as a whole (USDI and USDC 1996). Participants involved in the process are issued ''Certificates of Inclusion,'' which permit incidental take of species (USDI and USDC 1996).

For example, the Forest Practices Habitat Conservation Plan for the conservation of aquatic ecosystems by the State of WA was designed to cover five federally listed threatened or endangered salmonid species, 48 other fish and seven amphibian species across 3.7 million ha of nonfederal forestland in the state over the next 50 years (WSDNR 2005a). The plan was approved by the federal agencies in 2006. The foundation of the Forest Practices Habitat Conservation Plan is the state forest practices act and rules, updated to meet the recommendations of a multiple-stakeholder review, known as Forest and Fish report of 1999 (Call 2005). By meeting the requirements of the state forest practices act and rules, nonfederal landowners in WA are guaranteed an incidental take permit for species covered in the plan for 50 years, and can engage in forest management activities on their lands without any further legal restrictions under the ESA (WSDNR 2005a). An adaptive management process is used to determine whether changes or adjustments in forest practices rules and guidance are necessary to achieve program goals, performance target, or resource objectives (WSDNR 2005a). The Cooperative Monitoring Evaluation and Research committee was formed by resource and science experts who represent landowners, forest industry, environmental interests, state and federal agencies, and tribal governments (WSDNR 2005a). The committee develops and oversees research and monitoring programs as well as provides science-based technical advice during the adaptive management process. This framework for monitoring and adaptive management through stakeholder participation in the Forest Practices Habitat Conservation Plan could potentially be used as a model to remedy the general lack of coordinated monitoring and adaptive management in the HCP process.

Safe Harbor and Candidate Conservation Agreements under ESA

To supplement the passive nature of an HCP in protecting threatened and endangered species, the US Fish and Wildlife Service and the National Marine Fisheries Service developed two voluntary conservation programs that are intended to promote conservation of federally listed threatened and endangered species and rare species with a high likelihood of becoming listed under the ESA in the foreseeable future. Safe Harbor Agreements offer private landowners incentives to create or enhance potential future habitats (Safe Harbor) for species in exchange for no further future legal restrictions, allowing incidental take of endangered species and their habitat (US Fish and Wildlife Service 2001). Similarly, landowners can develop species conservation plans for rare species that are at risk of becoming listed under the ESA and make agreements, known as Candidate Conservation Agreements, with the US Fish and Wildlife Service or the National Marine Fisheries Service (US Fish and Wildlife Service 2002). In exchange, the landowners are assured of no further legal obligations in the event that the species become listed under the ESA; this process is called Candidate Conservation Agreements with Assurances. Once the term of Safe Harbor Agreements or Candidate Conservation Agreements ends, landowners are allowed to resume land use activities that may reduce the condition of habitat or populations as long as they maintain the baseline conditions agreed upon in the initial plan. Currently, only one nonfederal landowner of a plantation forest (144 acres = 58 ha) has entered a Safe Harbor Agreement with the US Fish and Wildlife Service in the Pacific Northwest Region (US Fish and Wildlife Service 2006). No nonfederal landowner of plantation forests has entered a Candidate Conservation Agreement in western OR and WA at this time. Consequently, the impacts of these programs are still uncertain relative to biodiversity conservation in the region's plantation forests.

State forest practices rules

Nonfederal landowners must comply with state forest practices rules in OR (ODF 2006) and WA (WFPB 2002). Hence, state forest practices rules have a great impact, in terms of area of nonfederal land, on how landowners manage their forests. To conserve biodiversity or ecological function of nonfederal forest lands, state forest practices rules in OR and WA primarily focus on retention of structural habitat elements, namely green trees, snags, and down wood, at stand scales and conservation of riparian and aquatic habitat for fish and other public resources. Improvement of structural habitat and protection of riparian areas are considered as key conservation strategies for many forest wildlife species in the region (e.g., Olson et al. 2001, 2007b). For example, in OR, nonfederal landowners are required to retain two snags or two green trees at least 30 feet (9.1 m) in height and 11 inches (28 cm) or greater in Diameter at Breast Height (DBH) and two pieces of live or dead down wood for each acre (0.4 ha) of land to enhance habitat complexity at stand scales (ORS527.676; ODF 2006). A similar structural habitat rule applies to landowners in WA (WAC222-30-020 [11]; WFPB 2002). The establishment of a Riparian Management Area, which includes retention of no-harvest riparian buffers and provides guidelines for forest management prescriptions in managed riparian buffers, is required in both states (OAR 629-635, ODF 2006; WAC 222-30-021, WFPB 2002; Olson et al. 2007b).

The riparian strategy in western WA requires landowners to establish a Riparian Management Zone comprised of: 1) a 50-foot (15 m) wide no-harvest buffer next to a stream; 2) a 10- to 100-foot (3 to 30 m) wide partial-harvest buffer next to the no-harvest buffer; and 3) a 22- to 67-foot (6.7 to 20 m) wide harvest buffer next to the partial-harvest buffer, on each side of a fish-bearing stream (WAC 222-30-021, WFPB 2002). Buffer widths for the partial-harvest buffer and harvest-buffer vary depending on stream size and forest site productivity. For non-fish-bearing streams, a no-harvest riparian buffer of either 50 feet (15 m) or 56 feet (17 m), depending on site sensitivities, is required only to protect selected portions (at least 50% of the stream length) of a stream on each side. Nonfederal riparian strategies in both OR and WA are less protective relative to similar strategies for federal lands, which include a no-harvest riparian buffer of at least 300 feet (91 m) on each side of fish-bearing streams and of at least 150 feet (46 m) on each side of permanently flowing non-fish-bearing streams (USDA and USDI 1994).

Small forest landowners in WA have an option to participate in a Forestry Riparian Easement Program (WAC 222-21, WFPB 2002). In this program, landowners receive a minimum of 50% of fair market stumpage value for those trees that are left unharvested, as mandated by the state rule to preserve riparian function, in exchange for leasing the volume of unharvested timber to the sate as a riparian buffer for 50 years (WSDNR 2005b). This program recognizes the contribution of small forest landowners to the conservation of riparian habitat.

As a state regulation addressing conservation of biological resources at a broad spatial scale, the WA forest practices rules require statewide analysis of watersheds, known as Washington Watershed Analysis, by dividing the state into watershed administrative units, each of which is approximately 4,047 to 20,234 ha in size to protect and restore public resources, including fish, water, and capital improvements of the state or its political subdivisions as well as cultural resources (WAC 222-22, WFPB 2002). Washington Watershed Analysis is a collaborative effort among resource scientists, landowners, agencies, tribes, the public, and other stakeholders. An interdisciplinary team of experts assesses resource conditions and identifies sensitive areas within each watershed. Forest management plans are developed for each watershed, and site-specific prescriptions are developed in cooperation with field managers, agency personnel, and landowners (WFPB 1997).

There also are likely unintended negative consequences of state forest practices rules to the conservation of biodiversity. For example, timber harvest prescriptions in riparian management zones in WA require retention of at least 20 trees/acre (~50 trees/ha) in timber-harvest buffer, preferably conifer with DBH > 12 inches (30 cm), and also encourage hardwood-to-conifer conversion through thinning from below in partial-harvest buffer (WAC 222-30-021, WFPB 2002). These prescriptions to maintain conifer dominance in riparian management zone are intended to maintain the recruitment of large conifer debris to enhance stream habitats (WSDNR 2005a). However, the operation to selectively remove hardwood would reduce habitat heterogeneity and possibly biodiversity because hardwood patches typically maintain a high species diversity of various groups of organisms (Harris 1984; Gomez and Anthony 1996, 1998; Neitlich and McCune 1997; Pabst and Spies 1998; Hagar 2007). Furthermore, under the reforestation stocking standard in OR (OAR 629-610-0020, ODF 2006), landowners are required to stock each forest stand with a fixed minimum number or basal area per acre of seedlings, saplings, or trees > 11 inches (28 cm) in DBH of acceptable species, well distributed throughout the stand. This minimum tree stocking requirement fundamentally limits landowners' options to enhance heterogeneity within stands during the reforestation process, and could potentially reduce spatial heterogeneity of forest stands across the landscape, although it was intended to promote a viable reforestation.

Forest certification

Guidelines in state forest practices rules are passive in nature because they are intended to lower impacts of management rather than to create particular types of structure to enhance habitat for species. For landowners who are willing to contribute more than the minimum requirement, options are available to pursue a wide variety of voluntary forest certification programs. Forest certification is a process in which forest management practices are evaluated by an independent certification organization based on a set of ecological, social, and economic standards (Society of American Foresters Study Group 1995). It provides a voluntary incentive for landowners who desire to be recognized for their management practices toward sustainable forestry. Although most forest certifications requires some conservation measures for biodiversity, their standards and guidelines are highly variable among certification organizations.

The American Tree Farm System is a voluntary certification program with the largest participation by small non-industrial landowners in the US. Its standards and guidelines encourage landowners to conserve biodiversity and maintain or enhance habitat for native fish, wildlife, and plant species (Standard 6, American Forest Foundation 2002). However, their performance measures and indicators for the Biodiversity Standard (Standard 6) do not provide a list of specific elements of habitat or biodiversity to be considered in the development of the landowner's conservation and management plan. The standards and guidelines provide great latitude for landowners to decide what constitutes biodiversity on their land. For example, landowners are required to manage forests to maintain or enhance habitat for fish, wildlife, and plant species that are ''desired by owner'' (Performance Measure 6.2 and Indicator 6.2.1), whereas opportunities to protect rare species and special habitat features are considered and addressed in the landowner's management plan only where such opportunities are practical (Indicator 6.1.1). The lack of strong language and specific goals and guidelines to conserve biodiversity leads to uncertainty that American Tree Farm System certification would provide landowners incentives to conserve biodiversity or manage habitat beyond what is already required by the State forestry practices rules. Because landowners can manage habitat for their own desired species, they may choose to manage for game species with some tangible recreational values (e.g., trout, deer, and elk), and may not encourage management and conservation of habitat for rare and endangered species, which often do not present tangible values. Other limitations with the American Tree Farm System may include lack of a requirement to monitor species. It also may be ineffective for implementing conservation practices at broad spatial scales because the certification is intended for small landowners.

An increasing number of industrial forests with large landholdings in OR and WA has been certified in recent years by the Sustainable Forestry Initiative (SFI), a third-party forest certification developed by the American Forest & Paper Association, an industry trade group based in the US (Fletcher et al. 2001). One of the SFI's land management objectives outlines the use of stand- and landscape-level measures to enhance wildlife habitat and to promote conservation of biodiversity, including forest flora and fauna, and aquatic fauna (Objective 4, SFI 2005). Under this biodiversity objective, landowners are required to facilitate programs to conserve biodiversity, including species, habitat, ecological or natural communities at both the stand and landscape level; protect threatened and endangered species; and locate and protect known sites of imperiled species and communities (Performance Measures 4.1-4.2, SFI 2005). However, SFI does not provide specific guidelines nor criteria for these conservation programs to be acceptable or successful. Furthermore, landowners are not required to address landscape-level conservation measures not only when credible scientific data are absent but also when landscape-level conservation measures are inconsistent with landowners management objectives and where practical (Objective 4, Indicator 5, SFI 2005). Consequently, SFI may potentially certify forests owned by landowners who have no intention of developing landscape-level conservation measures because of incompatibility of such measures with their land use or resource production objectives.

Under the SFI, the stand-level retention of habitat elements, such as snags, mast-producing trees, down wood, den trees, and nest trees, is based on regionally appropriate science (Objective 4, Indicator 4, SFI 2005). When compared with OR Forest Practices rules, requirements to satisfy the biodiversity objectives under SFI did not considerably exceed those already required under OR Forest Practices rules (Fletcher et al. 2001). Therefore, SFI certification may not have a significant positive impact on conservation of biodiversity in OR and WA beyond the impact from State Forest Practices Rules and HCPs under ESA.

Forest certification administered by the Forest Stewardship Council (FSC), a nonprofit-worldwide organization, is by far the most comprehensive certification program and provides more detailed criteria on conservation of biodiversity as well as other environmental and socio-economic concerns than SFI and OR practices rules (Fletcher et al. 2001). Under the FSC Principle 6, landowners are required to conserve biodiversity and its associated values, including water resources, soils, and unique and fragile ecosystems, and maintain the ecological functions and the integrity of the forest, such as structure and composition (Principle 6, FSC 2000). FSC differs from SFI in at least the following key points, outlined in their Pacific Coast regional forest stewardship standard (FSC 2005; SFI 2005).

First, the FSC Pacific Coast regional forest stewardship standard requires an environmental impact assessment at every relevant spatial scale from the stand or on-site facility where trees are harvested and processed to the entire landscape of the ownership. Biodiversity and ecosystem characteristics considered in the environmental impact assessment encompass structural, compositional, and functional elements. Landowners are asked to provide descriptions of ecological processes, common plant and animal species and their habitats, rare plant community types, rare species and their habitats, water resources, and soil resources (6.1.a, FSC 2005) and to compare a wide variety of measures of habitat complexity and spatial heterogeneity between current and historic variability of forest conditions, including composition and distribution of tree species, tree age-classes, structural habitat elements, habitat patches, forest seral stages, and other identifiable forest ecological types (AC6.1.3, FSC 2005).

Second, implementation of monitoring and adaptive management is considered as an integral element under the FSC certification. Monitoring of management activities and of environmental impacts is required by the FSC for large and/or intensively managed forests (Principle 8, FSC 2000, 2005); furthermore, an adaptive management process is used to revise management plans based on the monitoring results (Adaptive management, 8.4, FSC 2005). Elements of biodiversity to be periodically monitored included composition and observed changes in the flora and fauna (8.2, FSC 2005), specifically the changes in conditions of populations and habitats of threatened species relative to recovery goals, major habitat elements, and occurrence of rare species (8.2c, FSC 2005).

Third, FSC requires conservation of habitats for rare, threatened, or endangered species, and forests with rich biodiversity, such as old-growth forests in the US Pacific Northwest. This is implemented by designation of ‘‘High Conservation Value Forests’’ (Principle 9, FSC 2000, 2005), for which landowners are required to develop management plans to maintain or enhance ecological and biological values of High Conservation Value Forests. FSC does not require landowners to establish High Conservation Value Forests as no-harvest reserves and allows timber harvest in High Conservation Value forest harvest to the extent that such operation assure both quality and area of High Conservation Value forests for a long term (9.2, FSC 2005). To maintain and enhance areas and quality of these forests, annual monitoring is conducted to assess effectiveness of landowners' measures on conservation attributes (9.2, FSC 2005).

Fourth, under the principle of ''Plantation Forestry'' (Principle 10, FSC 2000, 2005), FSC addresses management standards at stand and landscape scales with specific guidelines to enhance spatial heterogeneity, stand complexity, and connectivity of forest habitats. At landscape scales, landowners are required to address the spatial arrangement among stands of different ages and rotation periods, wildlife corridors, and riparian zones that follow the pattern of forest stands found in the natural landscape characteristic of the region (10.2, FSC 2005). Also, they need to incorporate the spatial and functional relationship of their plantation to the surrounding area's natural forests, late-seral forests, and long-rotation forests into a management plan (10.1.b, FSC 2005). At forest stand scales, landowners are required to practice uneven-aged forest management using long rotation periods (>80 years) for a portion (30–50%) of their land to promote late-seral forest habitat; furthermore, they are required to enhance quality of early- and mid-seral wildlife habitat by maintaining structural and compositional diversity (10.5a, FSC 2005).

Among the state forest practices rules and three forest certification programs we assessed, FSC certification most comprehensively addressed fundamental elements of conservation of biodiversity and provided the most detailed criteria for each conservation element. A previous assessment similarly found that FSC addressed environmental and socio-economic issues better than SFI and OR forest practices rules (Fletcher et al. 2001). One of the strengths of FSC certification under the Pacific Coast regional forest stewardship standard is monitoring and adaptive management of large and/or intensively managed forests to advance biodiversity conservation. Furthermore, the FSC Pacific Coast regional forest stewardship standard provides clear guidelines that specifically address management for spatial heterogeneity and connectivity among forest stands across a landscape. However, it is still too early to tell whether these strict and ideal conservation standards of FSC will be successfully administered by landowners to yield significant positive contributions to the conservation of biodiversity. FSC's strict conservation standards may discourage landowners from choosing FSC certification.

For example, currently 13 nonfederal forests in 299,575 ha in OR and WA are certified by FSC (FSC 2006), whereas at least 16 forests with at least 3,254,997 ha are certified by the third-party certification option under SFI (SFI 2006).

Conclusions

Over the last couple of decades, a wide variety of innovative management approaches has been proposed to balance timber production and conservation of biodiversity in the US Pacific Northwest. Many of these approaches integrate ecological principles of natural disturbances into improvement of habitat heterogeneity at stand scales, landscape scales, or both. Among such approaches, reserve-matrix approach of the NWFP is the very first to comprehensively address forest management and conservation of biodiversity at multiple spatial scales.

A better integration of historical disturbance regimes into management of matrix lands appears to reduce the sharp contrasts in stand conditions between reserves and matrix by encouraging the development of larger late-successional patches and more variable tree canopy cover relative to conventional reserve-matrix approach; however, volume of timber production may be reduced. On the other hand, in disturbance-prone landscapes, options to actively manage entire landscapes may be necessary to reduce risk of catastrophic disturbance events, restore natural forest stand conditions, and protect and promote habitats of rare species, while producing timber throughout the process. On a landscape of predominantly young forest stands managed for timber production, one approach for conservation of biodiversity would be to use active management to provide full representation of forest stands in different structural stages of development across landscapes. Hence, the choice of landscape management approaches needs to consider the balance among conservation of biodiversity, restoration of ecosystems, timber production, and characteristics of disturbance in systems. At stand scales, landowners can promote heterogeneous habitat patterns and associated biota by planting tree seedlings at irregular spacing, thinning at various densities within or between stands, extending stand rotation age, artificially creating snags and down wood, and retaining structural legacies either through variable retention harvest in either aggregated or dispersed pattern.

There are no state laws or rules that explicitly require conservation of biodiversity on nonfederal lands in OR and WA. Current state forest rules may be lacking at least in the following points to ensure conservation of biodiversity on nonfederal lands. First, state forest practices rules generally do not address conservation or management of habitat at broad spatial scales (e.g., spatial configuration of various stand types), even though many industrial forests are large enough to consider landscape-level management guidelines. Second, some state forest practices rules, such as minimum tree stocking requirements (OAR 629-610-0020, ODF 2006) and riparian conservation strategy to selectively maintain conifer over hardwood trees (WAC 222-30-021, WFPB 2002), may have unintended negative consequences to reduce biodiversity by limiting landowners' options to enhance habitat heterogeneity. Some of the inherent limitations of the state forest practices rules may be the tendency to require landowners to meet a minimum standard for conservation and the inability to encourage landowners for continuous, incremental improvement of habitat for biodiversity on their land.

Under the ESA, the development of a HCP provides regulatory incentives for nonfederal landowners to protect populations and habitats of threatened and endangered species. To enhance effectiveness of an HCP as a recovery strategy of endangered species on nonfederal lands, the following measures could be considered: (1) develop economic incentives in addition to the incidental take permit for landowners who incrementally improve or enhance habitat and population conditions for endangered species, beyond baseline conditions; (2) establish quantitative baseline measurements on distribution, population level, and habitat conditions within the planning area for all species considered in the HCP, and develop quantitative goals for the recovery of population or habitat conditions for each species (Kareiva et al. 1999; Harding et al. 2001); (3) monitor population trends and habitat conditions, and integrate monitoring results into an adaptive management process (Wilhere 2002); (4) coordinate quantitative measurements of endangered species population trends and habitat conditions among landowners, agencies, and other stakeholders as part of monitoring and adaptive management processes (Noss et al. 1997; Kareiva et al. 1999); (5) develop multi-species HCPs based on a species-specific conservation strategy for each species and limit species covered under the HCP to only those with credible quantitative baseline information on species distribution, population levels, and habitat conditions within the planning area to help minimize adverse management impacts (Rahn et al. 2006).

Successful approvals of multi-species state-wide programmatic HCPs by federal agencies may encourage more states to develop similar programmatic multi-species HCPs and potentially replace individual HCPs. The potential future trend toward multi-species programmatic HCPs would shift the nature of the HCP process from a fine-filter conservation approach for a specific species at a specific site to a coarse-filter conservation approach for many species over a broad landscape. Multi-species programmatic HCPs at a state level may be able to remedy some of the limitations of individual HCPs, such as the lack of coordinated monitoring and adaptive management processes. On the other hand, there also are concerns over the implication of multiple-species state-wide programmatic HCPs for the conservation of biodiversity. First, effectiveness of adaptive management to adjust to a higher conservation standard would be limited if minimum or some low standards were used as an initial mitigation measure for potentially disturbing management activities (e.g., no-harvest riparian buffers cannot be widened overnight once a riparian area is harvested following the current forest practices rules). Second, previous multi-species conservation approaches have been showed to be ineffective (Boersma et al. 2001; Taylor et al. 2005). Third, negative consequences of management activities could potentially spread over the entire state. Fourth, nonfederal landowners are allowed to continue management activities without making any change for the duration of the HCP under the no surprise policy of the ESA. Hence, failure of multi-species programmatic HCPs at a state level could have significant negative consequences on conservation of biodiversity across the landscape over a long period of time.

Among the state forest practices rules and three forest certification programs we reviewed, FSC certification most comprehensively addressed fundamental elements of conservation of biodiversity and provided the most detailed criteria for each conservation element. However, positive contributions of FSC certification to conservation of biodiversity may be limited to relatively small land areas because of its tough conservation requirements for landowners' management activities. Consequently, current conservation standards on nonfederal lands would largely remain lower than those on federal lands. It is likely that any removal of conservation measures on federal lands due to a policy change would not be compensated by the current level of conservation efforts on nonfederal lands. Furthermore, future changes in strategies for biodiversity conservation on federal lands may occur without coordination with nonfederal lands because of the differences in regulatory and voluntary incentives between ownerships.

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