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Landscape composition creates a threshold influencing Lesser Prairie-Chicken population resilience to extreme drought

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HIGHLIGHTS

- Drought and land cover change interact to reduce Lesser Prairie-Chicken abundance.
- Our estimates of abundance indicate a decreasing population from 1978 to 2010.
- Decreased grassland reduces population resilience to extreme drought events.
- A threshold of cropland:grassland exists below which the population declines.

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ABSTRACT

Habitat loss and degradation compound the effects of climate change on wildlife, yet responses to climate and land cover change are often quantified independently. The interaction between climate and land cover change could be intensified in the Great Plains region where grasslands are being converted to row-crop agriculture concurrent with increased frequency of extreme drought events. We quantified the combined effects of land cover and climate change on a species of conservation concern in the Great Plains, the Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*). We combined extreme drought events and land cover change with lek count surveys in a Bayesian hierarchical model to quantify changes in abundance of male Lesser Prairie-Chickens from 1978 to 2014 in Kansas, the core of their species range. Our estimates of abundance indicate a gradually decreasing population through 2010 corresponding to drought events and reduced grassland areas. Decreases in Lesser Prairie-Chicken abundance were greatest in areas with increasing row-crop to grassland land cover ratio during extreme drought events, and decreased grassland reduces the resilience of Lesser Prairie-Chicken populations to extreme drought events. A threshold exists for Lesser Prairie-Chickens in response to the gradient of cropland:grassland land cover. When moving across the gradient of grassland to cropland, abundance initially increased in response to more cropland on the landscape, but declined in response to more cropland after the threshold ($\delta = 0.096$, or 9.6% cropland). Preservation of intact grasslands and continued implementation of initiatives to revert

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cropland to grassland should increase Lesser Prairie-Chicken resilience to extreme drought events due to climate change.

1. Introduction

Understanding responses of wildlife populations to landscape and climatic variation is key for determining how resilient populations are to environmental change. Resilience can be defined as the capacity of a system to absorb disturbances without changing structurally or functionally (Holling, 1973) or the ability of a system to return to a pre-disturbed state (Pimm, 1984). Understanding population resilience is critical for conserving species with dynamic fluctuations in abundance that are linked to habitat quality. Where quality is driven by highly variable or extreme environmental events, such as drought, understanding resilience to extreme climatic events is crucial for fully appreciating the population dynamics of a species (Jiguet et al., 2006). Additionally, understanding how changes in habitat affect species resilience during extreme climatic events can aid in mitigation efforts for species of conservation concern (Godfree et al., 2011; Oliver et al., 2013).

In addition to understanding the resilience of a species, projecting the combined effects of climate and land cover change on future wildlife populations is critical for managing species of conservation concern. Habitat loss and degradation interact with climate change to affect demographic rates of populations (Selwood et al., 2014), especially in highly dynamic ecosystems (Diffenbaugh et al., 2005), yet responses of populations to climate and land cover are typically quantified independently. The effects of landscape and climate change on wildlife may be compounded in areas such as the Great Plains of North America (Samson et al., 2004), where climate change is coupled with land cover change. For example, in the Northern Great Plains, land cover change has modified near-surface temperatures (Mahmood et al., 2006). Land cover change also causes shifts in avian community structure, as only a few grassland bird species respond positively to increases in agricultural cover (Coppedge et al., 2001). Bird species in the Great Plains are also likely to be disproportionately affected by projected temperature increases in the region (Peterson, 2003; Grisham et al., 2013).

Understanding how population dynamics are influenced by climatic variation and land cover change in the context of resilience is critical for predicting how a species may recover from extreme climatic events, such as drought (Oliver et al., 2013). If habitat management can decrease the recovery time for a population to return to pre-disturbed states after an extreme climatic event, conservation efforts can be targeted accordingly. For example, several prairie grouse species have large natural fluctuations in population abundance (Hudson et al., 1998; Williams et al., 2004; Garton et al., 2016), and are affected by extreme climatic events (Ross et al., in press). While fluctuations may exist naturally in prairie grouse populations, long-term, persistent declines are occurring for some species (Garton et al., 2016). Particularly, the loss and degradation of habitat (Fuhlendorf et al., 2002) and changes in climate (Grisham et al., 2013) may be causing these declines.

A sentinel species of conservation concern in the Great Plains is the Lesser Prairie-Chicken (*T. pallidicinctus*), which was listed as "threatened" under the Endangered Species Act in May 2014. Although the listing decision was vacated on procedural grounds by judicial review in September 2015, the concerns and impacts that prompted the initial listing decision remain. While affected by changes in climate (Grisham et al., 2013, in press; Ross et al., in press) and land cover (Fuhlendorf et al., 2002), no study we are aware of has simultaneously quantified the relative contribution of both of these factors to Lesser Prairie-Chicken population dynamics. Lesser Prairie-Chicken abundance declines during periods of drought throughout their range (Grisham et al., 2013, in press; Rodgers, 2016; Ross et al., in press), but are also negatively affected by changes in land cover and landscape fragmentation (Crawford and Bolen, 1976; Fuhlendorf et al., 2002). Landscape fragmentation decreases Lesser Prairie-Chicken home range size (Merchant, 1982), reduces recruitment (Hagen and Giesen, 2005), and subsequently, causes population declines independent of drought (Fuhlendorf et al., 2002). Due to a gap in knowledge about the interactive effects of various environmental conditions and land-cover change on the population, proposed management for Lesser Prairie-Chickens focuses primarily on habitat manipulation and improvements without accounting for potential future climatic states.

Our goal was to assess the resilience of Lesser Prairie-Chicken populations to the effects of drought, land cover change, and their interaction. We used threshold models, trends in the standard deviation of abundance, and return times following population declines to estimate shifts in resilience. Additionally, we quantified a population threshold for the landscape-scale cropland:grassland ratio of land cover.

2. Methods

2.1. Study area

Kansas has the largest abundance of Lesser Prairie-Chickens (McDonald et al., 2014). Furthermore, the Kansas Department of Wildlife, Parks, and Tourism is the only agency with long-term survey data of the species. Lesser Prairie-Chicken surveys incorporated three ecoregions in western (Short-Grass Prairie/Conservation Reserve Program Mosaic), southwestern (Sand Sagebrush Prairie), and south-central Kansas (Mixed-Grass Prairie), covering a large portion of the species' core range