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Pinyon-juniper removal has long-term effects on mammals

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ABSTRACT

Removing tree cover is a common forest management practice, and pinyon-juniper woodlands in the western United States have been the focus of tree reduction efforts for decades. The scale and intensity of tree removal practices are expected to increase as technology advances and as land managers are tasked with meeting multiple objectives, including fire prevention and habitat enhancement for livestock and wildlife of conservation concern. However, the long-term consequences of pinyon-juniper removal on animal communities are virtually unknown. The objectives of this study were to assess whether mammal habitat use differs between reference pinyon-juniper woodlands and stands that were mechanically disturbed by chaining more than 40 years ago, and to determine if these differences are associated with particular habitat characteristics. We used remotely triggered wildlife cameras to evaluate differences in mammal habitat use of historically chained sites ($n = 22$) and reference sites ($n = 22$) in northwestern Colorado. Our results demonstrate marked differences in habitat use between chained sites and reference woodlands for most detected mammal species. Bobcat, mountain lion, American black bear, golden-mantled ground squirrel, and rock squirrel all showed a negative response to historically chained sites, indicating long-term effects of tree removal on these species. In contrast, habitat use of chipmunk, mountain cottontail, and coyote did not differ between chained and reference sites. For most species, habitat use was influenced by specific vegetation characteristics, such as proportion of tree cover, which could be factored into management decisions. By understanding the long-term consequences of tree removal for diverse mammal species, we are better equipped to adapt forest management practices to benefit species of both economic and conservation concern.

1. Introduction

Removing or reducing tree cover to benefit livestock or game species has been a common forest management practice for decades (Aro, 1971; Yahner, 1984; Redmond et al., 2013; Bergman et al., 2015). The scale and intensity of tree removal practices is expected to increase as technology advances and land managers are tasked with meeting multiple objectives, including fire prevention and enhancing forage and habitat for livestock and shrub-dependent wildlife in areas undergoing urbanization and energy development (Connelly et al., 2000; Redmond et al., 2013; Bergman et al., 2014). Although tree removal practices are widespread and pervasive in some forest ecosystems, little is known about the long-term effects of tree removal on wildlife communities (Bombaci and Pejchar, 2016).

During the last half-century, pinyon-juniper (P-J) woodlands have been a major focus of both forest conservation and tree reduction efforts (Evans, 1988; Redmond et al., 2014). Collectively, P-J woodlands are the third largest vegetative community in the United States, covering over 40 million hectares (Romme et al., 2009). P-J woodlands are also an important source of food and cover for woodland-dependent wildlife species and forage for livestock (Schott and Pieper, 1987; Romme et al., 2009). However, both pinyon and juniper trees have been expanding into grasslands and shrublands for the past 150 years (Romme et al., 2009). Pinyon-juniper expansion into grasslands and shrublands reduces forage for livestock, increases fuel for wildfires and reduces habitat for economically important or rare species that depend on open habitats, such as mule deer (*Odocoileus hemionus*) and Greater Sage-grouse (*Centrocercus urophasianus*) (Terrel and Spillett, 1975; Evans, 1988). Tree removal and reduction has thus become a common tool for forest and wildlife management in P-J ecosystems (Aro, 1971; Bergman et al., 2014).

Historically, a mechanical technique known as chaining was the most common method for removing tree cover (Aro, 1971; Evans, 1988; Miller and Wigand, 1994; Redmond et al., 2014). Between 1950 and 1964, 1.2 million hectares of P-J were removed via chaining in the U.S. (Box et al., 1966). Chaining uproots trees and shrubs

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by dragging heavy anchor chains between two bulldozers across the forested landscape (Aro, 1971; Sedgwick and Ryder, 1986; Bureau of Land Management, 2008). Chaining is an efficient method for killing older, larger trees over a large area, and increasing herbaceous forage for livestock and economically important wildlife (Aro, 1971). Because chaining removes all or most trees, P-J woodlands are replaced with open grassland and shrubland habitats (Tausch and Tueller, 1977). Over time, the removal of P-J cover can shift the plant community from a woodland-dominated system to a shrub-dominated system (Redmond et al., 2013). Specifically, P-J removal can lead to reduced tree cover and increased cover of shrubs and perennial grasses (Evans, 1988; Yorks et al., 1994; Redmond et al., 2014). Although the use of chaining has tapered off since the 1970's (Redmond et al., 2013), it has been replaced with other tree removal methods that also reduce pinyon and juniper cover and increase herbaceous vegetation (Owen et al., 2009; Huffman et al., 2013; Redmond et al., 2014).

Regardless of the method employed, tree removal and subsequent changes to the plant community may fundamentally alter habitat use by mammals (Andren et al., 1994), particularly in slow-recovering systems, such as P-J woodlands (Schott and Pieper, 1987). Mammals contribute to important ecological processes, such as seed dispersal and nutrient cycling, and small and medium-sized mammals are prey sources for predatory birds and large carnivores (Holechek, 1981). Thus, understanding the long-term effects of the widespread practice of P-J removal on mammal species is both ecologically interesting and important for the conservation and management of ecosystems.

The short and long-term effects of tree removal on medium and large-sized mammals in temperate and arid forest systems remain poorly understood (Crooks, 2002), and most studies of small mammals evaluated effects only shortly after tree removal. For example, habitat use of generalist rodent species (e.g., deer mouse, *Peromyscus maniculatus*) increased immediately following chaining (Baker and Frischknecht, 1973; O'Meara et al., 1981; Sedgwick and Ryder, 1986). Specifically, O'Meara et al. (1981) and Sedgwick and Ryder (1986) recorded greater numbers of least chipmunks (*Tamius minimus*) in chained sites than in undisturbed references sites, but found a decrease in the total abundance of pinyon mouse (*Peromyscus truei*) – a pinyon-juniper specialist. Sedgwick and Ryder (1986) also found that golden-mantled ground squirrels (*Callospermophilus lateralis*) were caught less often in chained sites than in reference sites. In New Mexico, lagomorphs preferred chained sites to reference sites immediately following disturbance (Kundaeli and Reynolds, 1972; Howard et al., 1987). With the exception of Howard et al. (1987), these aforementioned studies occurred in the few years following tree removal. Inference about changes in species composition immediately following habitat disturbance (e.g., 1–3 years) may or may not predict long-term effects on community dynamics (Stouffer et al., 2011). Although long-term effects on species can go undetected in short-term studies (Laurance et al., 2002; Laurance et al., 2011), these baseline studies provide the unique opportunity to revisit historic mechanically disturbed sites and compare short and long-term changes to mammal habitat use.

We investigated whether tree removal intended to increase forage for livestock and mule deer has long-term consequences for other mammal species. Using remotely-triggered wildlife cameras, we compared mammal habitat use within areas of P-J woodlands that were chained >40 years ago and reference woodlands in the Piceance Basin of Northwest Colorado, USA. Our research objectives were to (1) evaluate differences in habitat use between historically chained and reference sites, and (2) identify vegetation characteristics that influenced habitat use in our study area. Where mammal habitat use is associated with particular vegetation characteristics, we suggest incorporating these characteristics into future forest management practices, with the objective of minimizing impacts on species of conservation concern.

2. Methods

2.1. Study site

We examined mammal habitat use in historically chained and intact P-J woodlands on public land managed by the Bureau of Land Management in the Piceance Basin of northwestern Colorado, U.S.A. Dominant land uses in this P-J ecosystem include oil and gas extraction and domestic livestock grazing (Northrup et al., 2015). The area is topographically diverse and consists of high plateaus and deeply incised valleys. Our sampling sites ranged from approximately 1500–2400 m in elevation. Woodlands are dominated by pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) (Sedgwick, 1987). The dominant shrubs are antelope bitterbrush (*Purshia tridentata*), mountain mahogany (*Cercocarpus montanus*), big sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus* spp.), common chokecherry (*Prunus virginiana*), and Saskatoon serviceberry (*Amelanchier alnifolia*) (O'Meara et al., 1981; Sedgwick, 1987).

2.2. Site selection

To assess habitat use of mammals in chained and reference woodlands, we established sampling sites in areas that historically underwent mechanical tree removal via chaining ("chained sites") and P-J woodlands that had not been mechanically disturbed or subject to any large-scale disturbance ("reference sites"). We identified areas that had been chained in the 1950's – 1970's using local knowledge from land managers and aerial imagery. We visited each historically chained location to confirm that no additional disturbance (i.e., prescribed fire, wildfire, or mechanical tree removal) had occurred since the initial disturbance. This was evidenced by the presence of many large, decaying, fallen trees and the absence of charred debris. Nine chained areas ranging in size from 3 to 1243 ha were identified. Using Geographic Information Systems (GIS), we established 22 sampling sites throughout these areas. We placed our first sampling site within each chained area by picking a random location in the approximate center of an accessible portion of the area. We then placed additional sampling sites in each cardinal direction, such that all sites were at least 250 m apart. Because we began allocating sites in the smallest chained areas first, our design allowed for one site in each of the smallest areas and up to 6 sampling sites in the largest areas (Fig. 1).

Reference sampling sites ($n = 50$) had been previously established across similar elevations and soil types (i.e., loam) within the study area for an ongoing wildlife-monitoring program. All reference sites were randomly placed on the landscape using GIS and were buffered from disturbed areas (e.g., other areas of tree removal or fire) by at least 250 m. Each reference site was ground-truthed to verify that it was within P-J woodlands. We randomly selected 22 reference sites for this study from the larger pre-existing set of reference sites using GIS to maintain a consistent sampling effort between the chained and reference sites (Magurran, 2004). Because five of the nine historically chained areas were spatially aggregated on the landscape, we stratified reference sites such that 16 sites were randomly selected from locations near the large cluster of chained areas (Fig. 1B). The remaining 6 sites were geographically dispersed across the study area (Fig. 1A). This design ensured that all reference sites were within 15 km of the historically chained areas (Fig. 1).