Forest Ecology and Management 424 (2018) 288–311

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Tamm review

Reconciling wildlife conservation to forest restoration in moist mixed-conifer forests of the inland northwest: A synthesis☆

Larry L. Irwin[a,*], Robert A. Riggs[b], Jacob P. Verschuyl[c]

[a] National Council for Air and Stream Improvement, Inc., P.O. Box 68, Stevensville, MT 59870, United States
[b] Riggs Ecological Research, 62710 Booth Lane, LaGrande, OR 97850, United States
[c] National Council for Air and Stream Improvement, Inc., P.O. Box 1259, Anacortes, WA 98221, United States

ARTICLE INFO

Keywords:
Adaptive management
Birds
Forest restoration
Habitat modeling
Landscape collaborative
Landscape simulation
Mammals
Mixed conifer forests
Silviculture
Wildlife conservation

ABSTRACT

Moist, mixed conifer (MMC) forests, which encompass more than 11 million ha in the Inland Northwest, USA and adjacent Canada, were extensively modified after Euro-american occupation by now-outdated forestry practices and wildfire suppression. Those activities homogenized tree composition and density, modified forest soils, increased risks to insect and disease epidemics, and, in combination with longer drought periods ultimately increased the prevalence of unusually severe wildfires to further homogenize landscapes. Recommendations for restoring structure and function include re-establishing natural fire regimes and disturbance-patch size distributions across landscapes, as well as restoring and maintaining large, old early-seral dominant trees (LOEST), large snags and coarse woody debris, while accounting for physiographic influences. Implementing such recommendations with sensitivity to wildlife conservation requires additional details to account for habitat needs at the planning levels of national forests and districts. We synthesized silviculture-specific literature for wildlife species of greatest conservation concern listed in the strategic wildlife conservation plans of Inland Northwest states ("strategy" species), others of social and economic importance ("focal" species), and some others that are either important in the ecologies of strategy species or otherwise offer literature having particular relevance to MMC silviculture ("facilitative" species). Evaluations of habitat selection behavior and comparisons of species-specific habitat values to tree-stocking guidelines used by silviculturists indicated that most species reviewed are likely to respond positively to restoration, and that a wide array of extant silvicultural methods can be used, provided that large snags and acceptable levels of coarse woody debris are recruited or retained. Thinning followed by routine prescribed burning will be problematic for some wildlife species. Knowledge of wildlife responses to variation in the size distribution of disturbance patches is limited, as is knowledge of wildlife population responses to intentional forestry. Coupling new wildlife research to forest modeling and manipulative experiments within adaptive management and monitoring frameworks will improve predictions of wildlife population responses over the long time frames and multiple spatial scales associated with strategic planning.

1. Introduction

Following Euro-american settlement, moist mixed-conifer (MMC) forests of the interior northwestern U.S. and adjacent areas generally shifted from predominance by large, old, early- to mid-seral, shade-intolerant tree (LOEST) species toward increasingly homogeneous mosaics (Lehmkuhl et al., 1994, Stine et al., 2014) dominated by late-seral, shade-tolerant trees (Arno et al., 2000, Keane et al., 2002, Stine et al., 2014). In these landscapes, early-seral dominant trees include ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), Douglas-fir (*Pseudotsuga douglasii*) and western white pine (*P. monticola*), whereas shade-tolerants include grand fir (*Abies grandis*), white fir (*A. concolor*), and subalpine fir (*Abies lasiocarpa*). Tree densities now are often 2–6 times greater than historically (Marcot et al., 1997). These changes have contributed to increased fuel loads, drought stress, insect and disease risks (Stine et al., 2014), impoverished soils and altered soil microbial processes (Harvey et al., 1999), and also to probable declines of some wildlife species associated with early-seral forests (Swanson et al., 2011; Johnson et al., 2013; Lukacs et al., 2018). Exacerbated by climate warming and wildfire suppression (see Sheehan et al., 2015), these changes have shifted fire regimes from predominantly mixed-severity fires (Agee, 2005) toward regimes with greater prevalence of

☆ Adapted from Technical Bulletin (In prep.), National Council for Air and Stream Improvement, Inc., 1513 Walnut Street, Suite 200, Cary, NC 27511, United States.

* Corresponding author.
E-mail address: llirwin@blackfoot.net (L.L. Irwin).

https://doi.org/10.1016/j.foreco.2018.05.007
Received 18 February 2018; Received in revised form 2 May 2018; Accepted 3 May 2018
0378-1127/

Table 1
Wildlife literature almost never referred to "moist mixed conifer forest" *per se* but rather to various forest or vegetation "types". To help clarify the ecological extent of MMC forests for the purposes of this review, dominant potential vegetation types (PVTs) or plant associations are reconciled below between two aggregate ecological classifications that specifically include MMC forests (Powell et al., 2007; Stine et al., 2014). PVT and association acronyms used in this table are spelled out in Appendix Table A1.

Powell et al. (2007)		PVT[2] orPlant Association[3]	Stine et al. (2014)	
PVG[1]	PAG[1]		Moisture[4]	Fire-severity[5]
Dry upland forest	Warm dry	PSME/PHMA5	Moist-dry	Low to mixed
Moist upland forest	Warm moist	ABGR/BRVU	Moist	Mixed
Moist upland forest	Warm moist	PSME/HODI	Moist-dry	Low to mixed
Moist upland forest	Warm moist	PSME/ACGL-PHMA5	Moist-dry	Low to mixed
Moist upland forest	Warm very moist	ABGR/ACGL	Moist	Mixed
Moist upland forest	Cool moist	ABGR/CLUN2	Moist	Mixed
Moist upland forest	Cool moist	ABGR/LIBO3	Moist	Mixed
Moist upland forest	Cool moist	ABGR/VAME	Moist	Mixed
Moist upland forest	Cool moist	ABLA/VAME[6]	(Not listed)	(Not listed)
Moist upland forest	Cool moist	ABLA/LIBO3[6]	(Not listed)	(Not listed)
Moist upland forest	Cool moist	ABLA/TRCA	(Not listed)	(Not listed)
Moist upland forest	Cool very moist	ABGR/GYDR	Moist to wet	High
Moist upland forest	Cool very moist	ABGR/POMO-ASCA2	Moist to wet	High
Moist upland forest	Cool very moist	ABGR/TRCA	Moist to wet	High
Moist upland forest	Cool wet	ABGR/TABR2/CLUN2	Moist to wet	High
Cold upland forest	Cold dry	ABGR/VASC	Moist-dry	Low to mixed

[1] PVT is Potential Vegetation Group; PAG is Plant Association Group.
[2] As characterized by Powell et al. (2007).
[3] As characterized by Stine et al. (2014).
[4] Approximate moisture regime.
[5] Approximate fire-severity regime.
[6] While Stine et al. (2014) did not list subalpine fir (ABLA) types *per se*, they did include subalpine fir in the potential tree composition of grand fir analogues (ABGR/VAME, ABGR/LIBO3).

extensive high-severity fires that reinforced stand and landscape homogenization (Hessburg et al., 2015, Hessburg et al., 2016). Extensively disturbed MMC forest landscapes are expected to support fewer species considered in need of conservation (McWethy et al., 2010).

Current conditions now challenge forest managers to restore forests that will be more resilient to wildfire and climate change. Stine et al. (2014) and Hessburg et al. (2015) promoted restoration based on landscape ecology principles that would stimulate natural fire regimes and ecological processes by resurrecting historical patch-size distributions, developing a "backbone" of LOEST, and recruiting and retaining large snags and coarse woody debris. Hessburg et al. (2016) refined those suggestions by promoting prescribed fire, managed fires, and management activities that reduce tree densities and create extensive openings dominated by shrub patches and grasslands on southerly slopes and ridges and develop more extensive tree stands on northerly slopes and valley bottoms. Acknowledging significant scientific uncertainty and noting that it may not be possible to re-create the historic range of variation (HRV) among those attributes under added stresses of climatic shifts (Thompson et al., 2008), Stine et al. (2014) also proposed using adaptive management experiments to guide development of a future range of variability (FRV) for these landscapes, which hopefully would be more resilient. Climate and wildfire will certainly be more influential in forest planning than in the past (Keane and Loehman, 2012; Hessburg et al., 2015; Sheehan et al., 2015; Hessburg et al. 2016). Resoration plans for MMC forests may also include some prescriptions developed for drier ponderosa pine and Douglas-fir forests by Churchill et al. (2013): restore LOEST, create within- and among stand variation by retaining *i*ndividual trees or *c*lumps of trees, and creating *o*penings, or ICO forestry.

Yet, environmental concerns for wildlife may translate into activism that would complicate efforts to restsore resilient landscapes because the silvicultural methods that will be applied must be demonstrably sensitive to wildlife. Furthermore, given that future forest management will necessarily depart from historical practices, managers should be prepared to test their expectations for wildlife by subsequent monitoring of responses to manipulative silvicultural experiments at multiple scales, which would also provide the basis for modifying restoration plans and for silvicultural innovations over time. Such efforts will be particularly important for wildlife species that are in greatest need of conservation actions because their populations are small, declining, or of uncertain status, and also for some of the more common species that have important ecological, social, cultural, or economic values.

The complexity of accommodating multiple wildlife species across multiple scales introduces several technical challenges. These include identifying the most appropriate wildlife species and habitat components to monitor, identifying or designing silvicultural methods that can reasonably be expected to accommodate those species, and specifying the temporal and spatial scales at which wildlife responses to restoration silviculture may be best planned, implemented, monitored, and managed. To address some of those challenges Stine et al. (2014) suggested broadscale mapping of "source" habitats (e.g., Wisdom et al., 2000; Johnson and O'Niel, 2001) for "focal" wildlife species, estimating their population status, and also conducting meta-population analyses for large-bodied vertebrates. Source habitat was defined as macro-vegetation presumed by species experts to contribute to stationary or positive population growth in a specified area and time (Wisdom et al., 2000). Focal species are typically those of particular conservation interest or concern, a concept that has been extended to include some species deemed representative of, or serve as proxy for, others (Wiens et al., 2008; Suring et al., 2011).

Stine et al. (2014) recognized that additional guidance would be required to implement their findings at the administrative levels of national forests and districts. To that end, our goal is to complement the ecological syntheses in Stine et al. (2014) and Hessburg et al. (2016) with a review of silviculture as it relates to wildlife in MMC forests. Our principal objectives are:

(a) identify a set of wildlife species that should provide the most valuable feedback via monitoring responses to manipulative adaptive