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Inconsistent outcomes of heterogeneity-based management underscore importance of matching evaluation to conservation objectives

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ABSTRACT

Conservation policy often incentivizes managers of human-impacted areas to create landscape heterogeneity to maximize biodiversity. In rangeland, patchy disturbance regimes create landscape heterogeneity (patch contrast), but outcomes of heterogeneity-based management are rarely tested for a universal response. We analyzed four habitat variables – vegetation structure, plant functional group composition, litter cover, and bare ground – from five experimental rangelands in Oklahoma and Iowa, USA. We tested for response consistency to heterogeneity-based management across and within locations. We calculated effect sizes for each variable to compare patch contrast on pastures managed for heterogeneity (patch burn-grazing) and pastures managed for homogeneity (grazing with homogeneous fire regimes). Effects varied considerably across and within locations. Effects of heterogeneity-based management were positive for all variables at only three of five experimental rangeland locations. No location showed a consistent pattern of positive effect across all four variables, although one location showed no effect for any variable. At another location, we found a positive effect of heterogeneity-based management on litter cover and bare ground, but no effect on vegetation structure and plant functional group composition. We discuss effect variability and how the fire–grazing interaction applies to rangeland management and conservation. Although it is accepted practice to use heterogeneity-based management to increase rangeland habitat diversity, managers should also confirm that evaluation metrics match desired conservation outcomes.

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1. Introduction

Heterogeneity and patchiness are central themes in environmental management (Ostfeld, 1997; Wiens, 1997) and have been suggested as specific goals of conservation policy (Benton et al., 2003; Fischer et al., 2008, 2006). Policy emphasis stems from growing evidence that heterogeneity enhances biodiversity, especially in human-impacted landscapes (Franklin and Lindenmayer, 2009; Ricketts et al., 2001; Tews et al., 2004). At the same time, it is important that heterogeneity-based conservation programs are cost-effective and ecologically sound (Drechsler et al., 2007; Ohl et al., 2008; Toombs and Roberts, 2009).

Essential to the assessment of conservation programs are appropriate monitoring and understanding of the ecological drivers of landscape heterogeneity (Eyre et al., 2011; Wallington et al., 2005). Heterogeneity results from variation in the extent, frequency, and intensity of abiotic and biotic processes, including disturbance (Fraterrigo and Rusak, 2008; Pickett and White, 1985). Throughout the evolutionary history of many rangeland ecosystems, fire and grazing have been influential disturbances affecting heterogeneity (Allred et al., 2011). In managed rangeland, prescribed fire is applied in discrete patches to replicate the spatially- and temporally-shifting mosaic of pre-European landscapes (Fuhlendorf and Engle, 2004; Fuhlendorf et al., 2009). Known as patch burn-grazing (McGranahan et al., 2012a), such heterogeneity-based management creates a landscape mosaic to support greater biodiversity than conventional, homogeneity-based management (Coppedge et al., 2008; Doxon et al., 2011; Engle et al., 2008; Fuhlendorf et al., 2006). As such, managers are often encouraged to promote landscape heterogeneity to conserve rangeland fauna (Toombs et al., 2010).

Relatively little research has tested the universality of the theory that heterogeneity-based management creates meaningful rangeland diversity, and even less has presented experimental results in a manner accessible to environmental managers and policy-makers. We use a meta-analytical approach with data from five rangeland locations in the North American Great Plains to determine whether heterogeneity-based management (patch burn-grazing) increases spatial heterogeneity in four variables (vegetation structure, plant functional group composition, litter cover, and bare ground) when compared to conventional, homogeneity-based management (grazing without spatially discrete fire). Each variable is important to rangeland fauna, including birds, small mammals, and invertebrates (Table 1). We calculate an effect size for each variable at each location to compare the level of patch contrast – "the degree of difference between patches" (Kotliar and Wiens, 1990) – created by heterogeneity-based management versus homogeneity-based management. Although we do not expect all study locations to universally respond to heterogeneity-based management (McGranahan et al., 2012a), we predict that habitat variables should respond consistently within each location. We discuss these results with respect to conservation goal-setting and the evaluation of management outcomes.

2. Methods

2.1. Data

We used an existing dataset of five rangeland experiments in Oklahoma and Iowa, USA (McGranahan et al., 2012a). Experimental locations include: Cooper Wildlife Management Area, Woodward County, Oklahoma; Klemme Range Research Station, Washita County, Oklahoma; Oklahoma State University Range Research Station, Paine County, Oklahoma; Tallgrass Prairie Preserve, Osage County, Oklahoma; and the Grand River Grasslands, Ringgold County, Iowa. The experimental locations spanned a broad geographic range (ca. 650 km) and represented different grassland types, tract sizes,

Table 1 – Examples of habitat functions for rangeland wildlife associated with four vegetation variables analyzed in this study.

Habitat variable	Observed wildlife response	References
Plant functional group composition	Conservation plantings comprised of grasses, legumes, and forbs increase habitat value for ring-necked pheasant nesting and brood-rearing	Matthews et al. (2012)
	Diversity of conservation plantings support diverse bird communities	Patterson and Best (1996)
Vegetation structure	Sward height affects prey density, predation risk among insectivorous grassland birds	Atkinson et al. (2004)
	Bird nest site selections based on vegetation structure, variable among species	Fondell and Ball (2004)
	Grasshopper species richness increased with heterogeneous vegetation structure	Joern (2005)
Bare ground	Ground-foraging birds depend on access to bare patches for food	Tagmann-Ioset et al. (2012) and Atkinson et al. (2004)
	Ca. 30% bare ground minimum habitat requirement for Mountain Plover	Knopf and Miller (1994)
	Ant community composition affected by changes in bare ground	Graham et al. (2008)
Litter cover	Litter cover < 25% doubled success rate of Greater Prairie-chicken nests	McKee et al. (1998)
	Altered litter cover associated with altered ant community composition	Bestelmeyer and Wiens (1996)
	Winter cover, greater soil moisture increase survival of grassland obligate butterflies	Vogel et al. (2010)