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Original Research

Precipitation and Soil Productivity Explain Effects of Grazing on Grassland Songbirds☆

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ABSTRACT

Temperate grassland ecosystems are imperiled globally, and habitat loss in North America has resulted in steep declines of endemic songbirds. Commercial livestock grazing is the primary land use in rangelands that support remaining bird populations. Some conservationists suggest using livestock as "ecosystem engineers" to increase habitat heterogeneity in rangelands because birds require a spectrum of sparse to dense vegetation cover. However, grazing effects remain poorly understood because local studies have not incorporated broad-scale environmental constraints on herbaceous growth. We surveyed grassland birds across a region spanning 26 500 km^2 in northeast Montana, United States to assess how distribution and abundance were affected by weather, soils, and grazing. We modeled bird abundance to characterize regional response to herbaceous cover, experimentally manipulated grazing to isolate its effect, and then scaled back up to evaluate how the regional environment constrains bird response to grazing. Regional models predict that a quarter of our study region was productive grassland where managed grazing could benefit specialist species; the remainder was nongrassland or low-productivity soils where it had low potential to affect habitat. Grassland species distributed themselves along a gradient of herbaceous cover with predictable shifts in community composition. We demonstrated experimentally that grazing influences bird communities within productive grasslands, with higher utilization promoting more Chestnut-collared Longspur *(Calcarius ornatus)* and fewer Baird's Sparrow *(Ammodramus bairdii)*. Results inform a new conceptual framework for grazing that explicitly incorporates the role of broad-scale environmental constraints.

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Introduction

Temperate grasslands are among Earth's most imperiled ecosystems (Hoekstra et al., 2004). In the formerly vast prairies of North America, agricultural conversion spread west following European settlement into the 20th century (Ostlie et al., 1997). Conversion of highly arable tallgrass prairie in the eastern plains is now nearly complete (Samson et al., 2004). Recent demand for ethanol, high commodity prices, and advances in agricultural technology have influenced continued westerly expansion of the corn belt and accelerated loss and fragmentation of mixed-grass prairie (Wright and Wimberly, 2013; Roch and Jaeger, 2014; Lark et al., 2015). Seemingly small annual rates of conversion have summed to cumulative grassland losses that conservation has been unable to mitigate (Doherty et al., 2013). For wildlife that depends on grassland, these losses contribute to an extinction debt that is accumulating rapidly.

One important indicator of habitat loss is the steep and consistent decline of endemic songbird populations (Brennan and Kuvlesky, 2005; Sauer et al., 2014). From 1966 to 2013, the proportion of North American grassland species with significant negative population trends was nearly twice that of all avian species combined (0.75 vs. 0.39; Sauer et al., 2014). These populations depend on grasslands to support them, and recent declines suggest that habitat loss may be approaching critical levels.

Privately owned rangelands have little formal protection status but support most (85%) remaining grassland habitat (NABCI, 2013) and threatened bird populations (Lipsey et al., 2015). Millions of hectares of grassland remain intact within the ranching economy of the western Great Plains. Nonfederal rangelands, used for livestock grazing, represent the single largest land-use class in the United States (about 167 million ha or 21% of the total land area, excluding Alaska; USDA, 2013). Although quick economic returns from crops and subdivision provide a constant incentive to develop rangeland, the social fabric of rural communities tied to ranching traditions and supported by markets for livestock has shown remarkable resistance to land use change at a continental scale. Even so, these communities are declining as ranches

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are converted to cropland (Government Accountability Office, 2007) and exurban development (Brunson and Huntsinger, 2008). From 1992 to 2012, beef cattle operations in the United States declined by 19% (900 000 vs. 729 000) and beef cow numbers dropped by 12% (34.7 vs. 30.5 million; USDA-NASS, 2016).

Past studies have led to the widespread recommendation to use livestock as "ecosystem engineers" to increase structural heterogeneity in grasslands to benefit bird diversity (Fuhlendorf et al., 2006; Derner et al., 2009; Toombs et al., 2010). Birds respond to the structure of grassland vegetation (Fisher and Davis, 2010; Keyel et al., 2013), with some species preferring sparse grass and others selecting more dense cover (Knopf, 1996). In remaining grassland, structural heterogeneity is therefore important for maintaining regional species diversity (Bleho, 2009; Derner et al., 2009). Livestock management practices on rangeland may have homogenized habitat with negative consequences for diversity (Fuhlendorf and Engle, 2001). Several studies report songbird community shifts across a gradient of grazing intensity, with some species increasing under heavier grazing and others decreasing (Bock et al., 1993; Milchunas et al., 1998).

However, engineering grasslands to support diverse bird communities has remained elusive in practice because past studies do not account for how broad-scale environmental conditions constrain local-scale grazing effects. Nesting cover is an important habitat feature for ground-nesting songbirds (Davis, 2003; Henderson and Davis, 2014; Sliwinski and Koper, 2015), and its availability varies with level of grazing (Fondell and Ball, 2004; Lusk and Koper, 2013). Yet reported impacts of grazing on birds are site specific, and generalizations for management have been slow to emerge from the literature. For example, Sprague's Pipit (Anthus spragueii) is a species of conservation concern that is associated with heavy grazing in the mesic portions of its range (Madden et al., 1999) and light grazing in more arid regions (Davis et al., 1999).

Here, we provide evidence that sensitive species' diverse requirements for cover provide the mechanism through which grazing affects birds. Further, we show that this influence is highly dependent on environmental context. Using data from a broad (26 500 km^2) region of northeast Montana, United States, our objective was to characterize how livestock grazing interacts with the constraints of weather and soil to affect birds through a common denominator of herbaceous cover. First, we use regional data to describe how the bird community responds to variation in cover. Second, we use controlled, local experiments to isolate the effect of grazing on cover and birds. Lastly, we scale back to the regional level to assess how the environment constrains the effects of grazing. Results provide generalizable insights to optimize the role of grazing in multispecies songbird conservation.

Methods

Study Region

The study region included Phillips and Valley counties in northeast Montana (Fig. 1). In contrast with continental patterns of grassland ownership, this area contained a high proportion of public land that, along with adjoining private and tribal lands, comprises one of the largest tracts of intact native mixed-grass prairie in the United States (Cooper et al., 2001). More than 70% of the region was rangeland used for livestock grazing (Fig. A1). Of this, about half was grassland and about a third was shrub-steppe. The remainder included barren lands, woodland and wetland. Estimated normal year soil productivity of grassland ranged from 392 to 4 483 kg · ha^{-1}, with a mean of 1 283 kg · ha^{-1}.

Physiographically, the region is in the Glaciated Missouri Plateau subregion of the Great Plains (Fenneman, 1916). Largely glaciated during the Pleistocene (Colton et al., 1961), its landform is characterized by rolling hills with dry drainages. The Milk River bisects the region from the west to its confluence with the Missouri River in the east. The region comprises a transition zone between grassland and shrubland, with grasses dominating north of the Milk River and shrubs dominating in the south. Grasslands are diverse but generally dominated by cool-season perennial wheatgrasses and needlegrasses (e.g., *Pascopyrum smithii, Nassella viridula*). Common shrubs include *Artemisia tridentata, Artemisia cana,* and *Sarcobatus vermiculatus*. Six soil orders are described in the region including Alfisols, Aridisols, Entisols, Inceptisols, Mollisols, and Vertisols (Bingham et al., 1984; Bandy et al., 2004). Climate is cold semiarid (Peel et al., 2007), characterized by short, hot summers and long, cold winters (Cooper et al., 2001). Average annual precipitation is highly variable, ranging from 177 to 492 mm (1981 − 2014; PRISM, 2014) and falling mostly as rain in May − July (Cooper et al., 2001; Charboneau et al., 2013). For detailed descriptions of physiography, climate, geology, and floristic composition, see Charboneau et al. (2013).

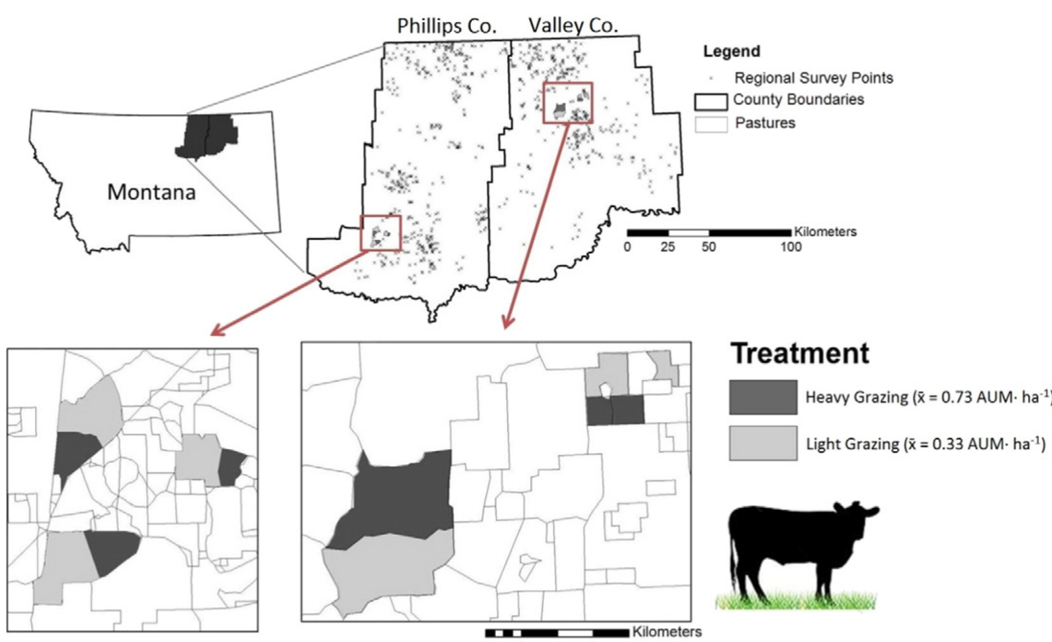

Figure 1. Northeast Montana and location of regional bird sampling points and pastures where grazing was experimentally manipulated, 2011 − 2013.

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