Twenty-five years of the Northwest Forest Plan: what have we learned?

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The Northwest Forest Plan (NWFP) has guided the management of 17 federal forests in the US Pacific Northwest for the past 25 years. The existing management plans for these national forests – which were amended by the NWFP – are now being evaluated for revision under the US Forest Service's 2012 planning rule. To help inform federal land managers, we reviewed the scientific literature published since the inception of the NWFP and report several key findings: (1) conservation of at-risk species within national forests is challenging in the face of threats that are beyond the control of federal managers, (2) management efforts to promote resilience to wildfire and climate change include restoring dynamics and structure at multiple scales and revisiting reserve design, (3) forest restoration can have an ecological and socioeconomic win–win outcome, (4) human communities benefit from many ecosystem services beyond the supply of timber, (5) collaboration among multiple stakeholders is essential for achieving ecological and socioeconomic goals, and (6) monitoring and adaptive management are crucial to learning about and addressing uncertainty.

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What happens after 25 years of implementing a plan that changed the management of 10 million ha of federal land? It is often not possible to adequately answer environmental policy questions like this due to a lack of monitoring and research. Fortunately, that is not the case for the 1994 Northwest Forest Plan (NWFP), which was accompanied by a regional monitoring program and ongoing research. The NWFP was a large, multi-agency effort to conserve biodiversity, particularly old-growth forests, northern spotted owl (*Strix occidentalis caurina*), marbled murrelet (*Brachyramphus marmoratus*), and other species associated with older forests on federal lands in western Washington and Oregon and northwestern California. It was also designed to protect and restore salmonid habitat, and to provide forest products to support local and regional economies. The NWFP was intended to be a 100-year plan but also to be flexible enough to adapt to new conditions, threats, and knowledge.

In a nutshell:

- The Northwest Forest Plan (NWFP) conserved old-growth forests and certain wildlife species, but did not meet other goals, including timber production
- New threats that are not well addressed in the NWFP include climate change, wildfire, and invasive species, particularly barred owls (*Strix varia*)
- Ecological and socioeconomic goals can be more effectively met by considering trade-offs and tailoring land management to variations in ecosystems and human communities within the NWFP area
- Increased thinning and judicious use of wildland fire can increase resilience to wildfire and climate change, especially in dry-forest zones
- Engaging citizens through collaborative decision making presents an opportunity to build trust

The outcomes of this plan and the scientific basis of its assumptions are now of particular interest to federal managers as they begin the process of revising forest plans in the NWFP area under the 2012 US Department of Agriculture Forest Service (USFS) planning rule. The NWFP amended individual forest plans in this region but those plans have been in effect for many years and their revision is mandated by the National Forest Management Act of 1976 (PL 94-588), which directs managers to revise land management plans across the US using the "best available science" (USFS 2012). The 2012 planning rule represents the most important change in federal forest biodiversity policy nationwide over the past 30 years (Schultz *et al.* 2013), but it has yet to be applied to forest plan revision in the NWFP area.

At the request of USFS managers, we completed a synthesis of recent science (Spies *et al.* 2018a) to inform revisions of forest plans and land management across 17 national forests occurring within the NWFP area. Synthesis development included public engagement and peer review overseen by the Ecological Society of America under the Office of Management and Budget guidelines for "highly influential" science (www.gpo.gov/fdsys/granule/FR-2005-01-14/05-769). Our review and synthesis were based on an unparalleled and ongoing 25-year monitoring program, and consideration of over 4000

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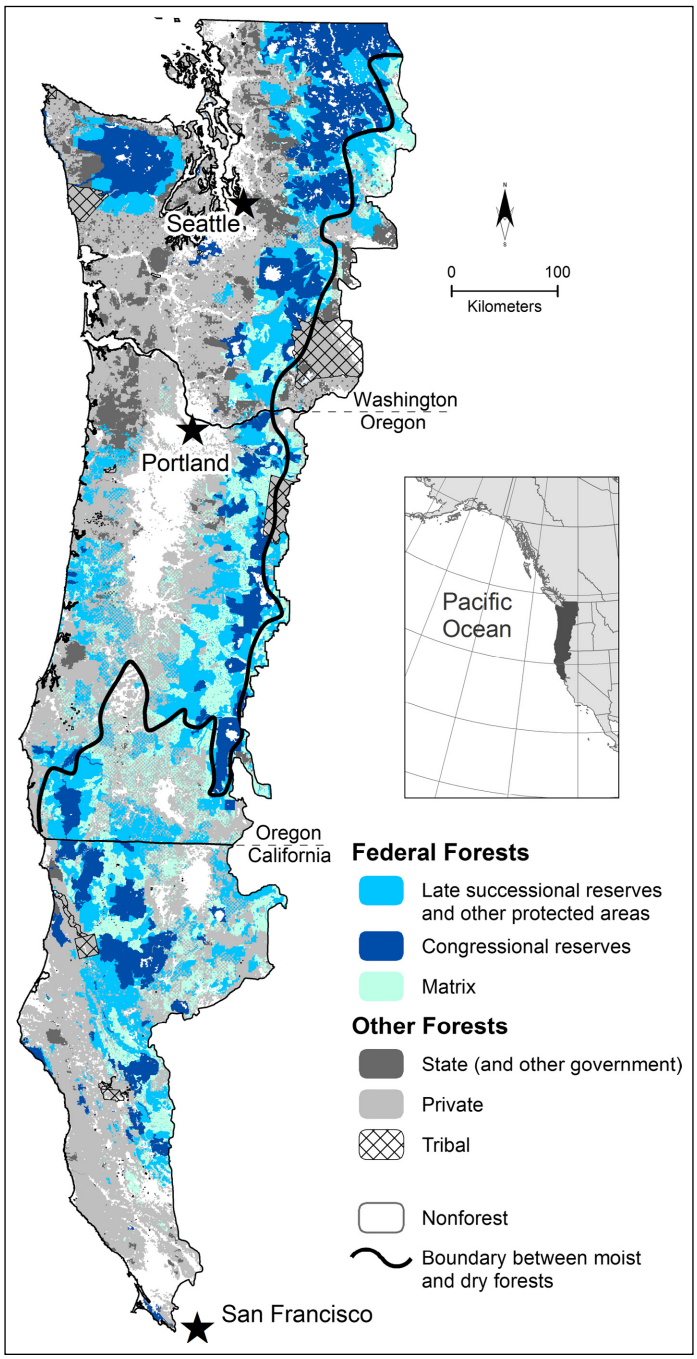

Figure 1. Forestland ownership and land allocations on federal forest lands (colored areas) within the area of the Northwest Forest Plan (NWFP). "Other protected areas" include administratively withdrawn lands and managed late-successional areas. Congressional reserves include National Park and Wilderness areas. Riparian reserves in matrix lands are not shown. Adaptive management areas, which were discontinued, are also not shown.

publications. We briefly review the background of the NWFP and then highlight six key findings from our review.

Background of the NWFP

In the early 1990s, federal forest management in the Pacific Northwest and northern California was in crisis because legal challenges for protection of Endangered Species Act (ESA)-listed species forced court injunctions that halted timber harvest on 10 million ha of federal land. In response, federal policy makers adopted the NWFP in 1994, to guide ecosystem management of federal forest land across the range of the northern spotted owl. The NWFP was unprecedented not only in its geographic scale and ecological diversity, but also in its social complexity and science engagement (Noon and Blakesley 2006; Reeves *et al.* 2006; Thomas *et al.* 2006).

The NWFP prioritized biodiversity conservation over timber harvesting by establishing (1) a network of late-successional reserves (LSRs) to protect most remaining old-growth forests and habitat for the northern spotted owl and marbled murrelet, (2) a network of riparian reserves and key watersheds to protect and/or restore salmonid habitat, (3) non-reserved "matrix" lands where timber could be harvested using methods that retained old-growth forest components, (4) adaptive management areas to test the plan's assumptions and new silviculture approaches, and (5) a regional ecological and socioeconomic monitoring program (Figure 1; Thomas *et al.* 2006).

The LSRs covered about 80% of the federal land base, and most contained roads and plantation forests established after clearcutting that began in the 1950s. The NWFP directed restoration in plantations in LSRs to increase ecological diversity and accelerate development of old-growth forest characteristics (eg large, old live and dead trees, multilayered canopies). The NWFP also stipulated that a predictable and sustainable level of timber harvest continue from federal forests, and was accompanied by initiatives to help timber-based communities transition and diversify economically (Charnley 2006).

Major outcomes of the NWFP

Our review found that the NWFP made substantial progress toward meeting several of its goals. It protected remaining old-growth forests from clearcutting and enabled growth and development of vegetation conditions to support threatened species, including salmonids and riparian-associated organisms (Davis *et al.* 2015, 2016; Spies *et al.* 2018b). However, while harvest of old-growth trees has essentially ceased on federal lands, populations of northern spotted owl and Washington populations of marbled murrelet, along with other bird species associated with older forests, have continued to decline (Lesmeister *et al.* 2018; Raphael *et al.* 2018; Phalan *et al.* 2019). The number of ESA-listed salmonid species and population units has increased (Reeves *et al.* 2018).

Effectiveness monitoring to determine whether management actions had their desired outcomes for older forests, northern spotted owl, marbled murrelet, and aquatic ecosystems has been continuous and quite valuable. The NWFP set an ambitious target for monitoring biodiversity by directing managers to "survey and manage" about 400 other species potentially associated with old-growth and riparian forests. However,

that program, particularly the pre-disturbance field surveys and annual species review panels, proved to be too expensive to execute and was terminated (Marcot *et al*. 2018), resulting in a dearth of data on the distribution of rare, little-known, and potentially at-risk species. Some of the responsibilities of the Survey and Manage Program were eventually transferred to other programs but only in Washington and Oregon. Under the 2012 planning rule, which has not yet been implemented in the NWFP area, biodiversity conservation efforts should emphasize ecosystem approaches and focus on a few species of concern including, but not limited to, ESA-listed species.

Other unrealized NWFP goals included providing a predictable and sustainable timber supply, new forest restoration-based jobs at levels that were expected by some communities, road decommissioning, and widespread restoration in riparian and dry forests (Charnley *et al*. 2018a; Reeves *et al*. 2018; Spies *et al*. 2018b). Differences between moist and dry, fire-prone forests of the region were recognized in the NWFP when it encouraged active management in LSRs in dry-zone forests to reduce fuels around northern spotted owl nesting habitat. But the NWFP directed managers to focus on younger stands (<80 years old) in LSRs in dry forests (USFS and BLM 1994), and little active management was carried out in older forests whose structure and composition had been substantially altered by fire exclusion. Finally, although the importance of implementation monitoring and adaptive management were acknowledged in the NWFP, these programs were discontinued after a few years by managers due to shrinking budgets. The loss of the programs made it difficult to understand what management actions were conducted, and greatly limited formal opportunities for learning.

Key findings

Many threats to biodiversity lie beyond the control of federal land managers

While the NWFP greatly reduced threats to biodiversity from clearcutting on federal lands, other threats persisted or emerged, several of which are beyond the jurisdiction and control of federal land managers. For example, competitive interactions between the non-native barred owl (*Strix varia*), whose range is expanding rapidly, and the northern spotted owl are contributing to population declines of the latter species (Wiens *et al*. 2014; Dugger *et al*. 2016; Lesmeister *et al*. 2018). A warming climate and forest densification after a century of fire exclusion are leading to drought-induced mortality of old-growth forests (van Mantgem *et al*. 2009) and an increasing area of large patches (>100 ha) of high-severity fires (Reilly *et al*. 2017), which has been the primary cause of declines in northern spotted owl nesting and roosting habitat (Davis *et al*. 2016). The northern spotted owl is adapted to a landscape mosaic of successional stages, but its use of early-successional conditions varies geographically and recent high-severity fire has denuded extensive areas of suitable habitat (Lesmeister *et al*. 2018). As such, despite NWFP and ESA protections, populations of northern spotted owls and their habitat are still declining.

Numerous lines of evidence suggest that habitat protections afforded under the NWFP have been necessary for northern spotted owl conservation (eg Anthony *et al*. 2006); otherwise, populations would have declined more rapidly over the past 25 years. However, the reserve strategy in the NWFP by itself will be insufficient for northern spotted owl recovery. A combination of additional habitat protections outside LSRs, as well as active management of barred owls, may stabilize declining northern spotted owl populations (Diller *et al*. 2016; Lesmeister *et al*. 2018), but these solutions involve trade-offs and contain many uncertainties. For instance, expanding the area of nesting and roosting habitat might benefit the northern spotted owl in moist forests but would reduce wildfire and climate resilience of forests in dry environments (see below). In addition, large-scale removal of barred owls is costly and raises ethical concerns. Further research is needed to understand if site characteristics may mitigate competitive interactions between northern spotted owls and barred owls.

Conservation of salmon and marbled murrelets also depends on factors beyond the control of federal forest managers, including ocean conditions that are sensitive to climate change, and watershed and vegetation conditions on non-federal lands (Figures 1 and 2; Raphael *et al*. 2018; Reeves *et al*. 2018). For example, salmonid spawning and rearing habitats in Pacific coastal areas often fall within stream reaches that occur on non-USFS lands (Figure 3). Wide-ranging carnivores, principally fisher (*Pekania pennanti*), Pacific marten (*Martes caurina*), Canada lynx (*Lynx canadensis*), and wolverine (*Gulo gulo*), are also threatened by activities on non-federal, privately owned lands, including habitat fragmentation, predation, rodenticides, wildfire, and removal of diseased and standing-dead trees as well as down wood (Marcot *et al*. 2018).

Because they do not have jurisdiction outside federal lands and are not responsible for managing fish and wildlife populations, which are controlled by many factors other than vegetation, federal land managers are limited in how much they can contribute to the conservation of wide-ranging species. This reality should temper expectations for federal land management plans and motivate regulatory and management agencies, as well as other landowners and stakeholders, to engage in cross-boundary conservation. Collaborative groups and other multilateral processes have emerged to engage public and private landowners and other stakeholders using an "all-lands" approach (Charnley *et al*. 2017; Davis *et al*. 2017; Butler and Schultz 2019). However, these efforts face challenges and success depends on many factors, such as trust, communication, strong partnerships, resources and management capacity, a supportive policy environment, community leadership, and agency participation (Cheng and Sturtevant 2012; Charnley *et al*. 2017; Cerveny *et al*. 2018).

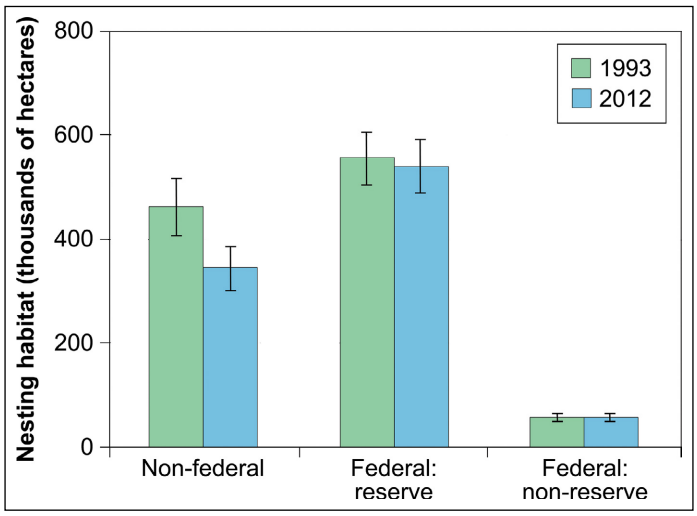

Figure 2. Estimated amounts of higher-suitability marbled murrelet (*Brachyramphus marmoratus*) nesting habitat in 1993 and 2012 on different land ownerships and allocations (Raphael *et al.* 2016). Error bars are 95% confidence intervals from 25 replicated model runs. Total forested land area within the marbled murrelet range in the NWFP area is 8.39 million ha. Adapted from Raphael *et al.* (2018).

Restore dynamics and structure at multiple scales and revisit reserve design

Managing for resistance and resilience to climate change depends on understanding historical fire regimes, including the frequency, severity, and spatial extent of fires, in addition to forest fuel and successional patterns (Hessburg *et al.* 2015). Returning forest ecosystems to historical conditions is likely impossible in the face of a changing climate, invasive species, and legacies of past forest management (Spies *et al.* 2018b); instead, climate-change adaptation is the goal. Historical ecological patterns and processes remain useful guideposts to understanding what resistance and resilience mean (Safford *et al.* 2012). In particular, the ability to quantitatively compare current conditions to past conditions is useful for setting measurable goals, even if those goals differ from historical conditions. Measurable goals are needed for successful application of the new planning rule (Wurtzebach and Schultz 2016), which sets forth a broad ecological framework for conserving biological diversity: namely, to rebuild resilience to disturbance and stressors to promote "ecological integrity" (that is, promote ecosystems that "…occur within their natural range of variation and can withstand and recover from most perturbations" [USFS 2012]).

Networks of large reserves are still considered foundational to conserving biodiversity under climate change (Watson *et al.* 2014), but alterations to the design and management of reserves may be needed in the NWFP area to meet new policy goals and threats to biodiversity. For instance, climate change and wildfire will continue to reduce and fragment suitable environments for some species in the NWFP area, especially late-successional species, mammalian carnivores, and species associated with cool-water

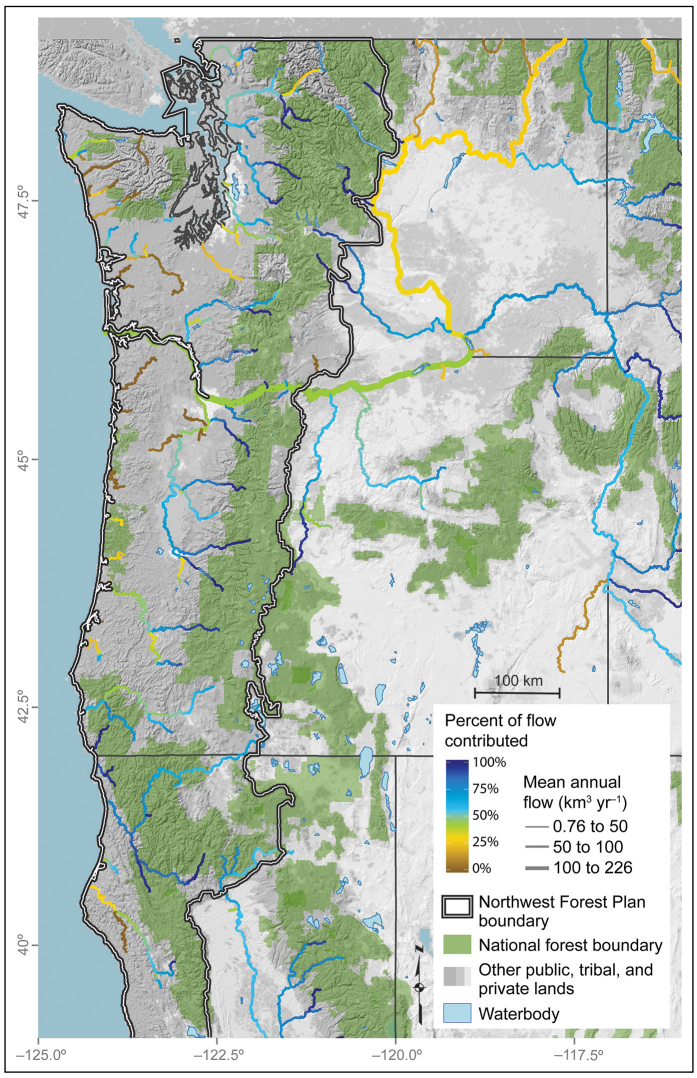

Figure 3. Distribution of major rivers on US Forest Service (USFS) (green) and non-USFS (gray) lands and percentage of annual streamflow contributed from USFS lands in Washington, Oregon, and northern California. Although USFS lands have a strong influence on streamflow in the Cascade Range and Sierra Nevada Mountains, contributions to streamflow in coastal and low-elevation areas are often dominated by other landowners. Data from www.fs.fed.us/rmrs/national-forest-contributions-streamflow-pacific-northwest-region-region-6 (Luce *et al.* 2017). Reproduced from Spies *et al.* (2018c).

streams. Revisiting the design of current reserves is important to help ensure that they protect climate refugia, promote habitat connectivity for endemic species sensitive to local conditions (Carroll *et al.* 2010), and buffer against habitat losses from wildfire (Reilly *et al.* 2018a).

To be most effective, reserves need to be designed and managed to account for variation in historical disturbance regimes (Figure 4; Reilly *et al.* 2018b; Spies *et al.* 2018b), as well as threats from invasive species (Lindenmayer *et al.* 2000) and climate change. The NWFP goal of conserving dense, multilayered, old-growth forests appears to be a relatively good match for managing for ecological resilience in moist forests where fire was historically infrequent (Figure 4; Spies *et al.* 2018b).

Variable density thinning of upland and riparian plantations within reserves can accelerate development of old-growth forest structure and increase its landscape connectivity. Fire suppression is also needed to protect old-growth forest remnants from large, high-severity fires (Halofsky *et al.* 2018). Yet fire suppression also reduces the occurrence of early-successional vegetation, which is an important component of forest biodiversity (Swanson *et al.* 2011). Even "old-growth species", such as the northern spotted owl in the southern part of its range (Franklin *et al.* 2000), rely on early-successional conditions, and salmonids require stream conditions promoted by landslides and debris flows that often follow high-severity fires (Reeves *et al.* 1995). Populations of bird species associated with early seral vegetation have decreased in the NWFP region over the past 25 years, and the areal extent of this vegetation type has declined on both private corporate timberlands (large landholdings intensively managed for timber production and profit) and federal lands (Phalan *et al.* 2019).

The reserve approach of the NWFP – which focuses only on fire-risk reduction and conservation of dense, multilayered forests – is inconsistent with management for ecological integrity in the dry, historically fire-frequent forests (fire frequency <50 years) that occupy 43% of the NWFP area (Figure 4; Spies *et al.* 2018b). In these forests, northern spotted owl nesting and roosting habitat (dense, multilayered forests) were likely limited in the past to fire refugia determined largely by topography. The abundance of northern spotted owl nesting and roosting habitat in dry forests increased during the 20th century as a result of fire suppression and exclusion (Figure 5; Lint 2005), which has led not only to larger patches of high-severity fire but also to a greater proportion of high-severity fire than had occurred historically (Reilly *et al.* 2017). Actions that would promote ecological integrity in fire-prone LSRs include thinning and prescribed fire to reduce fuel continuity and foster the development of trees resistant to droughts and large fires, and restoring low- and moderate-severity fire to support mosaics of open- and closed-canopy forests that vary with topography (Hessburg *et al.* 2015). Wildfires, including high-severity fire, also produce large woody debris, regenerate hardwoods, and promote productivity and landscape resilience for many aquatic species, including salmonids (Reeves *et al.* 2018), in both dry and moist forest zones. A focus on restoring fire and other natural disturbances as a foundational process differs from the original NWFP focus on conserving and restoring older forest habitat, but it is consistent with ecological restoration principles and the 2012 planning rule.

Fire is a critical process in both moist and dry ecosystems, but restoring fire or implementing a "fire surrogate" (eg thinning) is challenging for ecological and socioeconomic reasons. Meeting the goal of restoring dynamics and forest structure while sustaining dense, multilayered forests to support populations of northern spotted owl and other species will require coordinating between management and regulatory personnel, revisiting reserve design, developing new landscape-level conservation strategies, and potentially

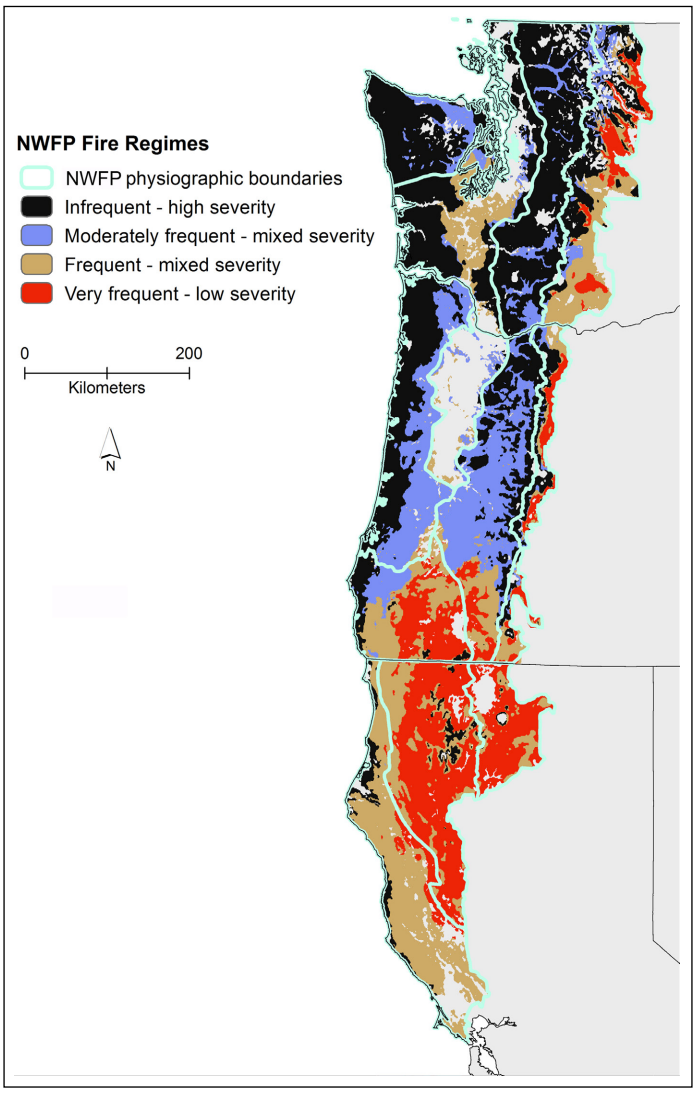

Figure 4. Historical fire regimes of the NWFP area. Moist forests occur in historically infrequent and moderately frequent fire regimes, whereas dry forests occur in frequent and very frequent fire regimes. Reproduced from Spies *et al.* (2018b).

making difficult trade-off decisions (Spies *et al.* 2018c). Given the limitations of restoring landscape patterns and dynamics, vegetation and fuels management would ideally focus on places where it can be most effective and consider broader use of managed wildfire (Barros *et al.* 2018). However, communities of people who live and work in fire-prone landscapes – including homeowners, who should be encouraged to reduce fuels and make structures less susceptible to ignition – must enhance their adaptive capacity and participation in wildfire planning; prescribed fire will also need to become more socially acceptable and receive adequate policy support (Calkin *et al.* 2014; Moritz *et al.* 2014).

Forest restoration can be a win–win situation

Active forest restoration of species and ecosystems depends on the capacity of local communities and federal agencies to implement management. Since the mid-20th century,

Figure 5. The Okanogan-Wenatchee National Forest, in the eastern Cascades (looking west toward Mission Peak) of Washington State, in (a) 1934 and (b) 2010, showing the increase in area and density of forest over that time. Fire exclusion effects on dry forests in the NWFP area typically began in the early 1900s. The landscape in 1934 would still resemble the mosaic of closed forests, open forests, woodlands, and grasslands that characterized dry, fire-frequent forest landscapes in the NWFP area prior to fire exclusion. Some of the forests in 1934 would have been influenced by settlement fires and logging. Reproduced from Spies *et al.* (2018b).

revenues from timber harvest have routinely helped finance other federal forest management activities. An 80–90% decrease in timber harvesting within NWFP federal forests since the NWFP was adopted (Figure 6) was accompanied by a 35% reduction in national forest budgets in the NWFP area following the first decade of the plan (Charnley *et al.* 2018a). Although national forest budgets have since increased to pre-NWFP levels (Grinspoon *et al.* 2016), the agency workforce on NWFP-area national forests in Oregon and Washington declined by 60% between 1993 and 2012. Timber production from non-federal land ownerships in the NWFP area has also declined since the late 1980s, albeit not as precipitously (Figure 6). These trends, along with industry restructuring, market conditions, and technological changes, led to mill closures and job losses in the wood products industry throughout the NWFP area, reducing infrastructure and business capacity for forest restoration on federal lands (Charnley 2006; Charnley *et al.* 2018a). Forest restoration requires not only workers who know how to remove unwanted vegetation and promote desired vegetation, but also mills that can process the removed trees and generate economic value to offset the cost of restoration. Ironically, the workers and mills that supported past federal forest management strategies that led to declines in biodiversity are now needed to work in new ways to help restore the forests.

In many rural forest communities, restoration jobs can help maintain the skills and capacity needed to promote ecological resilience on public and private lands while at the same time generating local economic opportunities. Given social pressure to avoid logging older trees even in non-reserved areas, producing wood from existing plantations in moist, productive forests using variable-retention silviculture may offer a win–win opportunity by providing early-seral vegetation and economic returns (Franklin and Johnson 2012). Restoration in less productive dry forests can also result in a win–win outcome, but in this case economic returns from wood products will be lower and may require subsidies to defray the costs of removing small-diameter wood of little commercial value (Adams and Latta 2005; Charnley *et al.* 2018a), especially over the long term, when prescribed fire would be the primary restoration tool. Structuring federal restoration contracts in ways that make them accessible to businesses in local communities, in addition to planning at large landscape scales over long time frames, would help create the consistent flow of work that is needed to attract investments in processing and contracting capacity.

Ecosystem services – more than timber supply

Socioeconomic conditions in human communities have changed in the NWFP area (Charnley 2006; Charnley *et al.* 2018a,b). Federal forest management now contributes to community socioeconomic well-being in ways that go beyond providing timber and jobs in the wood products industry. Although federal timber remains important, communities also benefit from jobs in forest restoration, firefighting, recreation and tourism, and non-timber forest products, as well as from the production of other ecosystem services such as water (Figure 3). By reframing the agency's mission around ecosystem services – and acknowledging the array of intangible services provided by forests, such as scenery, spiritual enrichment, and learning – the USFS may become more relevant and effective at increasing public support for its multiple-use mission (Deal *et al.* 2017). However, methods for quantifying ecosystem services and communicating with the public about those services are still evolving, and research–management partnerships are needed to accelerate progress.

Collaboration is essential

Public support for active forest management on federal lands may not be uniform due to diverse values and a lack of trust in federal land managers among some stakeholders (Davis *et al.* 2017; Cerveny *et al.* 2018), including local

residents who often express distrust of federal management prescriptions in part due to prior decades of clearcutting of old-growth forests and federal agency management of conflict around timber (Wondolleck 2013; Christensen and Butler 2019). Nonetheless, collaboration can enhance trust if it is based on clearly stated objectives, consistent communication, transparent processes, reasonable timelines, honored commitments, and opportunities for candid deliberation and genuine engagement among diverse stakeholders (Stern and Coleman 2015). Enduring personal relationships between federal employees and members of local communities are also important but are difficult to maintain given the frequent relocation of agency personnel, driven by personal decisions or agency policy (Cerveny *et al.* 2018). Effective forest management depends on understanding the cultural importance of places for local communities and stakeholders, which can shape community response to landscape change or proposed actions (Kil *et al.* 2014).

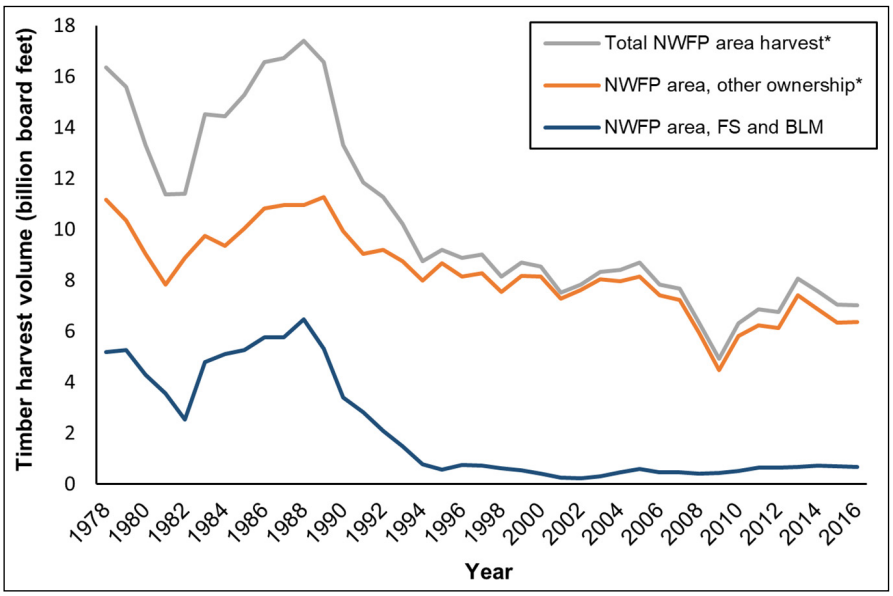

Figure 6. Volume of timber harvested in the NWFP area by landownership*, 1978–2016. Dips in timber harvest in the early 1980s and 2008–2009 are due to economic recessions. FS = US Forest Service; BLM = Bureau of Land Management. (*The California State Board of Equalization, the data source for timber volume harvested from non-federal lands in California, did not report volume harvested from non-federal ownerships by county prior to 1995; it only reported this volume for the state as a whole. Therefore, the "other ownership" and "total harvest" values for 1978–1994 include estimates for the volume harvested from non-federal ownerships in California's NWFP counties. Estimates were calculated based on the average percentage of the total volume harvested on non-federal lands in California's NWFP counties between 1995 and 2016.)

Minority populations are growing within the NWFP area (Charnley *et al.* 2018b) and finding ways to engage diverse populations in collaborations may improve federal forest management for a range of ecological (eg restoration) and socioeconomic (eg community well-being) goals. For example, collaborative engagement with American Indian tribes that recognizes treaty rights and other trust responsibilities can help land managers promote culturally important resources and values (Long *et al.* 2018). Tribal interests are closely aligned with several ecological goals that have become prominent since the NWFP was adopted, such as promoting historical fire regimes (including burning conducted by Native Americans), restoring a diversity of ecological communities (including rivers, wetlands, prairies, and hardwood forests), and promoting community well-being by sustaining ecosystem benefits.

Address uncertainty through monitoring and adaptive management

The NWFP monitoring program – possibly the largest such program undertaken anywhere in the world – has been essential to understanding the effectiveness of the NWFP and the ecological and social changes that have occurred since it was implemented. Nevertheless, adaptive management was discontinued (Stankey *et al.* 2003), a biodiversity monitoring program initially called for in the NWFP was not created (Marcot and Molina 2006), and socioeconomic monitoring was reduced to a minimum owing to limited funding and competing priorities. Major areas of uncertainty persist regarding the viability and fate of rare and little-known species, and the roles of fungi, lichens, bryophytes, invertebrates, and other taxa in ecosystem function. The lack of adaptive management and restoration activities may reflect a trend in which non-USFS stakeholders effectively reduced the range of management options and the autonomy of managers (Maier and Abrams 2018). Transdisciplinary efforts, adaptive management, and monitoring at the scale of large landscapes are among the most important strategies for implementing science-based management and adapting to a changing social–ecological environment (Sample *et al.* 2016). Management actions in the coming years will face considerable uncertainty, making it prudent to design treatments to facilitate learning.

Conclusions

NWFP monitoring and research over the past 25 years have revealed the complexities of managing for multiple ecological and social objectives across a large and diverse federal land base. In 1994, the primary trade-offs appeared to be between conservation of old-growth forests (to meet biodiversity goals) and timber production (to support local economies). We now understand that there are many more challenges in managing forests within the NWFP area, including accounting for climate change; wildfire regimes; trade-offs and synergies among species; ecosystems and

the services they provide; and social values. Preserving vegetation conditions to support at-risk species is necessary but insufficient if other factors control their populations. In addition, the 2012 USFS planning rule set a new policy framework and new approaches for identifying and meeting biodiversity and socioeconomic goals. Focusing management on iconic species and ecosystems such as the northern spotted owl and old growth in the Pacific Northwest was a strong motivator for protecting old-growth forests from clearcutting, but narrowly focused conservation goals can have unintended consequences (eg reducing the resilience of forests in fire-frequent areas) if they fail to adequately recognize broader social–ecological connections and a region's ecological and social diversity. Together with socioeconomic constraints, such goals can also reduce the flexibility that managers need to cope with emerging threats and social–ecological change.

While the NWFP has so far been successful in meeting several of its core ecological objectives, the broader challenge of restoring diverse ecosystems and fire regimes in the face of emerging threats necessitates even greater emphasis on adaptive management, including actions that facilitate restoration of natural processes and promote social–ecological resilience. The potential for adaptive learning to improve management may be realized more broadly when embedded within collaborative landscape restoration efforts, but such efforts will require investments in research and monitoring. Sustaining the many and sometimes competing values supported by forest ecosystems will increasingly depend on active, collaborative management inside and outside reserves, and across agency jurisdictions and ownership boundaries.

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