Fall and spring grazing influence fire ignitability and initial spread in shrub steppe communities

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Abstract. The interaction between grazing and fire influences ecosystems around the world. However, little is known about the influence of grazing on fire, in particular ignition and initial spread and how it varies by grazing management differences. We investigated effects of fall (autumn) grazing, spring grazing and not grazing on fuel characteristics, fire ignition and initial spread during the wildfire season (July and August) at five shrub steppe sites in Oregon, USA. Both grazing treatments decreased fine fuel biomass, cover and height, and increased fuel moisture, and thereby decreased ignition and initial spread compared with the ungrazed treatment. However, effects differed between fall and spring grazing. The probability of initial spread was 6-fold greater in the fall-grazed compared with the spring-grazed treatment in August. This suggests that spring grazing may have a greater effect on fires than fall grazing, likely because fall grazing does not influence the current year’s plant growth. Results of this study also highlight that the grazing–fire interaction will vary by grazing management. Grazing either the fall or spring before the wildfire season reduces the probability of fire propagation and, thus, grazing is a potential fuel management tool.

Additional keywords: fuel management, fuel moisture, grazing–fire interaction, grazing management, sagebrush, wildfire suppression.

Introduction

Grazing, fire and their interaction affect ecological dynamics of wildlands globally (Fuhlendorf and Engle 2004; Kerby et al. 2007; Waldram et al. 2008). However, little is known about the influence of grazing on fires in many ecosystems, in particular its potential to be used as a fuel management tool. As area burned in wildfires is increasing in some regions and incidences of large wildfires occur more frequently (Krawchuk et al. 2009; Adams 2013; Doerr and Santin 2016), it is critical to understand the effects of grazing. This is especially imperative in ecosystems experiencing unprecedented change from increased wildfire frequency (D’Antonio and Vitousek 1992).

The increase in large wildfires has resulted in billions of dollars expended annually to suppress wildfires in the US (National Interagency Fire Center 2017). These costs will likely increase because larger and more frequent and severe wildfires are expected with climate change and increasing CO₂ levels (Fried et al. 2004; Fulé 2008; Yue et al. 2013). These effects have resulted in an increased need for fuel management (Daugherty and Snider 2003; Snider et al. 2006). However, it is challenging and potentially prohibitively expensive to apply fuel management across vast wildlands. Grazing by livestock is likely the most cost effective and practical treatment to apply across large landscapes scales to manage herbaceous fuels (Davies et al. 2015). Grazing can reduce fuel biomass, heights and continuity, and increase fuel moisture content (Blackmore and Vitousek 2000; Briggs et al. 2002; Davies et al. 2010, 2015). These grazing-induced alterations to fuels can result in less extreme fire behaviour, intensity and severity (van Langevelde et al. 2003; Kimuyu et al. 2014; Evans et al. 2015; Davies et al. 2016). However, the effects of grazing, through fuel modification on ignition and initial fire spread (from ignition to the next fuel source) are unknown.

Grazing effects have largely been confined to comparing one grazing management strategy with ungrazed areas. Grazing influence on fuel characteristics, fire ignition and initial spread, however, likely varies by grazing management. Effects of grazing on plant communities depend on grazing management (Davies et al. 2014); therefore, intuitively, grazing effects on fire vary by grazing management. However, the effects of different grazing management on fuel and fire characteristics have not be investigated. Many grazing management strategies exist; however, three grazing scenarios typically occur before the wildfire season: (1) ungrazed in the past and current growing season (ungrazed); (2) grazed in the fall of the prior year, but ungrazed...
in the current year (fall-grazed); and (3) ungrazed in the prior year, but grazed in the spring of the current year (spring-grazed).

The purpose of the present study was to evaluate effects of fall and spring grazing by cattle (Bos taurus) on fuel characteristics and probability of fire ignition and initial spread during the wildfire season. We hypothesised that: (1) both grazed treatments would increase fine fuel moisture, decrease fuel biomass, height, continuity and cover, and decrease fire ignition and initial spread probabilities compared with the ungrazed treatment, (2) that these effects would be greater in the spring- than fall-grazed treatment.

Materials and methods

Study area

Five study sites were located ~50–56 km west of Burns, Oregon, USA (latitude 43°29′N, longitude 119°43′W). Climate is cool and wet in the winter and hot and dry during the summer. Wildfire season occurs during the summer, with most wildfires occurring in July and August. Study sites were Wyoming big sagebrush (Artemisia tridentata Nutt. subsp. wyomingensis Beetle and A. Young)—bunchgrass communities with an understorey dominated by native bunchgrasses. Shrub cover averaged 21% across study sites. Dominant bunchgrasses were Thurber needlegrass (Achnatherum thurberianum (Piper) Barkworth) and bluebunch wheatgrass (Pseudoroegneria spicata (Pursh) A. Löve). Average distance between study sites was 3 km. Elevation at study sites ranged from 1402 to 1469 m with slopes between 0 and 20%. Crop year precipitation (1 Oct–30 Sept) was 90 and 86% of the 30-year average in 2014–15 and 2015–16 respectively. These shrub steppe communities are estimated to have historically burned every 50–100+ years (Mensing et al. 2006).

Experimental design

We used a randomised complete block design with five sites (blocks) and three treatments. Treatments were randomly assigned to 50 × 50-m plots in each block. Plots had a 5-m buffer between them to reduce edge effects. Treatments were: ungrazed, fall-grazed and spring-grazed. Grazing treatments were applied with five heifers (365 to 450 kg) that grazed plots between them to reduce edge effects. Treatments were: ungrazed, fall-grazed and spring-grazed. Grazing treatments were randomly assigned during trials. Two bunchgrasses were selected at random on each sampling date in each treatment replicate and ignited with the lighter using the above procedure. Ignition occurred on the upwind side of the bunchgrass. A bunchgrass was considered burned if the entire crown was burned (i.e. black). Initial spread was considered successful if flames from the ignited bunchgrass ignited another fuel source.

Results

Probability of ignition differed among treatments and varied by date (Fig. 1; \( P < 0.001 \) and 0.021). Ignition probability was 170 to 220% greater in the ungrazed compared with the fall- and spring-grazed treatments (\( P = 0.001 \) and <0.001), but did not differ between grazed treatments (\( P = 0.284 \)). Probability of perennial bunchgrass burning varied among treatments (Fig. 1; \( P = 0.037 \)), but did not differ between dates (\( P = 0.448 \)).
Perennial bunchgrasses were 200% more likely to burn in the ungrazed than the spring-grazed treatments ($P = 0.013$). Bunchgrass burn probability did not differ between the ungrazed and fall-grazed treatments or the fall- and spring-grazed treatments ($P = 0.092$ and $0.238$). Likelihood of initial spread differed among treatments (Fig. 2; $P = 0.002$), but did not vary between dates ($P = 0.166$). Spread probability was greater in the ungrazed than in the fall- and spring-grazed treatments ($P = 0.030$ and <0.001) and greater in the fall-grazed compared with the spring-grazed treatment ($P = 0.022$). The probability of spread was 8 times greater in the ungrazed compared with the spring-grazed treatment in August. The interaction between date and treatment was not significant for ignition, bunchgrass burn probability or initial spread ($P > 0.05$).

Herbaceous fuel moisture varied among treatments and by date (Fig. 2; $P = 0.002$ and 0.022). Herbaceous fuel moisture was 1.6 to 1.9-fold and 2.0 to 2.2-fold greater in the grazed treatments compared with the ungrazed treatment in July and August respectively ($P = 0.004$ and <0.001). Grazed treatments did not differ in herbaceous fuel moisture ($P = 0.250$). Sagebrush moisture did not differ among treatments (data not shown; $P = 0.590$), but was 1.7 times greater in July than in August (data not shown; $P < 0.001$).

Herbaceous fuel cover varied among treatments (Fig. 3; $P = 0.014$) with it being 140 and 170% greater in the ungrazed compared with the fall-grazed and spring-grazed treatments respectively ($P = 0.021$ and 0.006). Herbaceous fuel cover did not differ between grazed treatments ($P = 0.414$). Continuity of herbaceous fuel varied among treatments (Fig. 3; $P = 0.050$). Herbaceous fuel continuity length was 1.5-fold greater in the ungrazed than spring-grazed treatment ($P = 0.018$), but did not differ between the ungrazed and fall-grazed treatments ($P = 0.170$) or grazed treatments ($P = 0.183$). Shrub cover and continuity did not vary among treatments (data not shown; $P = 0.288$ and 0.936). The height of perennial bunchgrass current year’s growth varied among treatments ($P < 0.001$). Perennial bunchgrass current year’s growth height was less in the spring-grazed (16 ± 2 cm) compared with the fall-grazed (38 ± 3 cm) and ungrazed (45 ± 4 cm) treatments ($P < 0.001$), but did not differ between the fall-grazed and ungrazed treatments ($P = 0.193$). Height of bunchgrass prior years’ growth varied among treatments ($P = 0.001$). It was greater in the ungrazed (18 ± 4 cm) treatment compared with the fall-(6 ± 1 cm) and spring-grazed (5 ± 2 cm) treatments ($P = 0.001$ and <0.001), but did not differ between grazed treatments ($P = 0.693$). Fine fuel biomass varied by treatment.
grazing did not influence current year’s herbaceous vegetation. Grazing had less effect on fuels than spring grazing because fall grazing management strategies was most evident in August, when the fall-grazed treatment was 6-fold more likely to have initial fire spread than the spring-grazed treatment (Fig. 2). Thus, spring grazing, compared with fall grazing, is more likely to induce changes in fuels that reduce the likelihood of wildfire, even though both treatments were associated with reduced ignition potential and initial fire spread.

Effects varied by grazing management strategy, highlighting the importance of understanding the complexity of grazing and the grazing–fire relationship and not treating grazing as a simply grazed or ungrazed. We only evaluated differences in timing of one grazing event; however, effects on fire likely vary by a host of factors including defoliation level and frequency, herbivore type, grazing history, plant community and site characteristics, and interactions among these factors. A better understanding of how grazing management influences fuels and subsequent wildfires across a broad range of plant community and site characteristics is needed to improve management. This is particularly important because of increasing frequency and size of wildfires (Fule´ 2008; Krawchuk et al. 2007; Adams 2013) and escalating cost of suppression (Calkin et al. 2005; National Interagency Fire Center 2017).

Grazing and fire occur across the majority of wildlands around the globe; therefore, our results suggest grazing is likely influencing the probability of initial ignition and spread of fires globally. Grazing, for example, has been demonstrated to reduce fire temperature and severity in Africa (van Langevelde et al. 2003; Kimuyu et al. 2014) and, similarly, in the United States (Davies et al. 2016). Thus, our results suggest that grazing has the potential to be managed to decrease the probability of wildfire propagation in many fire-prone ecosystems. Using livestock grazing to manage herbaceous fuels may be especially valuable in ecosystems that are experiencing a positive feedback between exotic grasses and fire. For example, exotic grass–fire cycles have developed in parts of Australia, tropical America and western North America (D’Antonio and Vitousek 1992).

A challenge with using grazing to manage fuels is that improper grazing can negatively affect plant communities (Daubenmire 1940; Mack and Thompson 1982; Reisner et al. 2013). Strategic application of grazing is needed to manage fuels, minimise undesired effects and achieve a broad range of management goals in fire-prone ecosystems. Fuel management will probably not be crucial every year, allowing for diverse management applications to sustain a wide array of ecosystem services. Fuel management is likely most beneficial after high-herbaceous-production years. Big wildfire years often occur after a year or two of above-average plant production (Knapp 1998; Westerling et al. 2003; Litell et al. 2009). Grazing effects,
however, by fuel characteristics, especially those fuels not influenced by grazing and fire weather (Strand et al. 2014; Schachtschneider 2016). Nevertheless, grazing is a tool that can decrease the probability of wildfire propagation.

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