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policy

A Restoration Framework for Federal Forests in the Pacific Northwest

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We outline elements of a forest restoration strategy designed to produce ecological and economic benefits on federal forests in Oregon and Washington, along with some of their policy and management implications. Implementation of this restoration strategy has begun on 11 projects (at scales from hundreds to thousands of acres) on federal lands. On Moist Forest sites (MF), the strategy calls for reserving older forest stands, thinning plantations to accelerate development of structural complexity, and implementing variable retention harvests in younger forests to help provide diverse early seral ecosystems. On Dry Forest (DF) sites, the strategy calls for silvicultural treatments that retain and release older trees, reduce stand densities, shift composition toward fire- and drought-tolerant tree species, and incorporate spatial heterogeneity at multiple spatial scales. Immediate goals of this restoration framework include increased ecological integrity and resilience in DFs, increased diversity and complexity of successional stages in MFs, and provision of wood products to local communities. Over the long run, we believe this program can provide an acceptable pathway to sustained yield on federal forestlands in the Pacific Northwest.

Keywords: Dry Forest, forest restoration, Moist Forest, northern spotted owl, old-growth, retention harvest

In the last few years, we have reported to members of the US Congress and the US Department of the Interior Secretary of Interior on the potential of developing management strategies in the Pacific Northwest (PNW) that integrate old-growth protection with other ecological and economic benefits on federal lands.[1] As with much of the western United States, extensive forestlands in the PNW are controlled by the federal government (Figure 1), and their use and management has long fueled conflicts between different groups and agencies. Recent successes with the thinning of plantations in western Oregon and Washington and fuel reduction projects in the wildland-urban interface by the USDA Forest Service in eastern parts of those states have helped to build public trust (Thomas et al. 2007, Toman et al. 2011) and we seek to build on those successes.

Ecological restoration on public lands, as suggested here, represents more than an academic exercise—it has become a sociopolitical reality. In fact, comprehensive ecological restoration is becoming the foundation of federal land management across the nation (e.g., Bosworth 2006). In 2009, the USDA Secretary of Agriculture announced a restoration vision for the national forests (Vilsack 2009), ultimately reinforced in the recently adopted US Forest Service planning rule (USDA 2012). Furthermore, activities to sustain habitat and restore ecosystem health are emphasized in the new northern spotted owl (NSO; *Strix occidentalis caurina*) recovery plan, which describes the restoration of ecosystem structures and processes as being good for NSO (USDI Fish and Wildlife Service 2011). In early 2012, the Secretary of Interior proposed expansion of ecological forestry projects in western Oregon to provide sustainable timber and healthier habitat (US Bureau of Land Management [BLM] 2012). These new projects will cover more than 5,000 ac and explore compatibility between forest restoration and protection of NSO.

But can restoration needs of federal forests in the PNW be fulfilled while also meeting other societal needs? Ecological restoration is grounded in principles of ecosystem science, including ecosystem dynamics, disturbance ecology, and landscape ecology. However, restoration activities will have to provide economic returns if they are to be widely implemented, with such benefits typically coming from commercial timber harvest. Indeed, shrinking federal budgets will require that restoration activities be at least partially self-supporting, if large-scale restoration is going to occur. Furthermore, significant skepticism about the effectiveness of

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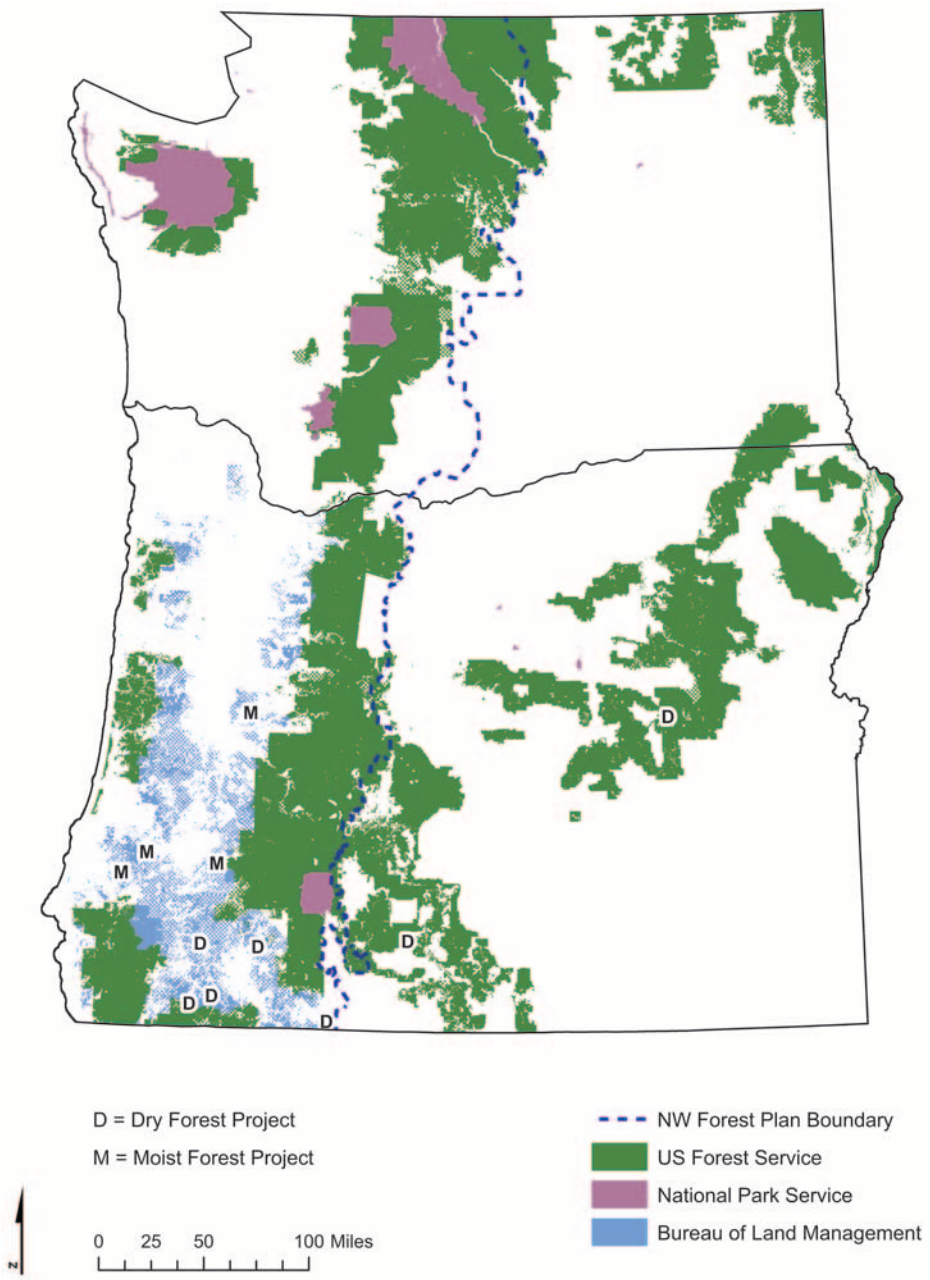

Figure 1. Distribution of federal forestlands in the PNW showing locations of projects demonstrating the restoration principles discussed in this article. (D. Johnson, Applegate Forestry, provided this figure.)

ecosystem restoration must be overcome, even though the general concept enjoys wide public support (Shindler and Mallon 2009).

A Strategic Restoration Framework

We begin with the following definition provided by the US Forest Service (USDA 2012, p. 21272) in its new planning rule:

> [Restoration is] the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Ecological restoration focuses on reestablishing the composition, structure, pattern, and ecological processes necessary to facilitate terrestrial and aquatic ecosystems sustainability, resilience, and health under current and future conditions.

In applying this definition we emphasize several elements. First, restoration should focus on entire ecosystems rather than individual attributes, such as fuels. Programs with singular resource objectives generally marginalize other important values (e.g., Gunderson et al. 1995), resulting in less resilient ecosystems and communities. Focusing broadly on restoring ecosystems serves a wider range of natural resource and stakeholder interests. Second, restoration should center on restoring resilience and functionality in the context of desired future conditions, even while learning from the past. Attempting to return landscapes to a given historical state is unlikely to create either resilience under current and future conditions or socially desirable outcomes (Hobbs et al. 2011). Third, restoration efforts should prioritize the most degraded environments. By "degraded" we mean, e.g., ecosystems where human activities have increased the risk of catastrophic disturbances or created extensive landscapes deficient in important successional stages, such as early seral and old-growth ecosystems. Finally, any comprehensive restoration effort must recognize differences among ecosystems and set treatment goals accordingly—a one-size-fits-all approach will almost certainly fail. Hence, we divide PNW federal forestlands into "moist forests" (MF) and "dry forests" (DF) because these contrasting environments require fundamentally different policies and practices, including approaches to old-growth conservation.

Defining MFs and DFs

The DF and MF classification of federally controlled forests with which we begin is a more appropriate ecological stratification than the traditional categorization of PNW forests as "westside" and "eastside." Rather than using geography, we used scientifically defined plant associations to assign forest sites to their respective DF and MF categories (Table 1), with both conditions occurring on both sides of the Cascade Range. These plant associations reflect distinctive compositions, growth conditions, and historical disturbance regimes (e.g., Atzet et al. 1992), such as broad gradients in fire behavior in PNW forests that reflect variability in both site and landscape conditions. Another advantage to plant associations is that they are readily identifiable in the field by trained resource professionals.

MF and DF sites have contrasting historic disturbance regimes. Historically, MFs generally experienced large infrequent (intervals of one to several centuries) wildfires, which included extensive areas where fire severity resulted in stand-replacement conditions (Agee 1993). DF sites experienced predominantly low- and mixed-severity fire behaviors at frequent (e.g., 5–35 year) intervals (Agee 1993, Perry et al. 2011). Some plant associations currently straddle the boundary between MF and DF stratifica-

Table 1. Assignment of plant association series and groups to MF and DF categories. Moist grand and white fir associations are intermediate and may be appropriately considered as either MF or DF, depending on circumstances.

MF	
	Western hemlock (*Tsuga heterophylla*) series
	Sitka spruce (*Picea sitchensis*) series
	Western redcedar (*Thuja plicata*) series
	Pacific silver fir (*Abies amabilis*) series
	Mountain hemlock (*Tsuga mertensiana*) series
	Subalpine fir-Engelmann spruce (*Abies lasiocarpa-Picea englemanni*) series
	Tanoak (*Lithocarpus densiflorus*) series
	Moist grand fir (*Abies grandis*) Plant Association Group
	Moist white fir (*Abies concolor*) Plant Association Group
DF	
	Ponderosa pine (*Pinus ponderosa*) series
	Oregon white oak (*Quercus garryana*) series
	Douglas-fir (*Pseudotsuga menziesii*) series
	Jeffrey pine (*Pinus jeffreyi*) series
	Dry grand fir Plant Association Group
	Dry white fir Plant Association Group

tion, but climate change is expected to increasingly shift these associations toward DF status with projected increases in wildfire frequency (e.g., Dello and Mote 2010, Spies et al. 2010).

Characteristics and Current State of MFs

MF ecosystems undergo many centuries of stand development and change after major disturbances, such as severe wildfire or windstorm, before achieving the massiveness and structural complexity of old-growth forests (Franklin et al. 2002). Ecosystem development is relatively well understood, with distinctive early seral, young, mature, and old stages (Franklin et al. 2002; Figure 2); intermediate disturbances can alter developmental patterns (Franklin and Spies 1991, Spies 2009).

Composition, structure, and function of existing unmanaged old-growth MFs generally are relatively unaffected by human activities, except at stand edges (Forest Ecosystem Management Assessment Team 1993). Management activities in these existing old-growth MFs, such as thinning, are not needed to sustain conditions in these forests and can actually cause old-growth MFs to diverge widely from natural forests in structure and function or become destabilized (Franklin et al. 2002). Wildfire suppression is typically consistent with efforts to retain such forests—i.e., it is not known to result in significant changes in MF ecosystems (Agee 1993).

Restoration may be needed in MF landscapes in which old-growth stands are embedded, however. Many MF landscapes are currently dominated by dense young plantations, which are low in biodiversity and deficient in the early (preforest) and late (mature and old-growth) successional stages, which are richest in biodiversity. Late-successional MFs provide habitat for thousands of species including the NSO and other habitat specialists (Forest Ecosystem Management Assessment Team 1993); past timber harvests have greatly reduced their extent and continuity (e.g., Wimberly 2002, Spies et al. 2007). Continued decline in NSO populations across much of its range have heightened the importance of retaining the remaining late-successional forests (Forsman et al. 2011).

Early successional or seral MF sites are highly diverse, trophic- and function-rich ecosystems that occur after a severe disturbance but before the reestablishment of a closed forest canopy (Greenberg et al. 2011, Swanson et al. 2011). Theoretically, disturbances of either natural (e.g., wildfire) or human (e.g., timber harvest) origin are capable of generating this stage. Large natural disturbances often produce high-quality early seral ecosystems provided they are not intensively salvaged and replanted (Swanson et al. 2011), but such disturbances are poorly distributed in time and space. For example, less than 1% of suitable NSO habitat (complex forest) was transformed by wildfire into early successional habitat between 1996 and 2006 in MF-dominated provinces of the Northwest Forest Plan (NWFP; USDI Fish and Wildlife Service 2011). Areas devoted to intensive timber production generally provide little high-quality early seral habitat for several reasons. First, few or no structures from the preharvest stand (e.g., live trees, snags, and logs) are retained on intensively managed sites but are abundant after severe natural disturbances (Swanson et al. 2011). Additionally, intensive site preparation and reforestation efforts limit both the diversity and the duration of early seral organisms, which may also be actively eliminated by use of herbicides or other treatments (Swanson et al. 2011). Consequently, many MF landscapes currently lack sufficient representation of high-quality early seral ecosystems because of harvest, reforestation, and fire suppression policies on both private and public lands (Spies et al. 2007, Swanson et al. 2011). Functional early seral habitat can be created using regeneration harvest prescriptions that retain biological legacies and use less intensive approaches to reestablishment of closed forest canopies, as discussed later.

Characteristics and Current State of DFs

Historical forest conditions on DF sites have been extensively summarized (e.g., Noss et al. 2006, Courtney et al. 2008, and Johnson et al. 2008). Low tree densities and dominance by larger, older trees of fire- and drought-resistant species, such as ponderosa pine (*Pinus ponderosa*) and western larch (*Larix occidentalis*), characterized many DF sites (Munger 1917, Youngblood et al. 2004, Spies et al. 2006, Kolb et al. 2007, Johnson et al. 2008; Figure 3). Spatial heterogeneity, including fine-scale low-contrast structural patchworks, was also characteristic (Franklin and Van Pelt 2004, Larson and Churchill 2012) (Figure 3). Denser, more even-structured stands, consisting of mixtures of Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), western larch, and ponderosa pine, occurred and even dominated some DF landscapes as a result of more severe fires and insect epidemics (e.g., Hessburg et al. 2005, 2007).

Composition and structure of existing DF landscapes have been dramatically altered by decades of fire suppression, grazing by domestic livestock, timber harvesting, and plantation establishment (Noss et al. 2006) resulting in (1) many fewer old trees of fire-resistant species, (2) denser forests with multiple canopy layers, (3) more densely forested landscapes with continuous high fuel levels, and, consequently, (4) more stands and landscapes highly susceptible to stand-replacement wildfire and insect epidemics (e.g., Hessberg et al. 2005, Noss et al. 2006). Outbreaks of western spruce budworm (*Choristoneura occidentalis*) and other defoliators are currently widespread in mature stands of grand fir and Douglas-fir and have been for over 30 years. In southwestern Oregon, DF sites that have not been previously harvested are largely occupied by dense maturing Douglas-fir stands, which appear to be the first generation of closed conifer forests on many of these sites. Historically, these DF landscapes were occupied by diverse communities including open grasslands, shrub fields, oak savannas, and mixed hardwood and conifer woodlands (McKinley and Frank 1996).

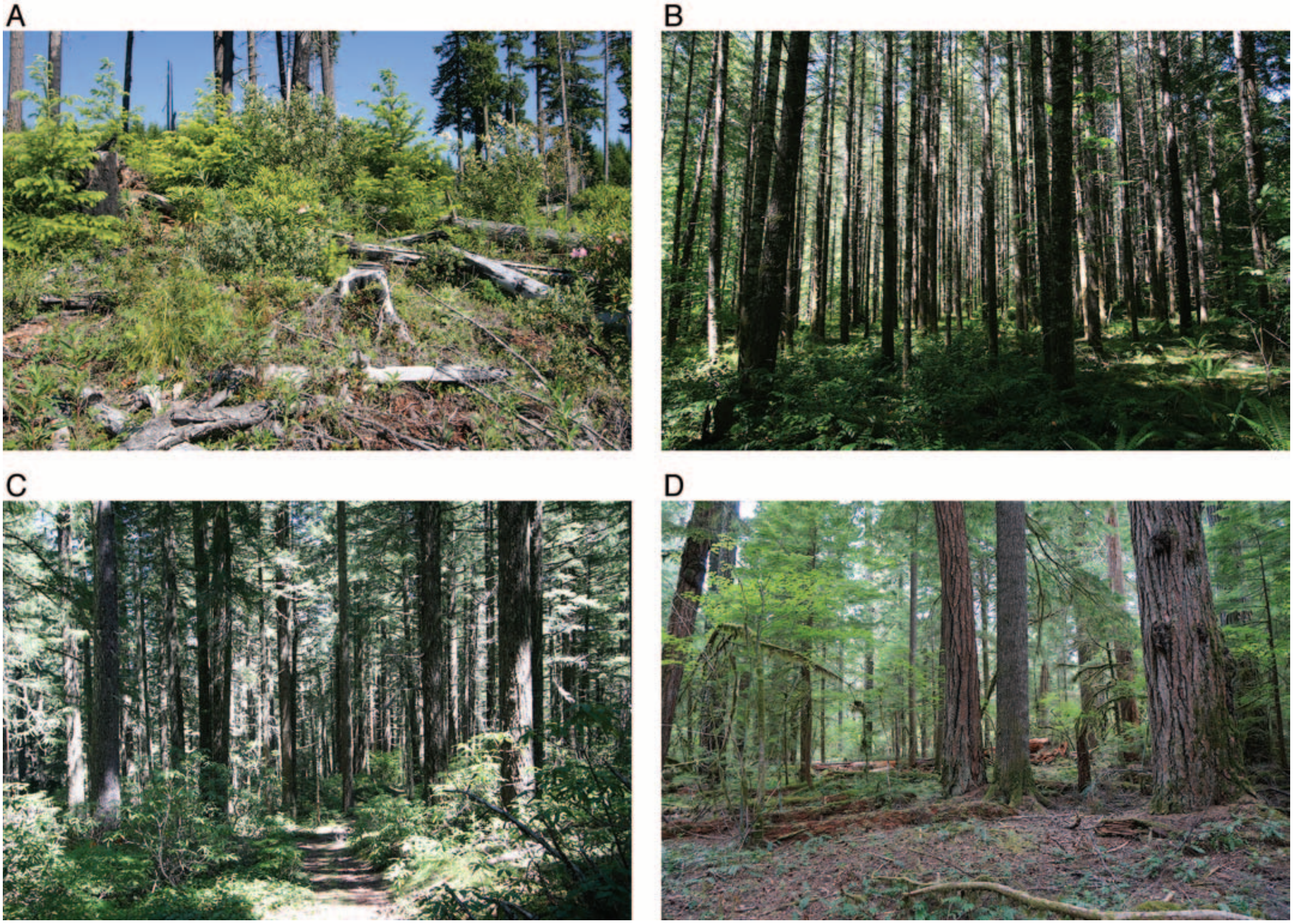

Figure 2. Major stages in MF development after a stand-replacement event. (A) Early seral or preforest ecosystem dominated by diversity of plant life forms. (B) Young forest ecosystem dominated by Douglas-fir with high stem densities and a closed forest canopy. (C) Mature forest ecosystem dominated by Douglas-fir, which is undergoing reestablishment of the understory community, including regeneration of shade-tolerant tree associates. (D) Old forest ecosystem dominated by mixture of tree species, including Douglas-fir and western hemlock, with a diverse and spatially variable understory of cryptogams, ferns, herbs, shrubs, and small trees.

Ecological Forestry as a Basis for Restoration Prescriptions

Our silvicultural proposals are based on "ecological forestry" concepts, which incorporate principles of natural forest development, including the role of natural disturbances in the initiation, development, and maintenance of stands and landscape mosaics (Seymour and Hunter 1999, North and Keeton 2008, Bunnell and Dunsworth 2009, Long 2009). Key elements of ecological forestry include (Lindenmayer and Franklin 2002, Franklin et al. 2007) (1) retaining structural and compositional elements of the preharvest stand during regeneration harvests (Franklin et al. 1997, Gustafsson et al. 2012); (2) using natural stand development principles and processes in manipulating established stands to restore or maintain desired structure and composition; (3) using return intervals for silvicultural activities consistent with recovery of desired structures and processes; and (4) planning management activities at landscape scales, using knowledge of spatial pattern, and ecological function in natural landscapes.

Protection of Older Stands and Trees

Elements of ecological forestry differ in their application, even though they share a common theme. For example, management of old trees and stands would vary as a function of forest type. On MF sites, older forest stands on federal lands are retained under our restoration strategy because of their ecological and social significance, whether they are located inside or outside of current reserves. In addition, older trees in any treated younger MF stands are also retained. On DF sites, older trees are retained under our restoration strategy, regardless of their size. On these sites, the focus is on individual old trees rather than stands because active management is often necessary to restore DF stands to more resilient conditions, including enhancement of the survival of old trees.

In the PNW, the occurrence of older trees and forests currently is far below the historic range of variability, despite their ecological importance (Spies 2009). Decades of legal battles over older stands and trees are clear evidence of societal interest in them; these conflicts have perpetuated stakeholder distrust of foresters and diverted attention from restoration (Thomas et al. 2007, Spies et al. 2009). Although it seems straightforward, classifying trees or stands as old is not a simple task. The age at which forests are deemed "older" is a social decision, influenced but not defined by scientific input, with age a commonly used surrogate in determining which forests are going to be

Figure 3. Dry Forest dominated by ponderosa pine illustrating the fine-scale mosaic that includes openings and patches dominated by tree reproduction and by mature and old trees; such conditions were historically characteristic of many, but not all, DF landscapes (Yakima Indian Reservation, Washington).

preserved from timber harvest. Age limits can also vary based on ecological thresholds, management objectives, and ease of implementation. For example, in a prior analysis we have used 80, 120, and 160 years to identify "older" in MFs (Johnson and Franklin 2009), an age range that goes from retaining all late-successional forests (80), to retaining most mature and all old-growth forests (120) or (at a threshold age of 160) retaining the oldest mature and all old-growth forests.

Given the importance of age, the initial selection of individual trees for retention in treated DFs is based on age rather than size—i.e., we use an age limit rather than a diameter limit.[2] Diameter limits can result in undesirable outcomes in DF restoration, such as by allowing removal of small older trees important to stand complexity and function. Diameter limits also can prohibit removal of large young trees that provide ladder and crown fuels and competition, thereby increasing the potential for wildfire or drought to kill old trees (McDowell et al. 2003, Johnson et al. 2008). We also do incorporate retention of younger, larger-diameter trees for wildlife and other purposes in our prescriptions, especially when they offer no threat to older trees.

Our focus on older trees rather than simply larger ones is because older trees have distinctive ecological characteristics and functions. Older trees are not simply larger versions of young trees. Trees acquire distinctive physiological and structural features from the aging process and responses to physical and biotic damage (e.g., wind, disease, parasites, and insects; Table 2). Such characteristic features of old trees (often including their larger size) make them structural cornerstones in forests, contributing to ecosystem services, such as wildlife habitat, resistance to fire and drought, and genetic reservoirs, and require centuries to replace.

MF Restoration Strategy

Our MF strategy focuses on increasing the underrepresented late-successional forests and early seral ecosystems (Table 3). Demonstration projects using these MF regeneration harvest principles are underway on the Roseburg and Coos Bay Districts of the BLM and at least two more projects are being planned (Figure 1; Wheeler 2012). As mentioned earlier, older forest stands on MF sites on federal lands will be retained (both inside and outside of current reserves) to protect their ecological and social significance. The MF strategy also includes the thinning of younger forests to accelerate development of structural complexity characteristic of older forest stands.

The most potentially controversial element of our MF restoration strategy is resumption of regeneration harvesting in younger stands using variable retention prescriptions (Figure 4). One specific objective of these harvests is to provide for continued creation of diverse early seral ecosystems in MF landscapes, as a part of a silvicultural system that includes management of mixed-age, mixed-species forests over long (e.g., 100–160 years) rotations. Very few regeneration harvests are currently planned in federal MFs in the PNW, outside of the projects described in this article, primarily because past proposed harvests in mature and old-growth stands have been litigated consistently. Existing timber harvests are currently confined to thinning younger stands (Baker et al. 2006, Thomas et al. 2007).

We expect the resumption of regeneration harvests on federal lands to be controversial partly because stakeholders usually equate it with the unpopular practice of clearcutting (Bliss 2000). However, we propose using variable retention harvesting and not clearcutting; these are very different approaches. Unlike conventional clearcuts, variable retention harvests incorporate significant elements of the preharvest stand

Table 2. Some distinguishing characteristics of old conifers of ecological significance.

Heartwood accumulations and development of thick fire-resistant bark (Van Pelt 2008)
Abundant microhabitats important for maintaining biodiversity (Michel and Winter 2009)
Highly individualistic canopies including large branches, epicormic branch systems, and multiple tops (Van Pelt 2008, Van Pelt and Sillett 2008)
Presence of cavities, pockets of decayed wood, and brooms (Van Pelt 2008)

Table 3. Elements of MF restoration strategy.

Retain existing older stands and individual older trees found within younger stands proposed for management, using a selected threshold age
Accelerate development of structural complexity in younger stands, using diverse silvicultural approaches (Bailey and Tappeiner 1998, Garman et al. 2003, Carey 2003, Wilson and Puettmann 2007)
Implement variable retention regeneration harvests (Franklin et al. 1997, Beese et al. 2003, Franklin et al. 2007, Gustafsson et al. 2012) in some younger MFs, retaining such structures as individual trees, snags, and logs and intact forest patches
Accommodate development of diverse early seral ecosystems following harvest, by using less intense approaches to site preparation and tree regeneration
Embed preceding objectives in a silvicultural system that includes creation and management of multiaged, mixed-species stands on long rotations (e.g., 100–160 yr)

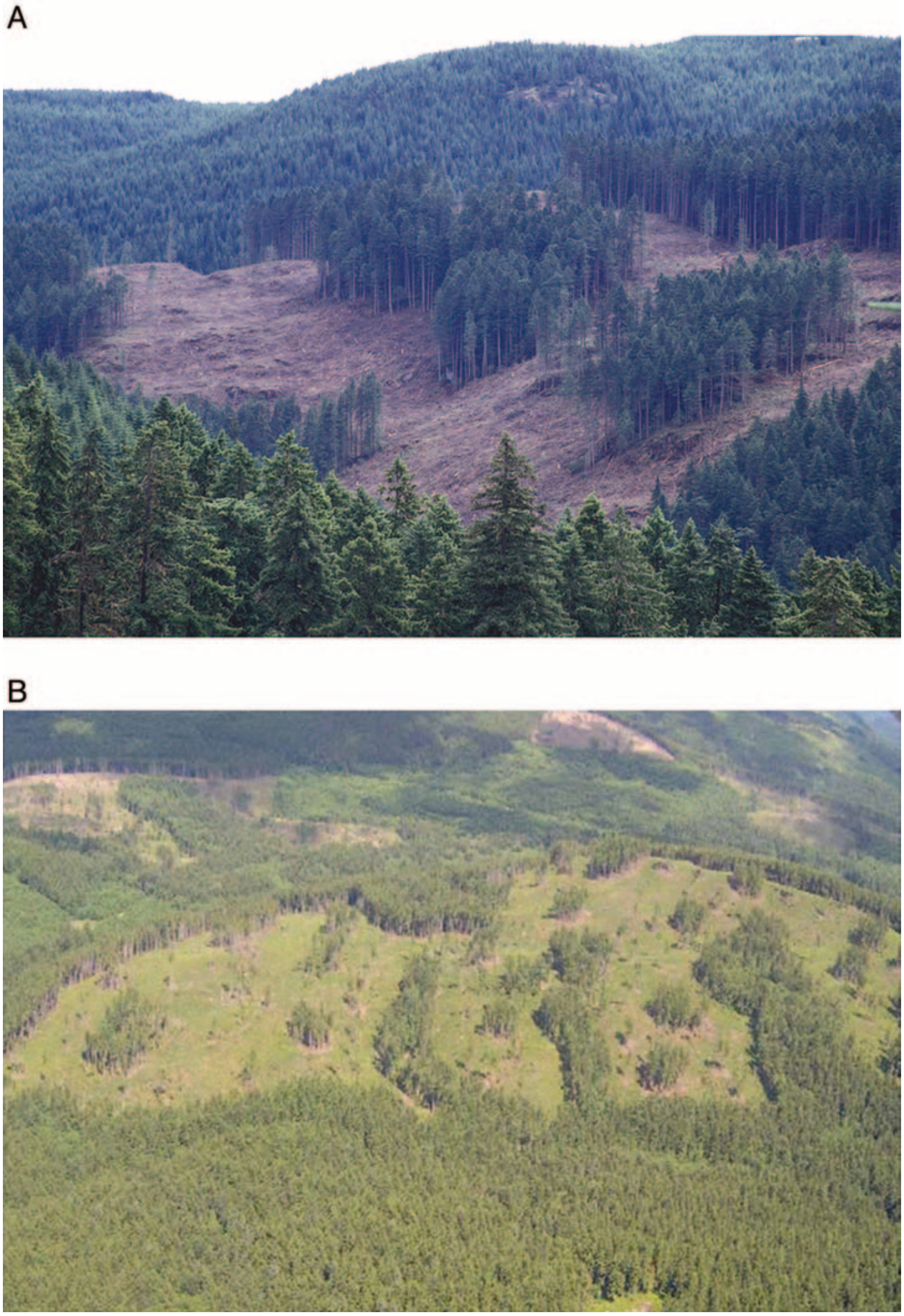

Figure 4. Ground and aerial views of variable retention regeneration harvest units. (A) Retention harvest unit with approximately 15% of the preharvest forest left in undisturbed patches or "aggregates," which include a diversity of structures (e.g., live trees, snags, and down logs). (B) Retention harvest unit with approximately 15% of the preharvest forest left in undisturbed patches of varying size, including some associated with protection of riparian and stream habitat. (Photo courtesy of Washington State Department of Natural Resources.)

through the next rotation, including undisturbed forest patches and individual live and dead trees, to enrich the biodiversity, ecological processes, and structural diversity of the postharvest stand (Franklin et al. 1997, Gustafsson et al. 2012, Lindenmayer et al. 2012; Figure 4). Our current proposal for MF regeneration harvest calls for retention of approximately 30% of the preharvest stand as patches, plus some additional retention (typically of green trees that are intended to become snags and logs) on harvested portions of the units. With these biological legacies and the significant open areas created by the harvesting, variable retention harvests provide optimal conditions for (1) development of diverse early seral ecosystems needed by significant elements of regional biodiversity (Swanson et al. 2011), (2) regenerating new cohorts of desirable shade-intolerant tree species, and (3) providing substantial flows of wood products. We view younger, previously harvested stands as the obvious candidates for regeneration harvests, given current levels of older forests are far below historic levels and policy direction calls for their retention as NSO habitat (USDI Fish and Wildlife Service 2011).

DF Restoration Strategy

Elements of this DF restoration strategy, including stand-level treatments and retention of dense forest habitat patches at the landscape level, have been or are currently being incorporated into projects on federal lands (e.g., Ager et al. 2007, Gaines et al. 2010, Brown 2012). Projects (Figure 1) using our DF principles are underway on BLM lands in southwestern Oregon, where the NSO is featured (Reilly 2012), the Malheur National Forest in central Oregon (Brown 2012), and the Fremont-Winema National Forest in south-central Oregon. DF restoration has a number of important stand- and landscape-level elements (Table 4; also see North et al. 2009 and Larson and Churchill 2012). Many DFs need silvicultural treatments to restore more resistant and resilient conditions, although details of prescriptions will vary with specific management objectives, plant associations, stand conditions, and landscape contexts.

The retention and nurturing of older trees and other significant structural elements of the DF stand is the starting point for this restoration strategy. Although many DFs include older trees, almost all such forests are highly modified structurally and compositionally by past management, which has greatly reduced older tree populations and increased stand densities. Currently, both remaining old trees and the forests in which they are embedded are at risk from intense wildfires, epidemics of defoliating insects, and competition, the latter resulting in accelerated mortality due to bark beetles (Noss et al. 2006, Courtney et al. 2008, Franklin et al. 2008). Selection of the threshold age for older trees is particularly important for DFs, because it is applied to all DF stands. In our work we usually use 150 years as the threshold age for older trees

Table 4. Elements of the DF restoration prescriptions.

Retain and improve survivability of older conifers by reducing adjacent fuels and competing vegetation—old trees can respond positively (e.g., McDowell et al. 2003)
Retain and protect other important structures such as large hardwoods, snags, and logs; some protective cover may be needed for cavity-bearing structures that are currently being used (e.g., North et al. 2009)
Reduce overall stand densities by thinning so as to (1) reduce basal areas to desired levels, (2) increase mean stand diameter, (3) shift composition toward fire- and drought-tolerant species, and (4) provide candidates for replacement old trees
Restore spatial heterogeneity by varying the treatment of the stand, such as by leaving untreated patches, creating openings, and providing for widely spaced single trees and tree clumps (Larson and Churchill 2012)
Establish new tree cohorts of shade-intolerant species in openings
Treat activity fuels and begin restoring historic levels of ground fuels and understory vegetation using prescribed fire
Plan and implement activities at landscape levels, incorporating spatial heterogeneity (e.g., provision for denser forest patches) and restoration needs in nonforest ecosystems (e.g., meadows and riparian habitats).

because (1) trees in DFs generally begin exhibiting some old-growth characteristics by this age and (2) significant Euro-American influences were underway by 1860, e.g., introduction of large domestic livestock herds (Franklin et al. 2008, Robbins 2009).

Other threshold ages for older trees could be considered in DFs, such as 100 and 200 years, but these introduce other problems. When 100 years is used as the threshold, many trees lacking old-growth attributes are retained, making it difficult to reduce stand densities to the desired levels. Additionally, this age threshold limits the removal of higher-valued trees and thus affects economic viability of treatments. Using 200 years, many trees that have old-growth cohort attributes will likely be removed, affecting the ecological value of the treatment. However, this age threshold would also allow harvest of more high-value trees, at least initially.

Retaining some denser forest areas in an untreated or lightly treated condition is a challenging landscape-level planning component of our DF restoration strategy. Most DF landscapes include species and processes that require denser forest as habitat, such as preferred nesting, roosting, and foraging habitat for NSO (USDI Fish and Wildlife Service 2011). Another more widely distributed example in PNW DFs is the northern goshawk (*Accipitor gentilis*; Crocker-Bedford 1990). Maintaining approximately one-third of a DF landscape in denser patches of multilayered forest has been proposed for the NSO (Courtney et al. 2008). In general, landscape amounts and distributions will be a function of topographic and vegetative factors along with wildlife goals. Untreated patches in the hundreds of acres could be preferentially located in less fire-prone areas, such as steep north-facing slopes, riparian habitats, and sites protected by natural barriers, such as lakes and lava flows. The longevity of the dense forest patches should be increased by restoring DF conditions in the surrounding landscape matrix (Agar et al. 2007, Gains et al. 2010). Losses of denser forest patches are inevitable, but—because the surrounding restored matrix still is populated with older, larger trees—suitable dense replacement habitat can be regrown within a few decades.

Ecological Forestry and Adaptive Management

Credible adaptive management will be essential to implementing our proposed restoration approach on federal forests in the PNW, because it includes significant new elements and affects the entire region. This is challenging because successful adaptive management has been limited in the PNW (Stankey et al. 2003, Bormann et al. 2007). Key elements include comprehensive regional analysis and planning, integrated monitoring and research activities, and systematic assessments of ecological and social outcomes by independent parties. Two elements requiring particular attention are (1) interactions between DF restoration and NSO populations and (2) effectiveness in creation of diverse early seral ecosystems using variable retention regeneration harvests.

Regional targets for total amount and spatial distribution of early seral ecosystems need to be scientifically assessed for the MFs on federal lands in the PNW. Determinations of natural range of variability of such habitat, such as has been done in the Oregon Coast Ranges (Wimberly 2002, Spies et al. 2007), is a good starting point. Additional focused research on early seral ecosystems is needed to (1) expand current knowledge of biodiversity and functions in early seral ecosystems of both natural and human origin and (2) explore different approaches (e.g., silvicultural prescriptions) for creating diverse early seral ecosystems.

Finally, road networks and plantation establishment after intensive harvesting have significantly affected both aquatic and forest ecosystems on both DF and MF landscapes (e.g., Franklin and Forman 1987, Forest Ecosystem Management Assessment Team 1993). Restoring aquatic and semi-aquatic ecosystems is a high-priority restoration concern throughout federal forests, but one that we cannot adequately address in this short article. Reducing the impacts of permanent roads on aquatic ecosystems is an important objective, but it must be weighed against needed access for restoration projects and long-term management.

Harvest Potential

We have estimated (Johnson and Franklin 2009) that our restoration strategy could increase timber harvest from the federal forests of the PNW over the next 15 years, primarily by resuming regeneration harvests in MFs and expanding the extent of restoration treatments (i.e., partial cutting) in DFs.

Our MF strategy adds regeneration harvests in younger stands to current thinning. The economic viability of such sales in normal markets is unquestionable, because regeneration harvests remove larger volumes per acre and include larger trees than are produced in the currently thriving thinning programs. However, a critically important undetermined variable is the MF land base available for regeneration harvests for several reasons, including some related to the strategy itself. For example, initial estimates using unmanaged stands as models suggest that our proposed silvicultural system might provide one-half of the per acre yields expected under intensive timber production (Johnson and Franklin 2012). On the other hand, the significantly greater wildlife and environmental benefits from the variable retention approach may result in greater social acceptability of this approach and, consequently, significantly broaden the land base on which it could be applied.

Our DF strategy calls for shifting from fuel treatments, a current focus of DF federal actions, to broad-scale ecosystem restoration. Stand-level harvest implications are difficult to clarify. Basically, we call for creating a more heterogeneous spatial pattern than in current practice, while conserving old trees and removing diameter limits on harvest. However, some DF stands clearly are economically marginal with viability depending on market conditions and mill proximity (e.g., Adams and Latta 2005, Johnson and Franklin 2009). Mill closures east of the Cascades have accentuated this problem, making comprehensive restoration dependent on new infrastructure investments. Accurate assessments of feasibility and timber yields from DF restoration await empirical data from field trials, such as the projects in Oregon using our restoration strategy (e.g., Brown 2012).

Integrating Restoration Strategies with Existing and Emerging Forest Policies

How well do our proposals for conserving old-growth and restoring MFs and DFs interface with existing PNW federal policies? Where are they consistent with existing policies and where are adjustments needed? Three important current policies are (1) the NWFP, which was adopted in 1994 for all federal forests within the NSO range; (2) interim management guides developed in the mid-1990s for eastside national forests beyond the NSO range (USDA Forest Service 1995); and (3) new policies proposed in the NSO Recovery Plan (USDI Fish and Wildlife Service 2011) and proposed critical habitat for the NSO (USDI Fish and Wildlife Service 2012).

Moist Forests

Retaining older forests on MF sites is generally consistent with existing and emerging policy. Much late-successional forest (more than 80 years) was protected in the NWFP as late-successional reserves (LSR) and riparian reserves (Thomas et al. 2007), and most of the remaining older forests on MF sites was recently recommended for retention in the NSO Recovery Plan (USDI Fish and Wildlife Service 2012). Commercial thinning in plantations to increase structural complexity is generally consistent with the NWFP (USDA Forest Service and US BLM 1994) and the NSO Recovery Plan and draft critical habitat rules allow for these actions (USDI Fish and Wildlife Service 2011, 2012), although recent findings on the negative impact of such thinning on some prey species of the NSO may create new limitations on harvest activities (Manning et al. 2012).

However, there are numerous policy issues that surround implementation of the regeneration harvest component of our restoration strategy on MF sites. Three provisions from the planning regulations implementing the National Forest Management Act (NFMA) are especially important:

1. The revised NFMA planning rule calls for national forestland to be identified as not suitable for timber production if "There is no reasonable assurance that such lands can be adequately restocked within 5 years after final regeneration harvest" (USDA 2012, p. 21266).[3] The definition of "adequate restocking" adopted in the *Forest Service Handbook and Regional Direction* would need to accept the concept of relating adequacy of stocking to prescription goals, such as creation of diverse early seral ecosystems, to allow the restoration strategy described here.
2. The planning rule incorporates a sustained yield requirement: "The quantity of timber that may be sold from the national forest is limited to an amount equal to or less than that which can be removed from such forest annually in perpetuity on a sustained yield basis" (USDA 2012, p. 21267). The plan may depart from this limit under certain conditions and after allowing public comment, but calculation of the long-term sustained yield remains a foundational element in national forest planning. Regeneration harvests are one major component of long-term sustained yield. Thus, it appears that this sustained yield provision will require the national forests to develop a long-term strategy that includes regeneration harvests on MFs. We do not know whether our proposed approach to regeneration harvest will be considered in this strategy.
3. The planning rule stipulates that "The regeneration harvest of even-aged stands of trees is limited to stands that generally have reached the culmination of mean annual increment of growth" (USDA 2012, p. 21267), but exceptions are allowed where the primary purpose of the harvest is something other than timber production. These exceptions are important because some stands, which otherwise would be candidates for a regeneration harvest, have not reached culmination.

Implementation of the regeneration harvest component on MF sites will also be affected by the recent NSO Recovery Plan (USDI Fish and Wildlife Service 2011) and proposed critical habitat for the NSO (USDI Fish and Wildlife Service 2012). Active management using ecological forestry principles is endorsed in both documents but there is uncertainty about the type, timing, and location of allowed activities. In a Presidential Memorandum (Obama 2012) released with proposed critical habitat, the Secretary of Interior is directed to ". . . develop clear direction, as part of the final rule, for evaluating logging activity in areas of critical habitat, in accordance with the scientific principles of active forest management and to the extent permitted by law." This direction will be critical to determining the extent to which regeneration harvests will be allowed within critical habitat.

Dry Forests

Interfacing our proposal for restoration of DFs with existing policy is complex, because candidate DFs are located both inside and outside the NWFP area. Within the NWFP areas, LSRs included DF landscapes in eastern and southern portions of the NSO range. The NWFP allowed for harvest in DF LSRs to restore and maintain natural ecological conditions (Forest Ecosystem Management Assessment Team 1993), although such activity rarely has been undertaken in the past (Thomas et al. 2007). Hence, our DF restoration strategy is consistent with the NWFP. DF restoration is explicitly encouraged in the NSO Recovery Plan (USDI Fish and Wildlife Service 2011), in part because potential for large wildfires and outbreaks of western spruce budworm greatly increase risks to large contiguous blocks of multilayered DFs (e.g., Courtney et al. 2008, Dello and Mote 2010). Still, it is not clear how this stated intent will be implemented and some owl biologists and environmentalists currently oppose any modification of suitable NSO habitat; litigation of this aspect of the NSO Recovery Plan is likely.

Outside the NWFP area, our proposals for restoration of DF are largely consistent with existing policy. We do substitute retention of older trees for the current interim upper diameter limit of 21 inches (see Brown 2012). However, increasingly, national forests have been granted exceptions to the "21 inch" policy to remove large, young white firs that have invaded historic ponderosa pine–dominated stands.

Still, as with MF, several policy issues remain regarding implementation of our DF restoration strategy:

1. We call for accelerated rates of treatment on a much broader DF land base than is currently proposed under fuel treatment programs. Simulations of fuel treatment effects show that thinning as little as 1%

of the forest per year can significantly alter fire behavior (Finney et al. 2007). Consequently, goals of thinning 20–30% of DFs over the next 20 years reflect budget and personnel shortages and a singular focus on fire. Unfortunately, fuel treatments alone leave most DFs and included old trees vulnerable to fire, drought, and insects, hence, our call for both an altered and an accelerated program.

2. Our strategy calls for a network of dense patches in treated landscapes, tailored to the situation and wildlife species of interest, a feature often not recognized in DF project implementation. However, there is a framework for such a network in the new NSO Recovery Plan and proposed critical habitat designation. Because many DF stands provide suitable habitat for NSO, it is essential to comprehensively plan the amount and spatial distribution of reserved dense forest patches and, conversely, identify areas for restoration treatment.
3. Although commercial treatments are central to our DF strategy, comprehensive restoration of DF landscapes will require investments from either timber sale revenues or appropriated funds (Adams and Latta 2005, Johnson et al. 2008). Such investments are problematic in a time of shrinking federal budgets.
4. Maintenance of restored DF conditions after initial mechanical treatments could be done with prescribed fire, possibly eliminating the potential for future timber production. We envision the continued use of harvesting to maintain desired conditions in many DF stands. Resolution of this question—controlled burns or harvest or both—is also related to addressing the sustained yield clause of the NFMA planning rule.

Conclusions and Implications

Our experiences thus far with projects implementing our restoration strategies, including extensive interactions with stakeholder groups, have been very useful in refining our strategy. Agency personnel have proved to be very capable of developing silvicultural prescriptions based on ecological forestry principles and implementing the resulting projects. We view our restoration strategy as a credible alternative to the extreme choices with which stakeholders are currently being presented of either managing federal lands for intensive wood production, on the one hand, or effectively preserving all of it for owls, on the other. This does not mean that we do not anticipate other challenges will arise that need to be addressed—several key issues must still be resolved, and we make the following recommendations to address these issues.

First, the lack of public trust in agency proposals probably has been the largest single obstruction in moving active management forward on federal forestlands. The general absence of credible third-party assessments has contributed significantly to this problem. We view such third-party review and public reporting as essential for successfully undertaking a major new innovative management program on federal lands.

Second, given the high potential for catastrophic resource losses in federal DFs, we advocate a comprehensive 20-year program for restoring one-half to two-thirds of PNW DF landscapes outside of wilderness and roadless areas through a combination of commercial and precommercial treatments. This will require a significant increase in the amount of commercial thinning undertaken (Johnson and Franklin 2009). The need to increase the pace of restoration was recently acknowledged by the US Forest Service (USDA Forest Service 2012).

Finally, resolving the MF land base on federal lands that will ultimately be available for reinstituting regeneration harvests is highly problematic both legally and socially. There are even questions about whether previously harvested stands will be available for such harvests. Some of them have been identified as NSO critical habitat; others provide habitat for other species requiring special treatment (Johnson and Franklin 2012). Three conclusions emerge: (1) our MF strategy provides a pathway to a long-term sustained timber yield from MFs that does not currently exist, (2) reversing the trend of the shrinking land base for timber production is a key element in determining sustainable timber harvests, and (3) developing public understanding and acceptance of the ecological need for creating diverse early seral ecosystems in MF will require significant effort.

Endnotes

1. This article is largely based on two more comprehensive reports (Johnson and Franklin 2009, 2012).
2. Age limits can be criticized as being more difficult to apply than diameter limits. However, effective visual guides to tree age based on external characteristics of trees have been developed (Van Pelt 2008) and used (e.g., Brown 2012). Furthermore, questions typically arise regarding only the subsample of trees that appear near the threshold age. Two caveats are relevant in the use of age as the first screen in selecting trees for retention: (1) stakeholders and agency personnel must agree on some allowance for errors in age estimation and (2) as noted, size is important for many wildlife species, such as cavity nesters, and will be considered in developing silvicultural prescriptions.
3. National forests operate under the 1982 planning rule until they develop new forest plans (USDA 1982). The wording on these provisions is slightly different in that rule, but the intent is similar.

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Case Study

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Roseburg District Pilot Project

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For the past 20 years, the US Department of the Interior (USDI) Bureau of Land Management (BLM) Oregon and California Railroad (O&C) lands of western Oregon have been the focus of intense debate. The O&C Lands Act of 1937 and the Endangered Species Act of 1973 have driven discussions regarding these lands since the northern spotted owl's listing in 1990. In an attempt to balance seemingly opposed interests, the Northwest Forest Plan was developed in 1994. Litigation within the courts has prevented a full implementation of the Northwest Forest Plan. For example, much of the plan's predicted sustained yield volume was supposed to have come from regeneration harvest in "old-growth" forests. The recent status quo has been a thinning-only approach,

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