



Grassland plant community spatial patterns driven by herbivory intensity

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ABSTRACT

Heterogeneity is a critical driver in rangeland ecosystems and can be used to direct and quantify management success across landscapes. Plant community dynamics and patterns are frequently examined in relation to herbivory, but most patterns are discussed either in a single dimension, or across species, but at small spatial scales within individual communities. Therefore, we designed a study to measure plant community spatial patterns across similar topographic position and soil type in pastures with three different herbivory intensities. We assessed plant community spatial patterns in the northern mixed-grass prairie near Streeter, ND, USA (46°45'N, 99°28'W) in pastures moderately or intensively grazed or non-grazed exclosures established for 25 years. Plant species composition and abundance were recorded along 50-m transects in three replicate pastures for each grazing intensity (n = 3) at mid-summer twice separated by 10 years. Fine and coarse-scale diversity were similar between the moderately and intensively grazed pastures and greater than the non-grazed exclosures in both years ($p \leq .05$). Plant species composition was similar among the three grazing intensities and years. Plant community heterogeneity was highest for moderately grazed pastures followed by intensively and non-grazed exclosures respectively. Similarly, patch size was smallest for moderate pastures followed by intensive pastures and non-grazed exclosures for both years. However, while patch size in both moderate and intensive pastures was similar across years respectively, patch size in non-grazed exclosures increased over time. Land management activities varying the disturbance intensities or timing of disturbance can influence specific species composition and relative abundance among species groups. Grazing intensity influenced both fine- and coarse-scale plant community patterns and created different, but stable, plant community patch sizes over time. Based on these results, the ecological cost of inactivity in managing grasslands may have profound consequences on plant community stability and the wildlife that depend on them.

1. Introduction

Heterogeneity is the principal driver of biodiversity in rangeland ecosystems and is frequently positively correlated with population and community stability (Wiens, 1997; Hovick et al., 2015; McGranahan et al., 2016). Rangelands are described as inherently heterogeneous, where composition, productivity and vegetation structure vary with disturbances, topo-edaphic features, and species interactions at multiple spatial and temporal scales (Patten and Ellis, 1995; Fuhlendorf and Smeins, 1998, 1999; Fuhlendorf and Engle, 2001; Limb et al., 2010a). Consequently, heterogeneity indices are increasingly used to direct and quantify management success across landscapes (Fuhlendorf et al., 2012). Because rangelands evolved with frequent disturbances, including grazing (Axelrod, 1985; Knapp et al., 1999), it is important for applied conservation and management actions to consider the role spatial and temporal grazing patterns in the creation and maintenance of heterogeneity in these systems (Fuhlendorf and Engle, 2001). Greater

understanding of landscape patterns at larger scales relevant to grazing management could greatly inform the conservation of biodiversity.

Heterogeneity is most commonly associated with spatial and temporal variability in vertical vegetation structure, which is strongly influenced by landscape disturbances such as fire and grazing, soil disturbance and inherent factors such as precipitation and soil nutrients (Fuhlendorf and Engle, 2004; Hovick et al., 2015; Bohrer et al., 2017). This in turn affects the size and juxtaposition of differing patches across landscapes which can also be influenced by management activities (Wiens, 1989; Fuhlendorf and Engle, 2001; Limb et al., 2009). Furthermore, scientists and land managers are increasingly aware of non-vegetative structure patterns that exist as a result of management activities. For example, understanding the spatial arrangement of bare ground is providing early detection for threshold development in arid landscapes (Ettema and Wardle, 2002), and patterns of soil surface temperature can be used to manage thermal gradients for biotic communities (Limb et al., 2009; Townsend and Fuhlendorf, 2010).

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However, expanding the use of landscape variation or heterogeneity as an indicator of habitat suitability or ecosystem stability is still largely restricted to univariate metrics (Reviewed by Adler et al., 2001; Brownstein et al., 2012; Bohrer et al., 2017). For example, variables used to measure heterogeneity are commonly singular (i.e. vegetation height, bare ground, soil temperature, etc.) rather than a compilation of multiple variables such as species composition.

Species composition and patterns within vegetation communities are frequently examined in relation to disturbances associated with land management practices (Milchunas and Lauenroth, 1993; Hobbs and Norton, 1996; Kahmen and Poschod, 2008). However, most patterns are discussed either in a single dimension (species richness), or across species, but at small spatial scales within individual communities (α -diversity). Patterns that exist at larger scales and across multiple communities (β -diversity) are infrequently reported and less well understood in relation to disturbance (Wagner, 2003). Studies that do address compositional heterogeneity and plant community patch size are often performed on a subset of species and fail to utilize the entire species pool (Mistral et al., 2000). However, opportunities to evaluate spatial patterns across landscapes, including community patterns, are becoming more available through the use of geospatial techniques (Kent et al., 2006; Brownstein et al., 2012) which can enable boundary detection within plant communities.

Landscape patterns generally rely on the theory that objects closer in proximity to one another are more similar than objects further apart (Fortin, 1999). Spatial autocorrelation provides a framework to quantify both similarity and randomness within landscapes, and thus enabling the determination of patch size, background heterogeneity, and maximum heterogeneity (Palmer, 2002). Utilizing these concepts, quantification of plant species patch sizes can be performed with a multivariate plant community dissimilarity index and dissimogram (Mistral et al., 2000). However, we have limited understanding of plant community spatial patterns, including community size, is limited particularly in relation to disturbances such as herbivory. Therefore, linking these concepts with larger scale disturbance ecology would provide meaningful recommendations for management and conservation as it relates to plant communities and domestic animal grazing.

Herbivores, common on rangelands globally, select grazing locations within heterogeneous landscapes to optimize the quality and quantity of forage uptake (Pyke, 1984; Briske et al., 2008). They concentrate herbivory in areas where disturbance decreased standing senesced biomass, which acts as a grazing deterrent by decreasing overall forage palatability and quality (McNaughton, 1984; Archibald et al., 2005; Allred et al., 2011). Consequently, plants more tolerant of herbivory tend to increase in frequently grazed areas, and species less tolerant of herbivory increase in areas grazed infrequently or altogether avoided (McNaughton, 1984). Research suggests that grazing selection also influences small-scale species composition and diversity (Hickman et al., 2004), but grazing influence at larger scales is less well understood. Generally, we know that changes in plant species composition and distribution in response to grazing can affect the species patch sizes and grazed pastures generally have larger patch sizes than non-grazed (Meyers et al., 2014). However, these reported patterns were not consistent across differing landscape positions and herbivory intensities. Furthermore, reports of plant community dynamics over time periods of two-four years with established treatment is limited in the literature (Limb et al., 2016) particularly the changes in plant community spatial patterns over time. Therefore, we designed a study to measure plant community spatial patterns across similar topographic position and soil type in pastures with three different herbivory intensities. We predicted that alpha diversity patterns would be greatest with moderate herbivory and beta diversity and patch size would be greatest with intensive herbivory. To address our predictions, our objectives were to 1) quantify small-scale, within community species patterns (α -diversity) and 2) identify larger across-community heterogeneity patterns (β -diversity and community patch size) in moderately, intensively and non-

grazed landscapes established for 25 years and sampled across two growing seasons separated by 10 years.

2. Methods

2.1. Site description

We addressed the influence of grazing intensity on landscape plant community patterns at the North Dakota State University Central Grasslands Research Experiment Center near Streeter, ND, USA (46°45'N, 99°28'W). This experiment center is situated in the Missouri Coteau ecoregion (USDA-SCS, 1981), dominated by fine-loamy mollisols and characterized by irregular rolling plains resulting from the collapse of “superglacial” sediment (Bluemle, 1991). The climate is continental with the majority (72%) of precipitation occurring between May and September. August is the warmest month with a mean temperature of 18.6 °C and January is the coldest month with a mean temperature of -15.3 °C (NDAWN, 2017). Weather patterns were similar to long-term averages for the preceding dormant (October–March) and growing-season (April–September) months for the two data collection years. Dormant-season precipitation received at the site prior to the 2004 growing season was 105% of the 50-year average and growing season precipitation was 126%. Mean monthly temperatures for the dormant season and growing season were 2.5° C warmer and 0.5° C cooler than the 50-year average. The 2013 dormant season received 132% of the 50-year average precipitation while the growing season received 84%. Temperatures were 1.2° C warmer during the dormant-season months and 2.5° C cooler during the growing season when compared to long-term averages.

The vegetation is classified as mixed-grass prairie dominated by western wheatgrass (*Pascopyrum smithii* [Rydb.] Å. Löve), green needlegrass (*Nassella viridula* [Trin.] Barkworth) and blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths). Other important species include sedges (*Carex* spp.), prairie junegrass (*Koeleria macrantha* [Ledeb.] Schult.), sages (*Artemisia* spp.), and goldenrods (*Solidago* spp.). Kentucky bluegrass (*Poa pratensis* L.) a non-native grass and western snowberry (*Symphoricarpos occidentalis* Hook.) native shrub, are important drivers if biodiversity changes in the region and are singled out as case-specific examples of change resulting from our treatment structure.

2.2. Experimental design

The grazing intensity experiment, initiated in 1988, took place on 13-ha pastures. Each pasture was randomly assigned moderate or intensive grazing intensities and replicated three times (N = 3). Randomly within three pastures, permanent grazing exclosures (1 ha each) were constructed on silty ecological sites (USDA-NRCS, 2015) to provide a non-grazed treatment. Pastures were grazed season-long, typically from mid-May to mid-September, and stocked with yearling mixed-breed heifers and steers to achieve 50% and 20% standing biomass at the end of the grazing season for the moderate and intensive treatments, respectively. This resulted in a 27-year mean stocking rate of 2.45 Animal Unit Months/ha for the moderate pastures and 6.85 for the intensive pastures.

We conducted plant species composition and abundance surveys on randomly selected silty ecological sites (USDA-NRCS, 2015) within each pasture and grazing exclosure at mid-summer in 2004 and 2013. We established two 50-m transects in cardinal directions and bisected at the midpoints to account for anisotropy—differences attributed to direction and orientation (Scheller and Mladenoff, 2002). We estimated percent canopy cover of each plant species in 25 1-m² frames, at alternating meters along each 50-m transect, using cover classes (1, 2–5, 6–10, 10–20, 21–30, 31–40, 41–50, 51–60, 61–70, 71–80, 81–90, 91–95, 96–100). We selected large sampling frames so that uncommon plants would be detected and provide a more representative diversity

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