Agriculture, Ecosystems and Environment 237 (2017) 258–264

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Reconsidering rest following fire: Northern mixed-grass prairie is resilient to grazing following spring wildfire

Emily A. Gates[a], Lance T. Vermeire[b,*], Clayton B. Marlow[a], Richard C. Waterman[b]

[a] Montana State University, Bozeman, MT, United States
[b] USDA-ARS Fort Keogh Livestock and Range Research Laboratory, Miles City, MT, United States

ARTICLE INFO

Article history:
Received 27 June 2016
Received in revised form 27 December 2016
Accepted 3 January 2017
Available online xxx

Keywords:
Grassland
Grazing management
Land management
Post-fire grazing
Rangeland
Wildfire

ABSTRACT

Current federal post-fire land management recommendations in the United States suggest that rangelands be rested from grazing for two growing seasons following fire to allow for proper recovery, despite the lack of empirical literature supporting this recommendation. This project was designed to determine if grazing the first growing season following a spring wildfire alters subsequent productivity and species composition of northern mixed-grass prairie. Following the April 2013 Pautre wildfire in northwestern South Dakota, 100 m^2 exclosures were erected in three burned pastures to simulate two growing seasons of rest. Grazing exclosures were paired with sites grazed both the first and second growing seasons following the fire and replicated across loamy and sandy ecological sites. Prior to grazing the second growing season, five 2 m^2 cages were placed at each grazed site to assess first-year grazing effects. Following the second growing season, productivity and species composition were determined for exclosures and cages. Productivity was greater for loamy than sandy ecological sites (loamy = 2764 kg ha^{-1}, sandy = 2356 kg ha^{-1}; $P = 0.0271$), but was similar between grazing treatments (rested = 2556 kg ha^{-1}, grazed = 2564 kg ha^{-1}; $P = 0.9550$). Ecological site strongly determined species composition. Loamy sites consistently contained more *Pascopyrum smithii*, *Bouteloua gracilis* and *Carex duriuscula* than sandy sites (30 v 0%, 18 v 8%, 4 v 1%; $P = 0.0004$, 0.0457 and 0.0382 respectively). The effects of grazing exclusion were limited to *Hesperostipa comata* and the non-native *Agropyron cristatum* composition. *H. comata* was more prevalent on rested sites (22 v 15%, $P = 0.0096$). *A. cristatum* experienced a grazing treatment by ecological site interaction as it was reduced by grazing on sandy sites, but was not affected on loamy sites ($P = 0.0226$). Results do not support the notion that a two growing season rest period following fire is required in the northern mixed-grass prairie.

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1. Introduction

Current federal land management recommendations in the United States decouple the historic disturbances of fire and grazing in North American prairies. Natural disturbances and the regimes in which they occur, far from being stressors as the nomenclature might imply, are integral ecological processes essential to long term ecosystem stability (Sousa, 1984). Scholars agree that prairies evolved under a tight, fire-grazing linkage, termed pyric herbivory, with herbivores being attracted to recently burned areas when given the freedom of selection (Anderson, 2006; Fuhlendorf et al., 2009). Recent literature suggests that not only are prairies well adapted to fire and post-fire grazing, but that the combination of these disturbance may be necessary for the maintenance of ecological processes in these grasslands (Collins and Barber, 1986). However, current federal recommendations suggest that rangelands should be rested from grazing following fire. Although this recommendation may be beneficial on some rangelands, it may be unnecessary or inappropriate when applied to all rangelands due to the large variety of rangeland ecosystems with individual disturbance regimes.

United States Forest Service (USFS) recommendations state, "Revegetated areas and areas that have been burned but not revegetated will be closed to livestock grazing for at least two growing seasons following the season in which the wildfire occurred to promote recovery of burned perennial plants and/or facilitate the establishment of seeded species. Livestock closures for less than two growing seasons may be justified, on a case-by-case basis, based on sound resource data and experience" (Blaisdell et al., 1982). The Bureau of Land Management utilizes an

* Corresponding author.
E-mail address: lance.vermeire@ars.usda.gov (L.T. Vermeire).

http://dx.doi.org/10.1016/j.agee.2017.01.001
0167-8809/Published by Elsevier B.V.

essentially identical recommendation (Bureau of Land Management, 2007). The rationale for these policies relies on several assumptions. First, it is assumed that fire will reduce plant vigor and productivity, rendering plants less capable of surviving a grazing event. However, literature indicates that plants may respond negatively, neutrally or positively to fire (Engle and Bidwell, 2001; Knapp et al., 2009; Russell et al., 2015). Additionally, it is assumed that fire will result in appreciable plant mortality, requiring the recruitment of new seedlings for recovery. There are examples of fire actually increasing germination and seedling accumulation of native species (Maret and Wilson, 2000) and reducing emergence of non-native species (Vermeire and Rinella, 2009). However, literature indicates that the plants of some ecoregions experience little mortality following fire (Benson and Hartnett, 2006; Haile, 2011) and that ecosystem recovery does not rely on seedling recruitment (Benson and Hartnett, 2006). Lastly, this recommendation assumes an increased risk of soil erosion following fire due to bare ground resulting from litter combustion and plant mortality, indicating that burned sites should be protected from the increased erosion that can result from grazing (Naeth et al., 1991). Conversely, ground litter and detritus can actually build up to detrimental levels, limiting productivity, in under-disturbed prairies (Knapp and Seastedt, 1986). Empirical evidence to support the recommendation for rest across the whole geographic region to which it is applied is sparse.

The few available references indicating that there may be a need for rest following fire originate primarily from the Great Basin and specifically assess the effects of fire and post-fire defoliation on caespitose grasses, primarily *Pseudoroegneria spicata* (Pursh) Á. Löve and *Festuca idahoensis* Elmer. Clipping following fire additively increased the mortality experienced by these species when compared to unclipped plants (Jirik and Bunting, 1994). These studies suggest that rest from grazing for 1–3 years following fire will allow for plant vigor and seed production of these caespitose grasses to return to pre-fire levels while avoiding additive mortality from defoliation (Patton et al., 1988; Bunting et al., 1998). The rest interval also allows newly recruited seedlings to become sufficiently established to withstand a grazing event without mortality being inevitable, as recommended by the theory of rest-rotation grazing management (Hormay, 1970). Within the Great Basin, recent research has questioned the need for post-fire rest (Bates et al., 2009; Roselle et al., 2010), but the response of the rhizomatous and caespitose species of the northern mixed-grass prairie is not widely documented.

Research in the northern mixed-grass prairie indicates that vigor and productivity generally remain unaffected or are enhanced by fire (White and Currie, 1983; Vermeire et al., 2014) with few, if any, plants experiencing mortality (Haile, 2011). Furthermore, many northern mixed-grass species have a rhizomatous or stoloniferous, rather than caespitose, habit (e.g. *Pascopyrum smithii* (Rydb.) Á. Löve, *Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths, *Bouteloua dactyloides* (Nutt.) J.T. Columbus, etc.) (Wakimoto et al., 2005). A recent study indicates that, while neither the caespitose *Hesperostipa comata* (Trin. & Rupr.) Barkworth nor the rhizomatous *P. smithii* mixed-prairie grasses experience immediate mortality following fire, rhizomatous grasses are overall less susceptible than caespitose grasses (Russell et al., 2015). Rhizomatous grasses are also less reliant on the regular recruitment of seedlings for propagation (Cheplick, 1998). Additionally, in the neighboring tallgrass prairie, composed of similar growth forms and subjected to similar disturbances as the northern mixed-grass prairie, Benson and Hartnett (2006) indicate that community recovery does not rely on germination of seed, but rather on tillering by surviving plants. Seasonality of fire further influences whether fire effects are negative, neutral or positive. In shortgrass prairie, dormant season fire may have no effect on plant vigor or survival, with effects essentially limited to the removal of litter, while fire during the peak of the summer growing season may limit productivity (Brockway et al., 2002). However, the evolutionary history of North American prairies indicates that most naturally ignited wildfires occurred during summer (Higgins, 1984), suggesting that prairies should be well adapted to fire even in the most damaging season. Species-specific or plant functional group responses can vary with fire factors, such as seasonality and intensity (Knapp et al., 2009). As such, it is important to identify how fire variables may affect species composition and how those changes can affect or be further altered by subsequent ecological processes, including herbivory. Adaptations to deal with the effects of fire should be equally apparent in soil quality as they are in the vegetation.

Canopy and litter cover have been shown to moderate soil moisture and quality (Hulbert, 1969) and reduce erosive potentials (Benkobi et al., 1993). Fire will readily consume existing litter whereas grazing reduces litter via biomass removal and trampling (Naeth et al., 1991), indicating that either fire, grazing or post-fire grazing could reduce soil moisture or quality and increase erosion. However, Knapp and Seastedt (1986) indicate that, in tallgrass prairie, litter can accumulate to such a degree that it will inhibit productivity. Furthermore, in moisture limited systems, decomposition of litter occurs at limited rates, necessitating augmented recycling of litter through fire or grazing to maintain sustainable nutrient cycling (Brockway et al., 2002).

Taking this all into account, it is probable that individual rangelands have the capacity to respond disparately to the same disturbance regimes. Additionally, responses within one rangeland system can be expected to differ as annual precipitation and ecological site change across the landscape. Precipitation patterns, not management regimes, have been shown to account for the majority of yearly variation in productivity on northern mixed-grass prairie (Derner and Hart, 2007). Furthermore, ecological sites have been shown to maintain individuality unless severely or frequently disturbed (Gibson and Hulbert, 1987). Thus, post-fire grazing considerations likely need to be based upon the type of rangeland as well as the yearly and topographical variations within each rangeland type, indicating that the responses of Great Basin caespitose grasses may not be reflective of the adaptive capacity of the northern mixed-grass prairie to respond to fire and grazing.

Though North American rangelands, particularly the northern mixed-grass prairie, are specifically addressed in this work, post-fire land management with respect to grazing is far from an issue unique to the United States or North America. In Norway, Vandvik et al. (2005) indicate that post-fire grazing in heathland systems should not be considered equivalent to the sum of the effects of fire and grazing applied individually. Kutt and Woinarski (2007) suggest that the effects of grazing immediately following fire in Australian tropical savanna woodlands are not well understood despite this being the most common management practice.

Given the limited empirical support for current management recommendations, we evaluated the effects of grazing and rest following spring wildfire on two ecological sites within the northern mixed-grass prairie. The objective of this study was to quantify the effects of moderate post-fire grazing versus rest on productivity, community composition and basal cover. White and Currie (1983) found no negative impact of fire on post-fire productivity and Vermeire et al. (2011 [Vermeire et al., 2014]2014) found no negative effects of summer fire or post-fire grazing on productivity. Vermeire et al. (2014) found minimal effects on community composition and Bates et al. (2009) found none when comparing grazed and rested sites following fire. Vermeire et al. (2014) observed that moderate post-fire grazing may reduce litter mass and Bates et al. (2009) suggested that litter frequency under post-fire grazing will recover to levels comparable to rested sites