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Long-term livestock grazing alters aspen age structure in the northwestern Great Basin

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ABSTRACT

We determined the age structure of quaking aspen (*Populus tremuloides*) over the period 1850–2009 in Hart Mountain National Antelope Refuge riparian areas to evaluate potential influences of (a) livestock herbivory and (b) climate on aspen demography. We found a significant decline in aspen recruitment ($p < 0.05$) in the late 1800s, coincident with the onset of high levels of Euro-American livestock grazing. Although livestock use was regulated following establishment of the refuge in 1936, low levels of aspen recruitment continued. After termination of livestock grazing in 1990, aspen recruitment on the refuge increased ($p < 0.05$) by more than an order of magnitude in comparison to levels occurring during the previous half-century of regulated grazing. Climate variables (i.e., Palmer Drought Severity Index, annual precipitation, and annual temperature) appeared to have little influence on long-term patterns of aspen recruitment. Overall, results are consistent with top–down forcing by livestock herbivory as the major factor associated with a century of reduced aspen recruitment on HMNAR. Where long-term declines in aspen are currently underway on grazed lands in the western US, land managers need to carefully consider the potential effects of livestock and alter, as needed, management of these ungulates to ensure retention of aspen woodlands and their ecosystem services.

1. Introduction

Quaking aspen (*Populus tremuloides*) are widely distributed across the western United States (US) and are valued for landscape diversity, wildlife habitat, aesthetics, recreational sites, wood fiber, and livestock forage (Shepperd et al., 2001). Aspen normally occur on moist sites and their canopies transmit substantial light, contributing to a biologically diverse understory. Thus, changes in aspen stand dynamics often index alterations in the composition and structure of understory plant communities (DeByle and Winokur, 1985). The age structure of aspen stands (i.e., number of aspen/ha vs. date of establishment) provides an important approach for characterizing stand dynamics as well as assessing the effectiveness of factors influencing them (e.g., Olmsted, 1979; Binkley, 2008; Halofsky and Ripple, 2008).

Aspen extent in the western US greatly decreased over the last century with losses in seven western states ranging from 49% to 96% (Bartos, 2001). Possible causes of decline include altered fire regimes, conifer competition, direct and indirect effects of a changing climate, high levels of ungulate herbivory, and others (Kay, 1997; Hanna and Kulakowski, 2012; Seager et al., 2013). However, where aspen stands occur interspersed with coniferous forests, such as on the western slope of the Rocky Mountains in Colorado, their coverage has not declined (Manier and Laven, 2002; Zier and Baker, 2006). In western Canada, aspen have been undergoing upslope range expansion due to the combined effects of forest harvesting and a warming climate (Landhauser et al., 2010).

Early studies (e.g., Houston, 1954) reported that livestock herbivory could be a major factor reducing aspen recruitment (i.e., growth of sprouts/seedlings into tall saplings and trees) and altering the composition of understory plant communities. Not only are aspen sprouts/seedlings and many of the deciduous shrubs and forbs associated with aspen stands highly palatable to livestock (DeByle and Winokur, 1985), but livestock often spend a high proportion of time within riparian areas. Thus, plants growing in these areas frequently experience high levels of herbivory and trampling (Kauffman and Krueger, 1984). Livestock use has not only been found to affect soils, biological soil crusts, hydrologic processes, and habitat conditions for terrestrial and aquatic species

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(Fleischner, 1994; Belsky et al., 1999), but it is the most widespread use of public lands in the American West, occurring annually across nearly one million square kilometers (Beschta et al., 2013). Although aspen dynamics in the western US can be affected by a variety of factors, regional studies have recently identified climate change as a major driver of aspen woodland decline (e.g., Rehfeldt et al., 2009; Hanna and Kulakowski, 2012).

For at least several decades prior to 1990, aspen recruitment in gallery forests along perennial streams on the Hart Mountain National Antelope Refuge (HMNAR) was absent or occurring only at low levels, and mortality of overstory aspen trees was common (Fig. 1a). Although overstory mortality has continued in recent years, a major increase in aspen recruitment is currently underway in many stands (Fig. 1b; Earnst et al., 2012). Today, aspen stands on the refuge generally exhibit a "two-layered" canopy – an upper layer comprised of sparsely occurring overstory trees, many of which are dying, and a dense understory of sprouts, saplings, and medium-sized trees (Fig. 1c). We undertook this study to identify when major changes in the age structure of riparian aspen woodlands occurred and the factor(s) likely contributing to such changes. Because conifer competition, wildfires, and wild-ungulate herbivory are not having widespread effects on aspen stand dynamics within the refuge (Dobkin et al., 1995; Earnst et al., 2012), we were left with three competing hypotheses: shifts in aspen age structure have been primarily influenced by (1) livestock herbivory, (2) climate, or (3) a combination of these two major ecosystem drivers.

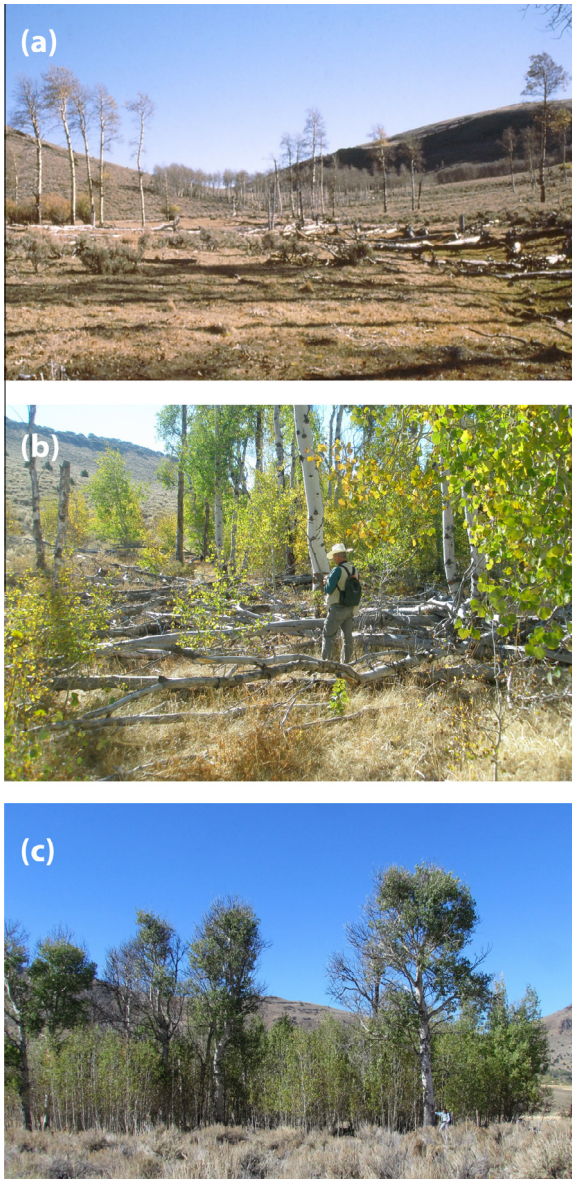

Fig. 1. Examples of aspen stands on Hart Mountain National Antelope Refuge showing (a) ongoing overstory mortality and a long-term lack of understory recruitment (1990 photo), (b) high levels of continuing overstory mortality with increased recruitment of understory aspen (2012 photo) and (c) remaining overstory trees with high levels of understory recruitment (2012 photo) resulting in a "two-layered canopy" indicative of a long-term recruitment gap.

1.1. Study area

HMNAR in southeastern Oregon (42°25′N, 119°40′W) is managed by the U.S. Fish and Wildlife Service and comprises 1125 km^2 in Lake County, with Harney County bordering the refuge's eastern edge. Hart Mountain is massive fault-block with a north–south trending axis and peaks up to 2444 m of elevation. A steep escarpment comprises the west side of the block whereas the east side descends in a series of rolling hills and low ridges to the sagebrush-shrub steppe typical of southeastern Oregon and the Great Basin. Rock, Guano, Deer, and Stockade Creeks are the primary perennial streams draining the eastern portion of Hart Mountain.

Upland vegetation on the eastern side of Hart Mountain consists primarily of sagebrush (*Artemisia* spp.) shrub steppe intermixed with smaller areas of bitterbrush (*Purshia tridentata*), mountain mahogany (*Cercocarpus ledifolius*), and western juniper (*Juniperus occidentalis*). Upland aspen (snow-pocket stands) occur on moist sites, often associated with seasonal snowpack accumulations (Dobkin et al., 1995; Earnst et al., 2012), and mostly comprised of dense stands of small trees. Nearly 90 ha of riparian habitat along intermittent and perennial streams on the refuge are dominated by aspen stands that were the focus of this study (FWS, 1994). In general, these stands persist in the absence of major disturbance (s) and represent a "stable" aspen type (Rogers et al., 2010; 2014).

Pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), and bighorn sheep (*Ovis canadensis*) reside on the refuge (HMNAR annual narrative reports). The refuge's summer pronghorn population of <500 animals in the 1970s increased to 1000–2000 animals by the 1990s. Over the past decade this population ranged from ca. 2000 to 3500 animals. Mule deer numbers during the last two decades have been estimated at well below 1000 animals (Oregon Department of Fish and Wildlife, unpublished data) and in 2003, a small herd of 15–20 elk (*Cervus elaphus*) began to use the refuge. However, neither pronghorn, deer, nor elk use the refuge as winter range at elevations supporting aspen.

After establishment in 1936, the refuge continued to be grazed each summer by domestic sheep, cattle, and horses. Except for small bands of feral horses, only cattle grazing occurred after 1946, with 30 fenced pastures eventually established for managing livestock distribution and forage utilization. Even with controlled livestock numbers and distributions, significant grazing impacts to upland and riparian plant communities, soils, and stream systems continued to accumulate (FWS, 1994). Livestock use on the refuge was eliminated following the 1990 grazing season (FWS, 1994).

2. Methods

In October 2012, we sampled riparian aspen along the four major perennial streams draining the eastern side of Hart Mountain's fault-block ridge, including Barnhardi Meadow which separates the upper and lower reaches of Rock Creek (Table 1 and