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Review and synthesis

Consequences of pinyon and juniper woodland reduction for wildlife in North America

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ABSTRACT

Pinyon and juniper (*Pinus* spp., *Juniperus* spp.) woodlands are expanding into shrublands and grasslands throughout much of western North America. Woodland reduction is frequently used to mitigate the effects of conifer encroachment on game species (e.g. mule deer *Odocoileus hemionus*) and shrub and grassland-obligate species (e.g. sage grouse *Centrocercus* spp.). Although these practices are widespread, previous studies on the effects of woodland reduction on animal communities have not yet been synthesized, making it difficult to set priorities for future research and practice. To address this gap, we first summarize the history of pinyon and juniper reduction in western North America and characterize known wildlife habitat associations in pinyon and juniper ecosystems. We then review and synthesize evidence from the scientific literature on wildlife responses to pinyon and juniper woodland reduction. We tallied the outcomes of these studies to determine the relative proportions of positive, negative, and non-significant responses by different taxonomic groups and functional groups. The majority (69%) of animal species responses to woodland reduction treatments were non-significant. However, particular groups of species (taxonomic and/or functional) were more likely to respond positively or negatively, depending on the woodland reduction treatment method. Unexpectedly, investigators often found non-significant or negative responses by ungulates to woodland reduction, and non-significant responses by sagebrush obligate species. However, few studies measured effects on sagebrush obligate species, which limits inference for this group. Indeed, our review demonstrates that the effects of woodland reduction are well-understood for only a subset of taxonomic groups (e.g. birds and small mammals); whereas other groups (e.g. reptiles and terrestrial invertebrates) are consistently under-studied. Further, a shortage of large-scale and long-term research limits our ability to fully understand spatial and temporal wildlife responses to woodland reduction. We encourage practitioners to design and implement pinyon and juniper reduction projects to experimentally assess the effects of these practices on both target and non-target species. Adopting consistent monitoring protocols across projects would also facilitate greater understanding of how factors such as treatment type, size, location and duration result in positive or negative impacts to diverse wildlife of conservation concern.

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1. Introduction

Pinyon and juniper (*Pinus* spp., *Juniperus* spp.) woodlands are one of the most extensive ecosystems in western North America (West, 1984) and support a high diversity of animal species compared with many other plant communities in this region (Finch and Ruggiero, 1993; Paulin et al., 1999). In certain areas, woodlands dominated by juniper trees, pinyon trees, or both (henceforth referred to as pinyon and juniper woodlands, irrespective of dominant cover type) have expanded in range and increased in stand density over the past century (Blackburn and Tueller, 1970; Miller and Rose, 1995, 1999; Stevens, 1999; Romme et al., 2009). The causes of this expansion have been attributed to numerous factors, including fire suppression, livestock grazing, natural recovery from disturbance, natural range expansion, altered climate patterns, and elevated carbon dioxide levels (Romme et al., 2009); yet the empirical evidence on the most important drivers of woodland expansion is mixed and incomplete (Romme et al., 2009). These woodlands are not expanding everywhere. For example, there has been extensive drought-induced woodland mortality, especially of *Pinus edulis* trees, in parts of the southwestern US (Breshears et al., 2005; Mueller et al., 2005; Floyd et al., 2009).

Where these woodlands have expanded into surrounding sagesteppe and forest ecosystems and are considered to impact species of economic or conservation concern, natural resource managers have reduced pinyon and juniper overstory to limit its spread (Miller and Wigand, 1994; Belsky, 1996; Noson et al., 2006). In particular, pinyon and juniper woodland reduction has been widely-used to improve forage and habitat quality for rare species (e.g., sage grouse *Centrocercus* spp.), hunted species (e.g., mule deer *Odocoileus hemionus*), and livestock (Plummer et al., 1968; Stevens, 1987; Baruch-Mordo et al., 2013; Bergman et al., 2014). The use of woodland reduction practices is increasing as resource managers try to meet the challenge of conserving and enhancing habitat for species sensitive to conifer encroachment (US Bureau of Land Management, 2011; Baruch-Mordo et al., 2013; DOI, 2013), and as a result of fuel reduction under the National Fire Plan (Schoennagel and Nelson, 2011).

Woodland reduction to limit pinyon and juniper expansion or to enhance habitat for target species may not benefit all animal species; pinyon and juniper specialists may decline and effects are not well-understood for some taxonomic groups. Yet, there is no synthetic review summarizing the consequences of these practices for wildlife. Such a review is needed to evaluate the success and shortcomings of current woodland reduction practices for diverse species, and to set priorities for future research and management.

In the following review, we address this need by first briefly summarizing the history of pinyon and juniper woodland reduction activities in western North America. We then discuss the diversity of animal species associated with pinyon and juniper woodlands to provide context for understanding how woodland reduction will affect a variety of taxonomic groups. We later review and synthesize empirical evidence from the scientific literature to address our primary research questions: (1) what are the effects of woodland reduction on wildlife?, and (2) how do these effects vary across different taxonomic groups, functional groups, treatment methods, and temporal and spatial scales? We also identify the scope (i.e., geographic, spatial and temporal scales, taxonomic groups, and treatment methods) to which our findings apply and highlight future research priorities to fill major gaps in understanding. Finally, we draw on the results of this review to discuss how these findings can be used to inform woodland reduction strategies that achieve multi-species conservation objectives.

2. Pinyon and juniper woodland reduction history

Pinyon and juniper woodlands cover 40 million ha of land in the United States (Romme et al., 2009) and are the third most extensive plant community in the country (West, 1984). Pinyon–juniper stands have expanded into non woodland areas and increased in tree density throughout much, but not all, of their range over the last 100–150 years (see Romme et al., 2009 for a comprehensive review of the patterns and drivers of woodland expansion). These changes have had diverse consequences for plant and animal communities. Areas of high pinyon and juniper cover have been associated with decreased diversity and cover of understory shrubs, herbs and grasses (Blackburn and Tueller, 1970; Tausch et al., 1981; Pieper, 1990; Gottfried et al., 1995; Tausch and West, 1995; Miller et al., 2000), and reduced numbers of understory seeds in the soil seed bank (Koniak and Everett, 1982; Poulsen et al., 1999). These vegetative changes have reduced habitat quality for some wildlife species and livestock by reducing forage availability (Short et al., 1977; Short and McCulloch, 1977; Hoenes et al., 2012). The loss of herbaceous cover in the understory may also make these stands more susceptible to soil erosion, with subsequent negative impacts on water quality (Roundy and Vernon, 1999). However, others have suggested that the evidence on the impacts of increased pinyon and juniper cover on forage quality and erosion properties is inconsistent (Belsky, 1996).

The demonstrated and perceived impacts of woodland expansion have often prompted land managers to reduce the density or limit the extent of pinyon and juniper woodlands using mechanical methods (e.g. chaining, bulldozing), or by thinning, prescribed fire, or combinations of mechanical removal and fire (Plummer et al., 1968; Aro, 1971; Tausch and Tueller, 1977; Stevens, 1987, 1999; Evans, 1988; West, 1988; Redmond et al., 2014). Historically, chaining has been the method most widely employed by land managers to reduce pinyon and juniper woodlands (Aro, 1971; Evans, 1988; Redmond et al., 2014). Evans (1988) reported that over 100,000 acres had been chained by 1988 on land managed by the Forest Service and the Bureau of Land Management.

Woodland reduction efforts have had mixed results in terms of successfully reducing tree cover and preventing re-establishment (Tausch and Tueller, 1977; Stevens, 1987; Evans, 1988; Van Pelt et al., 1990; Stevens and Walker, 1996; Redmond et al., 2013; Bristow et al., 2014). Tausch and Tueller (1977) reported that trees steadily reinvaded and dominated sites within 15 years of treatment, leading to declines in understory herbaceous plant abundance and requiring re-treatment. Evans (1988) also