

Assessment of landscape thresholds for lesser prairie-chickens in Kansas

by

Katryn Hannah Stafford

B.S., Missouri Western State University, 2023

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Division of Biology
College of Arts and Sciences

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2026

Approved by:

Major Professor
David Haukos

Copyright

© Katryn Stafford 2026.

Abstract

The lesser prairie-chicken (*Tympanuchus pallidicinctus*) is a grassland-obligate prairie grouse found in the southwestern Great Plains of the United States and currently occurs in four distinct ecoregions (Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, Sand Sagebrush Prairie, and Sand Shinnery Oak Prairie) across five states (Colorado, Kansas, Oklahoma, Texas, and New Mexico, USA). In recent decades, lesser prairie-chickens have suffered extensive habitat loss and degradation, reduced occupied range, and population declines. Ecological and anthropogenic factors such as changes in disturbance regimes, woody encroachment, conversion of grassland for agriculture, urban expansion, and energy development are contributing to population and habitat declines. Because lesser prairie-chickens require extensive native grasslands to meet breeding, brood-rearing, and nonbreeding needs, further loss of habitat can isolate populations and reduce population persistence. My objectives were to estimate and compare land cover variables (native grassland, CRP grassland, total grassland, cropland, trees/ha, and density of anthropogenic structures) between Focal Areas (CHAT 1) designated by Western Association of Fish and Wildlife Agencies (WAFWA) and Occupied Areas delineated by survey data in Kansas. On a smaller scale, I estimated land cover variables within 5 km of 335 lesser prairie-chicken leks in three different lek attendance groups (<10 males, ≥ 10 males, and Extinct leks) in Kansas. Lastly, within each lek attendance group, I determined the status of each lek relative to each ecological threshold and estimated the proportion of leks above and below thresholds in each ecoregion. Overall, the WAFWA Focal Areas (CHAT 1) exhibited differences in ecological threshold and landscape characteristics among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas. For example, Focal Areas in the Mixed-Grass Prairie Ecoregion contained greater proportions of native grassland

and total grassland but had the least CRP grassland. In contrast, Focal Areas in the Sand Sagebrush Prairie Ecoregion had the greatest CRP grassland but least total grassland overall. This suggests that population threshold concerns varied according to ecoregional landscape conditions. Landscape characteristics within Occupied Areas were relatively consistent among ecoregions, suggesting that lesser prairie-chickens may be selecting for similar landscape characteristics across its occupied range in Kansas. On a smaller scale, the Short-Grass Prairie/CRP Mosaic Ecoregion had the greatest proportion of leks with ≥ 10 males (39.47%) and the least proportion of leks that were vacated during the survey period (26.32%). Overall, leks in this ecoregion were surrounded by more CRP grassland and fewer trees within 5 km when compared to other ecoregions. Within the Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions, >80% of surveyed leks were either below the threshold of 10 males or Extinct. Leks in the Mixed-Grass Prairie Ecoregion had the greatest density of trees, followed by the lowest proportion of CRP grassland within 5 km. Lastly, leks in the Sand Sagebrush Prairie Ecoregion contained the fewest trees within 5 km, but high densities of anthropogenic development and agricultural operations surrounded concentrations of leks. Finally, lek attendance groups (<10, ≥ 10 , Extinct) were similar in the number of leks above and below identified ecological thresholds within each ecoregion. However, different land cover characteristics influencing threshold status were observed among ecoregions. A greater proportion of leks in the Short-Grass Prairie/CRP Mosaic and Mixed-Grass Prairie ecoregions exceeded the threshold of 2 trees/ha and were below the threshold for native grassland when compared to leks in the Sand Sagebrush Prairie Ecoregion. Conversely, the opposite pattern was observed in the Sand Sagebrush Prairie Ecoregion, as no leks exceeded 2 trees/ha and the least proportion of leks were below the threshold for native grassland. Despite these ecoregional differences, presence of CRP

grassland was highly influential; once combined with native grassland, 78.51% of leks exceeded 60% grassland, representing a 30.75% increase. This emphasizes the importance of CRP grassland on the landscape and is consistent with previous research demonstrating that CRP grassland supports lesser prairie-chickens during intensive drought, nesting, brood-rearing, roosting, and dispersal movements. Overall, my results suggest that implementation of management practices should be ecoregion specific to yield the most effective results and improve the persistence of the lesser prairie-chicken in Kansas.

Table of Contents

List of Figures	ix
List of Tables	xi
Acknowledgements	xvi
Chapter 1 - Evaluating Focal Area and Occupied Area Landscapes within the Lesser Prairie- Chicken Occupied Range in Kansas	1
Introduction	1
Study Area	15
Methods	17
WAFWA Focal Areas and Connectivity Zones	17
Occupied Areas	18
Delineation of Occupied Areas	19
Estimation of Leks per CHAT Focal Area or Occupied Area	19
Estimation of Land Cover Variables	19
Class and Landscape Metrics	21
Statistical Analyses	22
Ranking Focal Areas and Occupied Areas	22
Results	23
Comparisons Among Ecoregions	23
Comparisons Within Ecoregions	25
Discussion	28
Literature Cited	33
Tables	42
Figures	52
.....	53
Chapter 2 - Landscape composition surrounding stable and vulnerable lesser prairie-chicken leks in Kansas	55
Introduction	55
Study Area	71
Methods	74

Lek Survey Dataset	74
Lek Attendance Groups	75
Establishment of Lek Locations.....	76
Estimation of Landcover Variables.....	77
Statistical Analyses	80
Results.....	80
Ecoregions.....	81
Lek Attendance Groups per Ecoregion.....	83
Discussion	84
Literature Cited	91
Tables.....	100
Figures	119
Chapter 3 - Determining Status of Lesser Prairie-Chicken Leks in Kansas Relative to Ecological	
Thresholds.....	123
Introduction.....	123
Study Area	131
Methods	133
Lek Survey Dataset	133
Lek Attendance Groups	134
Establishment of Lek Locations.....	135
Estimation of Landcover Variables.....	136
Statistical Analyses	139
Results.....	139
Discussion	142
Literature Cited	146
Tables.....	152
Figures	159
.....	162
Appendix A - Chapter 3 Supplemental Data	164
Appendix Table A.1. Land cover variables were measured within 5 km of lesser prairie-	
chicken leks within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand	

Sagebrush Prairie ecoregions in Kansas, USA, from 2018-2023. A threshold status (Above/Below) was assigned to each lek for average lek attendance, proportion of native grassland, total grassland, cropland, trees/ha, and anthropogenic structures/ha.....	164
Appendix B - Chapter 3 Supplemental Data.....	189
Appendix B.1. Anthropogenic Structures were measured within 5 km of lesser prairie-chicken leks within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, from 2018-2023. A threshold status (Above/Below) was assigned to each lek for average lek attendance, proportion of native grassland, total grassland, cropland, trees/ha, and anthropogenic structures/ha.....	189

List of Figures

Figure 1.1. Distribution of lesser prairie-chicken focal areas, connectivity zones, current and potential habitat, and non-habitat in Kansas, USA, designated by the Western Association of Fish and Wildlife Agencies using the Critical Habitat Assessment Tool (USDA NRCS 2023).	52
Figure 1.2. Distribution of lesser prairie-chicken Occupied Areas determined by lek survey data within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA. Numbering corresponds with ranking in Table 1.8.....	53
Figure 1.3. Distribution of Western Association Fish and Wildlife Agencies Critical Habitat Assessment Tool Focal Areas (CHAT 1) and Connectivity Zones (CHAT 2) within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA. Numbering corresponds with ranking in Table 1.8.....	54
Figure 2.1. The four defined ecoregions in lesser prairie-chicken occupied range in Kansas, Colorado, Oklahoma, New Mexico, and Texas, USA.	119
Figure 2.2. Example of land cover variables (native grassland, cropland, woody vegetation, anthropogenic features) measured within 5 km of each lesser prairie-chicken lek in the Sand Sagebrush Prairie Ecoregion in Kansas, USA, during 2018-2022. Leks below the lek attendance threshold of 10 males (<10), represented by the red points, were surrounded by cropland, woody vegetation, and gravel/paved roads.	120
Figure 2.3. Example of land cover variables (native grassland, cropland, woody vegetation, anthropogenic features) measured within 5 km of each lesser prairie-chicken lek in the Sand Sagebrush Prairie Ecoregion in Kansas, USA, during 2018-2023. Extinct leks, represented by the light blue points, were surrounded by cropland, woody vegetation, and gravel/paved roads. Additionally, only two leks above the lek attendance threshold of 10 males (>10) were observed in this portion of the Sand Sagebrush Prairie Ecoregion.	121
Figure 2.4. Example of land cover variables (native grassland, cropland, woody vegetation, anthropogenic features) measured within 5 km of each lesser prairie-chicken lek in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA, during 2018-2023. Leks with <10 males, >10 males, and Extinct leks were surrounded by cropland, woody vegetation, and gravel/paved roads.....	122

Figure 3.1. Lesser prairie-chicken leks observed in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023 that were below the established threshold of >60% grassland.	159
Figure 3.2. Lesser prairie-chicken leks observed in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023 that were below the established threshold of >60% grassland when CRP grassland was included in land cover estimates.	160
Figure 3.3. Lesser prairie-chicken leks observed in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023 that exceeded the established threshold of <40% cropland.	161
Figure 3.4. Lesser prairie-chicken leks observed in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023 that exceeded the established threshold of <2 trees/ha.	162
Figure 3.5. Lesser prairie-chicken leks observed in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023 that were below the established threshold of >60% grassland and exceeded the threshold of <2 trees/ha.	163

List of Tables

Table 1.1. Identified landscape thresholds used to evaluate lesser prairie-chicken persistence within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA.	42
Table 1.2. Description of Western Association of Fish and Wildlife Agencies Critical Habitat Assessment Tool Focal Areas and Connectivity Zones, and Occupied Areas determined by lek survey data within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA.	43
Table 1.3. Comparison of average proportion (ha, $\pm$ SE) of native grassland, CRP grassland, total grassland, and cropland within the boundaries of each lesser prairie-chicken Critical Habitat Assessment Tool (CHAT) Focal Area ($n = 40$) and Occupied Area ($n = 12$) among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.	44
Table 1.4. Average number of individual trees, oil/gas wells, cellular towers, wind turbines, length of transmission lines, and length of roads per 100 ha within the boundaries of each lesser prairie-chicken Critical Habitat Assessment Tool (CHAT) Focal Area ($n = 40$) and Occupied Area ($n = 12$) among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.	45
Table 1.5. Comparison of average number of land cover patches, average patch size, patch density per 100/ha, and largest patch index within the boundaries of each lesser prairie-chicken Critical Habitat Assessment Tool (CHAT) Focal Area ($n = 40$) and Occupied Areas ($n = 12$) among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.	46
Table 1.6. Average proportion (ha, $\pm$ SE) of native grassland, CRP grassland, total grassland, and cropland within the boundaries of each lesser prairie-chicken Critical Habitat Assessment Tool (CHAT) Focal Area ($n = 40$) and Connectivity Zone ($n = 13$) among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.	47
Table 1.7. Average number of individual trees, oil/gas wells, cellular towers, wind turbines, length of transmission lines, and length of roads per 100 ha within the boundaries of each	

lesser prairie-chicken Critical Habitat Assessment Tool (CHAT) Focal Area ($n = 40$) and Occupied Area ($n = 12$) among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.....	48
Table 1.8. Ranking list of Western Association of Fish and Wildlife Agencies Critical Habitat Assessment Tool Zones (Focal Areas) and Occupied Areas determined by survey data within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA. Areas were ranked by the number of leks with >10 birds in attendance, followed by percentage of total grassland. ID corresponds to ID in Figures 1.2 and 1.3.....	50
Table 2.1. Identified landscape thresholds associated with lesser prairie-chicken (LEPC) persistence within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA.	100
Table 2.2. Total number (%) of lesser prairie-chicken leks evaluated for status relative to established landscape thresholds in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, within each lek attendance group. Leks were grouped based on average male attendance during 2018-2023.	101
Table 2.3. Comparison of average area ($\text{ha} \pm \text{SE}$) of native grassland, CRP grassland, total grassland, and cropland within a 5-km (7,854 ha) buffer around surveyed leks ($n = 335$) among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.	102
Table 2.4. The average area ($\text{ha} \pm \text{SE}$) of Conservation Reserve Program grasslands within a 4.23-km radius (5,621 ha) for surveyed leks ($n = 335$) in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.....	103
Table 2.5. The average count ($\pm \text{SE}$) of trees per hectare and distance (km) to nearest tree within a 5-km (7,854 ha) buffer around surveyed leks ($n = 335$) in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.....	104
Table 2.6. The proportion of lesser prairie-chicken leks containing individual cellular towers, individual wind turbines, and oil/gas wells within a 5-km (7,854 ha) buffer	

around surveyed leks ($n = 335$) in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.	105
Table 2.7. The average length (km $\pm$ SE) of paved/gravel roads and transmission lines, average distance (km $\pm$ SE) to the nearest paved/gravel road, transmission line, CRP field, and number of CRP fields within 5-km (7,854 ha) of each lek in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas.	106
Table 2.8. The average (ha $\pm$ SE) of native grassland, CRP grassland, total grassland, and cropland within a 5-km (7,854 ha) buffer around surveyed leks ($n = 114$) in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA, during 2018-2023.	107
Table 2.9. The average area (ha $\pm$ SE) of Conservation Reserve Program grasslands within a 4.23-km radius (5,621 ha) for surveyed lesser prairie-chicken leks ($n = 114$) in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA.	108
Table 2.10. The average count ($\pm$ SE) of trees per hectare and distance (km) to nearest tree within a 5-km (7,854 ha) buffer around surveyed leks in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA, during 2018-2023.	109
Table 2.11. The average length (km $\pm$ SE) of paved/gravel roads and transmission lines, average distance (km $\pm$ SE) to the nearest paved/gravel road, transmission line within, CRP field, and number of CRP fields within 5-km (7,854 ha) of each lek ($n = 114$) in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA during 2018-2023.	110
Table 2.12. The average (ha $\pm$ SE) of native grassland, CRP grassland, total grassland, and cropland within a 5-km (7,854 ha) buffer around surveyed leks ($n = 106$) in the Mixed-Grass Prairie Ecoregion in Kansas, USA, during 2018-2023.	111
Table 2.13. The average area (ha $\pm$ SE) of Conservation Reserve Program grasslands within a 4.23-km radius (5,621 ha) for surveyed lesser prairie-chicken leks ($n = 106$) in the Mixed-Grass Prairie Ecoregion in Kansas, USA.	112
Table 2.14. The average count ($\pm$ SE) of trees per hectare and distance (km) to nearest tree within a 5-km (7,854 ha) buffer around surveyed leks in the Mixed-Grass Prairie Ecoregion in Kansas, USA, during 2018-2023.	113
Table 2.15. The average length (km $\pm$ SE) of paved/gravel roads and transmission lines, average distance (km $\pm$ SE) to the nearest paved/gravel road, transmission line within, CRP field, and	

number of CRP fields within 5-km (7,854 ha) of each lek ($n = 106$) in the Mixed-Grass Prairie Ecoregion in Kansas, USA during 2018-2023.	114
Table 2.16. The average (ha $\pm$ SE) of native grassland, CRP grassland, total grassland, and cropland within a 5-km (7,854 ha) buffer around surveyed leks ($n = 115$) in the Sand Sagebrush Prairie Ecoregion in Kansas, USA, during 2018-2023.	115
Table 2.17. The average area (ha $\pm$ SE) of Conservation Reserve Program grasslands within a 4.23-km radius (5,621 ha) for surveyed lesser prairie-chicken leks ($n = 115$) in the Sand Sagebrush Prairie Ecoregion in Kansas, USA.	116
Table 2.18. The average count ($\pm$ SE) of trees per hectare and distance (km) to nearest tree within a 5-km (7,854 ha) buffer around surveyed leks in the Sand Sagebrush Ecoregion in Kansas, USA, during 2018-2023.	117
Table 2.19. The average length (km $\pm$ SE) of paved/gravel roads and transmission lines, average distance (km $\pm$ SE) to the nearest paved/gravel road, transmission line within, CRP field, and number of CRP fields within 5-km (7,854 ha) of each lek ($n = 115$) in the Sand Sagebrush Prairie Ecoregion in Kansas, USA during 2018-2023.	118
Table 3.1. Identified landscape thresholds associated with lesser prairie-chicken (LEPC) persistence within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA.	152
Table 3.2. Total number (%) of lesser prairie-chicken leks above or below established landscape thresholds (lek attendance, native grassland, total grassland, cropland, trees/ha, anthropogenic structures) in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA. Lek attendance was determined using average male attendance during 2018-2023.	153
Table 3.3. Total number (%) of lesser prairie-chicken leks above or below established landscape thresholds (lek attendance, native grassland, total grassland, cropland, trees/ha, anthropogenic structures) in the Mixed-Grass Prairie Ecoregion in Kansas, USA. Lek attendance was determined using average male attendance during 2018-2023.	154
Table 3.4. Total number (%) of lesser prairie-chicken leks above or below established landscape thresholds (lek attendance, native grassland, total grassland, cropland, trees/ha, anthropogenic structures) in the Sand Sagebrush Prairie Ecoregion in Kansas, USA. Lek attendance was determined using average male attendance during 2018-2023.	155

Table 3.5. Total number (%) of lesser prairie-chicken leks above or below established landscape thresholds for anthropogenic structures per 5-km radius in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA. Lek attendance was determined using average male attendance during 2018-2023.....	156
Table 3.6. Total number (%) of lesser prairie-chicken leks above or below established landscape thresholds for anthropogenic structures per 5-km radius in the Mixed-Grass Prairie Ecoregion in Kansas, USA. Lek attendance was determined using average male attendance during 2018-2023.....	157
Table 3.7. Total number (%) of lesser prairie-chicken leks above or below established landscape thresholds for anthropogenic structures per 5-km radius in the Sand Sagebrush Prairie Ecoregion in Kansas, USA. Lek attendance was determined using average male attendance during 2018-2023.....	158

Acknowledgements

First and foremost, I would like to thank my advisor Dr. David Haukos, without whom this would not have been possible. Thank you, Dave, for your dedication, endless support, encouragement, and guidance throughout my time as a graduate student. Never in my life did I think I would be capable of completing graduate school, so I thank you for giving me this opportunity and believing in me when I did not believe in myself. Thank you to my committee members, Dr. Mindy Rice and Dr. Dan Sullins for your encouragement, dedication, and expertise.

I want to thank all members of the Kansas Cooperative Fish and Wildlife Research Unit for their kindness and support during my time here. I thank past coop members who contributed to lesser prairie-chicken research and to my research efforts. It has been such a blessing to become a part of the beautiful world of grouse. Thank you to NRCS, FSA, and KDWP for providing funding for this research.

To my fellow graduate students and close friends, Elli, Mary, and Aleah, thank you all for your friendship and endless support from the very beginning. I enjoyed all our time together, whether we were playing video games or just chatting. Thank you for making the hard times easier. To my best friend from high school, Janae, thank you for being by my side for the last 10 years. I have been forever changed by your friendship and cannot imagine this world without you. To Kate, my best friend from undergrad, I was incredibly lucky to meet you in school and even luckier that our friendship continued. To my first wildlife technician partner, Sophie, you made field work bearable and dare I say fun. I am grateful to still be friends today. I am very proud of each of you and all you have and will accomplish in your lives. It has been wonderful to be surrounded by such smart, talented, strong, funny, and cool people. I am forever grateful that

our paths crossed when they did. Lastly, to my family, I thank you for supporting me throughout all my endeavors and encouraging me to do what I love. I have felt nothing but love from these people, and without them, I can promise I would not be completing this degree.

Chapter 1 - Evaluating Focal Area and Occupied Area Landscapes within the Lesser Prairie-Chicken Occupied Range in Kansas

Introduction

Prairie grouse are crucial indicators of the health of prairie ecosystems. They aid in sustaining ecological balance by relying on large, intact grassland landscapes with a wide variety of native plants and insects; thus, serving as umbrella species of prairie loss, degradation, or recovery. During the past century, several species of prairie grouse in North America such as the extinct heath hen (*Tympanuchus cupido cupido*), greater prairie-chicken (*T. c. pinnatus*), endangered Attwater's prairie-chicken (*T. c. attwateri*), and lesser prairie-chicken (*T. pallidicinctus*) have suffered extensive habitat loss and degradation, reduced occupied range, and population declines. Ecological and anthropogenic factors such as changes in disturbance regimes, woody encroachment, conversion of grassland for agriculture, disease, overharvest, herbicide/pesticide use, and energy development are contributing to these population and habitat declines (Gross 1928; Svedarsky et al. 2000; Bidwell et al. 2003; Kamm 2015; Rodgers 2016; Lautenbach et al. 2017; Spencer et al. 2017).

Of foremost concern is the loss and degradation of native grasslands that have resulted in isolation and localized extinction of many populations of prairie grouse species in North America (Lehmann 1941; Crawford and Bolen 1976; Morrow et al. 1996; Ross et al. 2016). As grasslands (e.g., the Great Plains) are reduced in quality and area, prairie grouse, such as the lesser prairie-chicken, face restricted movement and increasing isolation; absence of vegetation for breeding, brood-rearing, and nonbreeding stages; and overall significant decline in population abundance.

Lesser prairie-chickens and other prairie grouse require expansive grassland landscapes for population persistence and resilience. Because prairie-grouse habitat requirements vary among life stages (e.g., breeding, brood-rearing, nonbreeding), large, contiguous grasslands have been a central component of research and conservation efforts (Maestas et al. 2022; Boyd et al. 2024). For example, populations of lesser prairie-chickens in Texas, USA, are restricted to landscapes with $\geq 60\%$ native grassland (Crawford and Bolen 1976). Additionally, in Kansas, USA, the probability of use of an area by lesser prairie-chickens was greatest at $\geq 77\%$ native grassland with contiguous patches of grassland (Sullins et al. 2019). As native grassland continues to decline in area and connectivity, populations of prairie grouse may become more susceptible to demographic and genetic consequences.

As the Great Plains are reduced in quality and area, isolation and small size of prairie grouse populations can result in failure for the species to rebound in numbers (e.g., Allee effect), leading to localized extinction. The Allee effect describes a phenomenon where low population density decreases population growth rates and reproductive viability (Courchamp et al. 1999). As a result, once populations reach a critical abundance threshold, the likelihood of extinction greatly increases. Small or isolated populations are also subject to an “extinction vortex” where lack of genetic diversity allows deleterious mutations to dominate the population, also increasing the likelihood of local extinction (Gilpin and Soule 1986). These conditions have contributed to declines of prairie grouse populations and are likely contributing to contemporary prairie grouse range-wide population trends.

Historically, lesser prairie-chickens may have occupied much broader areas than the currently estimated occupied range (Boal and Haukos 2016). Uncertainty about the true historical range lies in a lack of documented observations, confusion regarding species

identification, and uncertainty with exact locations from anecdotal sightings (Boal and Haukos 2016; Rodgers 2016). In 2012, four ecoregions describing the occupied area of lesser prairie-chickens were established: Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic, Mixed-Grass Prairie, Sand Sagebrush Prairie, and Sand Shinnery Oak Prairie (Figure 2.1; McDonald et al. 2014). These ecoregions span the southwestern Great Plains across Texas, New Mexico, Oklahoma, Colorado, and Kansas, USA. The Sand Shinnery Oak Prairie Ecoregion is restricted to northwest Texas and eastern New Mexico, whereas the remaining ecoregions occur wholly or partially within Kansas. However, historical occupancy of these ecoregions differs across the species' range, with Rodgers (2016) indicating that lesser prairie-chickens were first documented in the Short-Grass Prairie/CRP Mosaic Ecoregion north of the Arkansas River during the mid- to late-1990s (Rodgers 2016).

From European settlement through establishment of the U.S. Department of Agriculture CRP, lesser prairie-chicken habitat consisted of mixed-grass prairie and tall and mixed-grasses within sand sagebrush (*Artemisia filifolia*) and sand-shinnery oak (*Quercus havardii*) prairies in the western portions of the species range. These landcover types were primarily associated with sandy soils within the short-grass prairie matrix of the High Plains region of the southwestern Great Plains (Boal and Haukos 2016). Within the Mixed-Grass Prairie Ecoregion, lesser prairie-chickens were historically associated with heterogeneous prairie landscapes characterized by perennial grasses intermixed with sand sagebrush and other shrubs on sandy or loamy soils (Dhillon et al. 1994). Following establishment of the CRP, reliable availability of mid- and tall-grass cover in the Short-Grass Prairie/CRP Mosaic Ecoregion north of the Arkansas River in Kansas facilitated expansion of lesser prairie-chicken occupied range and increased population abundance.

Habitat requirements for resilient lesser prairie-chicken populations consist of large areas of grassland within expansive landscapes (i.e., >20,000 ha) comprised of specific vegetation composition and structure for each life stage (Haukos and Zavaleta 2016). For example, ideal lek locations have short or lacking vegetation with good visibility at sites of relatively high elevation (Bidwell et al. 2003). Nest-site characteristics consist of selection for greater visual obstruction, horizontal cover, residual grass cover, and litter cover than available (Riley 1978; Riley et al. 1992; Giesen 1994; Pitman et al. 2005; Davis 2009; Hagen et al. 2013; Grisham et al. 2014). Brood-rearing habitat is characterized by sparse and short vegetation to allow for chick movement (Haukos and Zavaleta 2016). Additionally, female lesser prairie-chickens with broods often select areas that have greater food resources and thermoregulatory capacity (e.g., forb-dominated patches; Jamison et al. 2002; Hagen et al. 2005; Bell et al. 2010). To close out the annual life cycle, lesser prairie-chickens require denser grass cover during winter, with grasslands used for roosting and loafing and grain fields for foraging (Hagen et al. 2004; Haukos and Zavaleta 2016).

Post-settlement changes to prairie landscapes across the lesser prairie-chicken range have resulted in widespread conversion of native grasslands to agriculture and altered disturbance regimes. Expansive areas of extant prairies were cultivated and domestic livestock were introduced throughout the lesser prairie-chicken occupied range. The development and establishment of center-pivot irrigation systems in the High Plains during the 1960s-1980s altered landscapes and accelerated loss of native prairies (Spencer et al. 2017; Vhay et al. 2024). These technological advancements provided reliable irrigation from the Ogallala/High Plains aquifer but also contributed to widespread cultivation of prairie in the sandy soils at the core of lesser prairie-chicken distribution.

The U.S. Department of Agriculture introduced the CRP in 1985, encouraging soil conservation by initially planting perennial introduced (New Mexico, Texas, and Oklahoma) and native (Kansas and Colorado) mid- and tall grasses on highly erodible soils in exchange for annual rental payments. Lesser prairie-chicken populations quickly responded positively to the establishment of CRP through the species range. Lesser prairie-chickens are most likely to use CRP grasslands when landscapes are ~77% native prairie and where CRP fields are in areas of contiguous patches of native grassland (Sullins et al. 2018). The probability of lesser prairie-chickens occupying a landscape increases considerably when the land is managed by prescribed grazing or enrolled in CRP (Hagen et al. 2016). On a different scale, as the percentage of CRP enrolled in a 57-km² area exceeds 20%, the likelihood of lesser prairie-chickens occupying that landscape increases (Hagen et al. 2016). In the High Plains of Texas, USA, at the second order of selection, lesser prairie-chickens selected CRP fields with nonnative grasses and native grasses with forbs year-round, while row-crop agriculture and native grassland were avoided (Harryman et al. 2019). In the western portion of their occupied range, CRP grasslands disproportionally support lesser prairie-chickens during nesting and roosting periods (Sullins et al. 2018; Berigan et al. 2022). In the Sand Sagebrush Prairie Ecoregion, translocated lesser prairie-chickens selected CRP grasslands at the end of dispersal steps post-release (Berigan et al. 2024). Further, translocated lesser prairie-chickens in Kansas selected for CRP grassland within their home range and for nesting (Teige 2021). In northwest Kansas, presence of CRP grasslands provides reliable nesting habitat that was not present previously for lesser prairie-chickens during periods of drought (Sullins et al. 2018). As a result, lesser prairie-chickens dispersed north of the Arkansas River and established populations in previously unoccupied landscapes (Dahlgren et al. 2016).

The lesser prairie-chicken is a boom-bust species in a semi-arid region with dynamic and unpredictable environmental conditions (e.g., frequent intensive drought). Boom-bust population fluctuations are largely driven by intensive drought, which reduces reproductive success and adult survival, whereas wetter periods facilitate population increases (Grisham and Boal 2015). Increasing occurrence and intensity of drought in conjunction with declining habitat quality are therefore hindering population recovery (Haukos and Zavaleta 2016; Ross et al. 2016). During the 1960s-1980s, population estimates throughout the lesser prairie-chicken occupied range reported stable numbers with ~150,000 birds (Garton et al. 2016). Unfortunately, following a contemporary peak in abundance during the mid-late 1980s, a steep range-wide decline through the mid 1990s dropped to ~25,000 birds by approximately 1995. Populations increased to ~80,000 birds by 2008 but dipped again to ~37,000 birds in 2012 (Garton et al. 2016). A decade later, aerial surveys estimated ~26,591 birds, with >90% of extant lesser prairie-chickens occurring in Kansas (Nasman et al. 2022). Based on the most recent range-wide population survey, the Short-Grass Prairie/CRP Mosaic Ecoregion has become the species stronghold, supporting >70% of extant lesser prairie-chickens, with an estimated 19,847 individuals (Nasman et al. 2022). Populations in the Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions were much smaller with an estimated 4,512 and 1,713 individuals, respectively, and the Sand Shinnery Oak Prairie Ecoregion supported approximately 519 individuals (Nasman et al. 2022). There has not been a range-wide population estimate since 2022.

As a result of population declines and conservation concerns, the legal status of the lesser prairie-chicken has been under continual review since being petitioned for listing in 1995 under the 1973 Endangered Species Act (Rodgers 2016). Initially listed as threatened range-wide in 2014 under the Endangered Species Act, the ruling was vacated in 2015, with the species

officially removed from the list in 2016 (Boal and Haukos 2016). However, in 2022, the U.S. Fish and Wildlife Service proposed listing two Distinct Population Segments (DPS). In 2023, the Northern DPS (Kansas, Oklahoma, and Colorado) was listed as threatened, while the Southern DPS (Texas and New Mexico) was listed as endangered (U.S. Fish and Wildlife Service 2022). In 2025, a federal judge vacated the rule establishing the Distinct Population Segments, effectively leading to an eventual delisting of the species once again in 2026 (<https://www.federalregister.gov/documents/2026/02/26/2026-03883/endangered-and-threatened-wildlife-and-plants-removal-of-northern-and-southern-distinct-population>).

Despite the ongoing challenges surrounding the listing of the lesser prairie-chicken, established conservation practices have remained in place. In 2013, the Western Association of Fish and Wildlife Agencies (WAFWA) developed the Lesser Prairie-Chicken Range-Wide Plan, a conservation plan to address threats to lesser prairie-chickens across their historic and current occupied range (<https://wafwa.org/initiative-programs/lesser-prairie-chicken/>). Objectives of this plan included using the Crucial Habitat Assessment Tool (CHAT; <https://www.sgpchat.org/>) to identify Focal Areas (CHAT 1) and Connectivity Zones (CHAT 2; <https://www.sgpchat.org/>) for prioritizing landscapes with existing populations and high-quality habitat for conservation. Additionally, available, or potential habitat (Modeled Habitat, CHAT 3) and the estimated occupied range with an added 10-mile buffer (Modeled Non-Habitat, CHAT 4) are designated within this plan. These CHAT designations were based on the assumption of available habitat or expert opinion, rather than the presence of lesser prairie-chickens. This tool incorporates multiple criteria related to habitat quality, landscape composition, and potential threats to categorize areas based on their conservation value (Van Pelt et al. 2013).

In theory, Connectivity Zones link Focal Areas to enhance movements among Focal Areas by lesser prairie-chickens. Delineation is dependent on potential for connectivity. Connectivity Zone recommendations were made by scientists and managers using the information from the Range-Wide Plan, with four goals in mind: at least 40% good to high quality habitat; no greater than 2 miles between habitat patches; minimum of 5 miles in width; and few or no barriers to lesser prairie-chicken movement (Van Pelt et al. 2013). Monitoring leks, habitat conditions, and landscape characteristics of Focal Areas (CHAT 1) and Connectivity Zones (CHAT 2) allows for detection of population declines, assessment of factors potentially influence population demography, and initiation of proactive conservation actions. Moreover, assessing Focal Areas and Connectivity Zones relative to established thresholds allows for detection of population declines and initiation of proactive conservation actions. Finally, determination if designated Focal Areas represent landscape conditions similar to areas of known lesser prairie-chicken occupancy will provide evidence supporting continued use of Focal Areas for development of conservation strategies.

Occupied Areas represent areas of lesser prairie-chicken occupancy and dispersal connectivity. Occupied Areas were developed by Berigan et al. (*in prep.*) using lesser prairie-chicken lek locations in Kansas, including lek locations from ground surveys, aerial surveys, and opportunistic sightings from 1963-2023. A resistance surface representing potential barriers to dispersal was used to estimate least-cost paths among locations, creating a network of potential connectivity across the landscape. This network was then reduced to the minimum number of connections necessary to link the groups of lek locations (Berigan et al. *in prep.*).

Conservation-focused programs such as the CRP and Conservation Banking have provided critical support for lesser prairie-chicken populations by restoring and protecting

habitat across their occupied range. Conservation Banking is a market-based approach to species and habitat conservation that involves partnerships among landowners, government agencies, and developers. Landowners permanently protect and manage habitat for a target species in exchange for U.S. Fish and Wildlife Service-approved credits, which can be sold to developers to mitigate negative effects to the same species elsewhere. Like the CRP, this program provides financial incentives for landowners while promoting habitat conservation for species of concern (U.S. Fish and Wildlife Service n.d.). However, effectiveness of these programs depends on a clear understanding of which landscape features most strongly influence lesser prairie-chicken lek occurrence and persistence.

Importantly, ecological thresholds, critical points at which relatively small changes in landscape features result in rapid declines in population abundance and occupied area, influencing lesser prairie-chicken occupancy and persistence have been identified in recent decades (Hagen et al. 2007; Environmental Protection Agency 2016). Landscape-level thresholds have been linked to grassland extent, tree density, and anthropogenic structures (Crawford and Bolen 1976; Ross et al. 2016; Lautenbach et al. 2017; Sullins et al. 2018; Plumb et al. 2019; Table 2.1). Within the lesser prairie-chicken occupied range, specifically surrounding leks, assessing landscapes for thresholds can identify areas at heightened risk of population decline or local extinction. This knowledge will enable more effective conservation prioritization and management strategies.

Grasslands are critical for each life stage of lesser prairie-chickens, providing required cover to meet life history requirements, food resources, protection from predators, and can improve population resilience to intensive drought. At least 60% grassland in a landscape is required for lesser prairie-chicken population persistence and long-term occupancy (Crawford

and Bolen 1976). Research in Kansas found that lesser prairie-chickens are constrained to areas with >70% grasslands within a 5-km radius (Sullins et al. 2018). Like other grouse species (e.g., greater prairie-chicken), lesser prairie-chickens will use cropland for food resources. In Texas, lesser prairie-chicken populations were found in areas with 63-95% native grassland; land use of the remaining area was grain sorghum. No lesser prairie-chicken leks were recorded in areas with >37% cultivation (Crawford and Bolen 1976). Similarly, in Kansas, as the proportion of cropland exceeded approximately 23%, available grassland decreased along with the probability of use by lesser prairie-chickens (Ross et al. 2016; Sullins et al. 2018). Further, a cropland-to-grassland ratio of 1:10 (~9.6% cropland) was defined for resilience to intensive drought, with population persistence of lesser prairie-chickens declining if this ratio was exceeded (Ross et al. 2016).

Historically, lesser prairie-chickens evolved in prairie landscapes with few to no trees. Fueled by precipitation and a lack of fire, trees located in the sand prairies of central Kansas (i.e., Mixed-Grass Prairie Ecoregion) flourished, causing a major loss of lesser prairie-chicken habitat (Rodgers 2016). Further, incentives (e.g., living snow fences) for planting trees in the western Great Plains were implemented in the late 1800s, contributing to loss of habitat throughout the occupied range. The encroachment of woody vegetation, particularly eastern red cedar (*Juniperus virginiana*), elicits avoidance behaviors by lesser prairie-chickens and other grassland birds in Kansas (Lautenbach et al. 2017; Silber et al. 2024). An increase in woody vegetation prompts declines in grasshopper sparrow (*Ammodramus savannarum*), dickcissel (*Spiza americana*), and eastern meadowlark (*Sturnella magna*) populations (Silber et al. 2024). Despite normally selecting for different vegetation types and varying amounts of herbaceous cover, each species selected for relatively flat areas, <6% shrub cover, and <1% tree cover (Silber et al.

2024). Lesser prairie-chickens were 40 times more likely to use habitats with 0 trees/ha when compared to landscapes with 5 trees/ha (Lautenbach et al. 2017). Additionally, lesser prairie-chickens were 19 times more likely to use habitats that were >1 km from the nearest tree compared to habitats <100 m away from the nearest tree (Lautenbach et al. 2017). Female lesser prairie-chickens selected for habitats with <2 trees/ha and distances >300 m from a tree when placing nests. Thresholds were established as no nests were observed in areas with >2 trees/ha and habitat use ceases completely with 8 trees/ha (Lautenbach et al. 2017).

Lesser prairie-chickens will avoid multiple types of anthropogenic structures, such as transmission lines, distribution power lines, oil wells, gas wells, wind turbines, and cellular towers (Plumb et al. 2019). Roads and oil/gas energy development, along with associated noise, are perceived as a potential threat by lesser prairie-chickens (Hagen et al. 2011; Lipp 2016). High densities of anthropogenic structures negatively affect lesser prairie-chicken space use; thus, they often select areas with minimal structures within a 2-km radius (Sullins et al. 2019). Avoidance of these structures varies with the density at the landscape scale, life-stage of individuals, and availability of high-quality habitat, with some lesser prairie-chickens reducing avoidance distance when there is sufficient access to high-quality habitat (Lautenbach et al. 2017; Plumb et al. 2019). Several grouse species, including lesser prairie-chickens, negatively respond to power lines (e.g., transmission and distribution power lines). These structures influence movement, nest-site selection, and general habitat use (Patten et al. 2005; Beck et al. 2006; Hagen et al. 2007; Wolfe et al. 2007; Stevens et al. 2012). Plumb et al. (2019) reported that in all analyses, lesser prairie-chickens consistently avoided distribution power lines. While distribution lines were not differentiated from transmission lines in many studies due to lack of transmission lines, results suggest negative effects on lesser prairie-chickens. Lesser prairie-

chickens established home ranges and placed nests farther from powerlines than what would be expected at random (Plumb et al. 2019). It was reported that the probability of use of an area decreases at a powerline density of 0.15 km per 12.6 km² (Sullins et al. 2019). Further, transmission lines and distribution power lines can elicit a negative response to the newness (neophobia) and size of the structure. A different study suggested that the tallest features on the landscape (e.g., towers, windmills, and transmission lines) were avoided at greater distances (Peterson et al. 2020).

Oil and gas well development affects not only lesser prairie-chickens, but other species of grouse as well. Greater sage-grouse (*Centrocercus urophasianus*) have been documented avoiding both oil and gas wells; similar avoidance behaviors have been observed in lesser prairie-chickens (Green et al. 2017). Areas with >2 wells/12.6 km² have 8 times lower rate of use (Sullins et al. 2019). Additionally, space use declines with greater well density, as female lesser prairie-chickens avoided areas containing 23 wells/250 ha (Plumb 2015). However, effects of oil and gas wells can vary among scales of selection (i.e., second and third order of selection; Johnson 1980), with distance to wells not being a significant predictor of home range or nest placement at the second-order selection scale. Despite this, lesser prairie-chickens selected areas farther away from oil and gas wells than what was available within their home range (Plumb et al. 2019).

While gravel and paved roads may not be as problematic as other anthropogenic structures, there are still some risks associated with these features. Gravel and paved roads, and noise produced from cars may trigger avoidance behaviors in lesser prairie-chickens, resulting in potential deterrence from the area (Plumb et al. 2019). Female lesser prairie-chickens established nesting sites farther from paved roads than what would be expected (Hagen et al. 2011).

Positively, the effect of county roads appears lower than that of other anthropogenic features, as avoidance was not observed when road density was <15 km per 12.6 km^2 (Sullins et al. 2019). These patterns of habitat use may have cascading effects on reproductive behavior, including lek establishment.

The lekking period is the first stage of the breeding season, followed by nesting and brood-rearing. Leks are often established on slightly elevated ground in areas with sparse vegetation (Boal and Haukos 2016). In addition to grassland sites, lesser prairie-chicken leks have been observed in green wheat fields, bare corn fields, cut hay fields, livestock holding or watering areas, abandoned oil pads, and roadsides. Male lesser prairie-chickens arrive at leks in early spring (late Feb – early Mar) to establish territories with females visiting a few weeks later. Males attract females with an exhilarating courtship display consisting of booming, fanning their tails, and rapidly stomping on the lek (Applegate and Riley 1998). Females may visit multiple leks before choosing a mate and typically nesting within 3.2 km of the nearest lek (Boal and Haukos 2016). Additionally, male lesser prairie-chickens often return to the same lek year after year. Thus, prevention of lek isolation and maintaining connectivity among leks is important for persistence of local populations (Applegate and Riley 1998; Boal and Haukos 2016). An intrinsic threshold regarding lek attendance, determined using aerial and ground lek survey data, has been recently established. This threshold suggests that lesser prairie-chicken leks with <10 males present at the lek have a much greater probability of extinction within 5 years, while leks above this threshold (≥ 10) have a greater probability of persistence (Whetten et al. *In Review*; Chapter II). This threshold and trends in lek attendance may hint at future population declines that can be attributed to Allee effects, such as those that greatly diminished populations of heath hen and Attwater's prairie-chicken.

Recognition of ecological thresholds as a result of sensitivity to environmental changes and influences by lesser prairie-chickens has increased identification of causes of localized extinction due to habitat loss, decreased habitat quality, and low population level. Failure to meet habitat requirements (e.g., >60% grassland) and surpassing other thresholds of features surrounding leks will likely result in decreased attendance, lek abandonment, and eventual extinction. Assessing and monitoring thresholds can identify populations of lesser prairie-chickens at risk of localized extinction, highlight areas with relatively greater conservation need, and inform conservation efforts of potential risks of future landscape changes (e.g., anthropogenic development).

My goal was to estimate and compare land cover variables (native grassland, CRP grassland, total grassland, cropland, trees/ha, and density of anthropogenic structures) between designated Focal Area (CHAT 1) and Occupied Area that have been designated for populations of lesser prairie-chickens. I estimated the same land cover variables for Connectivity Zones (CHAT 2) for additional context related to future use of potential corridors. Using ecological thresholds that affect lesser prairie-chicken persistence, I applied a rank to each Focal Area and Occupied Area in each ecoregion, highlighting areas where conservation efforts would be most effective. Additionally, I calculated class (total area, largest patch index, edge density) and landscape (total area, number of patches, total edge, edge density, and contagion) metrics within each Focal Area and Occupied Area. I predicted that Focal Areas in the Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion will have more native grassland than Focal Areas in the Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions. Similarly, I hypothesized that Occupied Areas in the Short-Grass Prairie/CRP Mosaic Ecoregion would have greater proportion of CRP grassland compared to Occupied Areas in the Mixed-Grass Prairie and

Sand Sagebrush Prairie ecoregions. A comprehensive evaluation of landscape conditions within WAFWA CHAT Zones and currently occupied areas can provide knowledge of those areas within the reported lesser prairie-chicken occupied range in Kansas capable of supporting populations. Additionally, areas with active populations of lesser prairie-chickens can be prioritized, while previously occupied areas can become target for population restoration.

Study Area

Three defined ecoregions of the lesser prairie-chicken occupied range in Kansas were of focus for this study. The Short-Grass Prairie/CRP Mosaic Ecoregion is a semi-arid climatic zone north of the Arkansas River with a range of 25-51 cm annual precipitation. This ecoregion is dominated by fine, sandy loam soil and primary land use includes CRP grasslands, livestock grazing, and row-crop agriculture (Robinson et al. 2018; Kansas Department of Wildlife and Parks 2022). Grasses present in this ecoregion include big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), hairy grama (*Bouteloua hirsuta*), sideoats grama (*B. curtipendula*), blue grama (*B. gracilis*), and buffalograss (*B. dactyloides*). The forb community is comprised of Illinois bundleflower (*Desmanthus illinoensis*), prairie sunflower (*Helianthus petiolaris*), annual buckwheat (*Eriogonum annuum*), sand milkweed (*Asclepias arenaria*), nine-anther dalea (*Dalea enneandra*), and western ragweed (*Ambrosia psilostachya*; Lauver et al., 1999). The CRP fields were planted with native grasses species including big bluestem, little bluestem, sideoats grama, blue grama, buffalograss, switchgrass (*Panicum virgatum*), and golden feather grass (*Sorghastrum nutans*). Starting in the mid-1990s, CRP fields were interseeded with forbs such as white sweet clover (*Melilotus albus*), yellow sweet clover (*M. officinalis*), Maximillian sunflower (*Helianthus maximiliani*), Illinois bundleflower, purple prairie clover (*Dalea purpurea*), and prairie coneflower (*Ratibida columnifera*; Fields 2006). Woody species

found in this ecoregion include bur oak (*Quercus macrocarpa*), green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), eastern cottonwood (*Populus deltoides*), sugar maple (*Acer saccharum*), river birch (*Betula nigra*), and hackberry (*Celtis occidentalis*; Kansas Department of Wildlife and Parks 2022). Salt cedar (*Tamarix spp.*) is a non-native species and eastern red cedar (*Juniperus virginiana*) is native; both of these invasive woody species are rapidly encroaching in this ecoregion.

The Mixed-Grass Prairie Ecoregion has a dry, sub-humid to semi-arid climate with a range of 51-76 cm of annual precipitation (Kansas Department of Wildlife and Parks 2022). Soils in this ecoregion are loamy. Primary land uses are livestock grazing, oil/gas extraction, and row-crop agriculture (Robinson et al. 2018). Grasses include big bluestem, little bluestem, blue grama, hairy grama, sideoats grama, western wheatgrass (*Pascopyrum smithii*), buffalograss, switchgrass, golden feather grass, sand lovegrass (*Eragrostis trichodes*), tall dropseed (*Sporobolus compositus*), and alkali sacaton (*Sporobolus airoides*). Forbs in this ecoregion include purple coneflower (*Echinacea purpurea*), leadplant (*Amorpha canescens*), dotted blazing star (*Liatris punctata*), heath aster (*Symphyotrichum ericoides*), hairy sunflower (*Helianthus hirsutus*), round leaf bladderpod (*Lesquerella ovalifolia*), western ragweed, lamb's quarters (*Chenopodium album*), Russian thistle (*Salsola tragus*), annual sunflower (*Helianthus annuus*), kochia (*Bassia scoparia*), and Patagonian plantain (*Plantago patagonica*). Native woody species include southern hackberry (*Celtis laevigata*), western snowberry (*Symphoricarpos occidentalis*), eastern cottonwood (*Populus deltoides*), eastern red cedar, honey mesquite (*Prosopis glandulosa*), and green ash (*Fraxinus pennsylvanica*; Robinson et al. 2018). Invasive woody species include salt cedar, with native species such as eastern red cedar also exhibiting rapid encroachment (Kansas Department of Wildlife and Parks n.d.).

The Sand Sagebrush Prairie Ecoregion is a semi-arid, drought-prone region with a range of 41-53 cm of annual precipitation. This ecoregion has sandy soil with dunes found throughout, primarily associated with river drainages (e.g., Cimarron, Arkansas). Irrigated row-crop agriculture, livestock grazing, and oil/gas extraction are the predominant land uses for this ecoregion. Sand dropseed (*Sporobolus cryptandrus*), sideoats grama, hairy grama, blue grama, big bluestem, little bluestem, sand bluestem (*Andropogon hallii*), buffalograss, prairie sandreed (*Calamovilfa longifolia*), and alkali sacaton are commonly occurring grasses. The forb community includes annual buckwheat, dotted blazing star, western ragweed, prairie sunflower, annual sunflower, Russian thistle, camphorweed (*Heterotheca subaxillaris*), Indian blanket flower (*Gaillardia pulchella*), tansy aster (*Machaeranthera tanacetifolia*), buffalo bur (*Solanum rostratum*), buffalo gourd (*Cucurbita foetidissima*), wax goldenweed (*Grindelia papposa*), prickly lettuce (*Lactuca serriola*), and maretail (*Conzya canadensis*). Woody and shrubby vegetation includes cottonwood, elm (*Ulmus spp.*), eastern red cedar, salt cedar, and sand sagebrush (*Artemisia filifolia*; Vhay 2022).

Methods

WAFWA Focal Areas and Connectivity Zones

Within the lesser prairie-chicken occupied range in Kansas, the WAFWA established Focal Areas (CHAT 1), Connectivity Zones (CHAT 2), Modeled Habitat (CHAT 3), and Modeled Non-habitat (CHAT 4; Figure 1.1). Only Focal Areas and Connectivity Zones were used in my analyses. There were 40 delineated Focal Areas: 18 in the Short-Grass Prairie/CRP Mosaic Ecoregion; 13 in the Mixed-Grass Prairie Ecoregion; and 9 in the Sand Sagebrush Prairie Ecoregion. One Focal Area in the Sand Sagebrush Prairie Ecoregion was omitted from this

study, as the majority of the area was in Colorado. To prevent overestimation of land cover variables, Focal Areas were not split between ecoregions. For example, if the greatest area of a Focal Area was in the Mixed-Grass Prairie Ecoregion, but was partially in the Sand Sagebrush Prairie Ecoregion, the Focal Area was considered to be in the Mixed-Grass Prairie Ecoregion. There were 13 established Connectivity Zones: 5 in the Short-Grass Prairie/CRP Mosaic Ecoregion, 7 in the Mixed-Grass Prairie Ecoregion, and 1 in the Sand Sagebrush Prairie Ecoregion. One Connectivity Zone in the Sand Sagebrush Prairie Ecoregion was omitted from this study, as the majority of the area was in Colorado.

Occupied Areas

Occupied Areas were developed by Berigan et al. (*in prep*). Lesser prairie-chicken populations were delineated using lek locations in Kansas identified from ground surveys, aerial surveys, and opportunistic sightings from 1963-2023 (Chapter II). A resistance surface of potential obstacles for lesser prairie-chicken dispersal was used to calculate least-cost paths (edges) between leks, forming a graph of connectivity among all leks (nodes) in the dataset (O'Donnell et al. 2022). The Prim pruning algorithm (Prim 1957) was used to reduce these edges to the minimum number and cost required to connect all nodes of the graph. The resulting product, called a minimum spanning tree (LCP-MST; Cormen et al. 2022), highlights the most important edges for ensuring lesser prairie-chicken connectivity among leks (Figure 2.2). Then, the LCP-MST was divided into hierarchical clusters of lesser prairie-chicken leks by removing edges longer than a maximum allowed distance, corresponding to the movement distances of lesser prairie-chickens over the specified timescale (Table 1.2; Berigan et al. *in prep*).

Delineation of Occupied Areas

In total, 3 hierarchical clusters were developed. I estimated land cover variables for all 3 to be thorough, but comparisons to WAFWA Focal Areas were made only for the smallest spatial scale (Scale 1). Occupied Areas were converted from image files to a raster, then from a raster to individual polygons. Occupied Areas were restricted to ≥ 5 km in area, as lesser prairie-chickens in Kansas are constrained to areas with $>70\%$ grassland within a 5-km radius (Sullins et al. 2019).

Estimation of Leks per CHAT Focal Area or Occupied Area

I used a spatial layer with lek locations from 2018-2023 to evaluate contemporary lek occurrence within each Focal Area or Occupied Area (Chapter II). I defined boundaries of each WAFWA CHAT Zone using the corresponding spatial layer (https://ags.wafwa-gis.org/arcgis/rest/services/SGP-CHAT/LPC_RWP_CHAT_Categories/FeatureServer). I determined the number of each lek type (<10 , ≥ 10 , Extinct) in each Focal Area and Occupied Area.

Estimation of Land Cover Variables

Grassland

Kansas land cover data were retrieved from the Ecological Mapping Systems of Kansas (Diamond et al. 2021). This layer consisted of 49 land cover classes for Kansas. I combined the following cover types for the native grassland category: mixed-grass prairie, mixed-grass prairie breaks grassland, sand sagebrush prairie, sandhills prairie, shortgrass prairie, chalkflat mixed-grass prairie, and western lowland grassland. To estimate the proportion of native grassland cover types within WAFWA CHAT Zones 1 & 2 and Occupied Area, I joined the Ecological Mapping Systems of Kansas grassland layer to each spatial layer for WAFWA CHAT Zones 1 &

2 and Occupied Areas in ArcGIS PRO 3.2. I then quantified the area of each grassland cover type within each polygon. The area of each cover type per polygon was displayed in the attribute table and summed to estimate the total area of grassland.

Conservation Reserve Program (CRP) data from 2021 were provided by the United States Department of Agriculture Farm Service Agency. The 2021 data represents the mid-point of the study's time frame (2018-2023). This variable was treated as a binomial variable (present/absent); Conservation Practice was not recorded. I estimated the area and proportion of CRP grasslands within WAFWA CHAT Zones 1 & 2 and Occupied Area. This variable was reported as a stand-alone metric and combined with native grassland to create the total grassland variable. Additionally, I report the total and average number of CRP fields (partial or whole) per WAFWA CHAT Zones 1 & 2 and Occupied Area.

To prevent overestimation of the native grassland and total grassland variables, I converted the Ecological Mapping Systems of Kansas raster to a polygon layer and removed overlap between native grassland and CRP grassland. I derived the mean, standard error, and proportion for each grassland variable (native grassland, CRP, total grassland) for CHAT Zones 1 & 2 and Occupied Area.

Cropland

I estimated cropland in the same manner as the native grassland variable. I calculated the mean, standard error, and proportion of cropland for WAFWA CHAT Zone 1 & 2 and Occupied Area.

Trees

I obtained 2021 Kansas tree data from EarthDefine (<https://www.earthdefine.com/treemap/>). This spatial layer was presented as a binary raster (1 =

tree, 0 = no tree) with 5-m resolution. To estimate the area of tree cover within WAFWA CHAT Zones 1 & 2 and Occupied Area, I first converted the EarthDefine tree raster into polygons. I then used Tabulate Area in ArcGIS PRO 3.2 to estimate the area of each tree polygon. I totaled the area of the tree polygons within WAFWA CHAT Zones 1 & 2 and Occupied Area.

Anthropogenic Structures

Anthropogenic structure spatial layers were obtained from several sources. Data for Kansas oil and gas wells, cellular towers, and paved/gravel roads were gathered from the Kansas Data Access and Support Center. Locations of individual wind turbines in Kansas were from the U.S. Geological Survey's Wind Turbine Database. Transmission line locations were obtained from the U.S. Department of Homeland Security open data site via ArcGIS.com. I estimated the quantity of individual oil/gas wells, cellular towers, wind turbines, and length of transmission lines and roads per 100 ha. To retrieve the count of oil/gas wells per polygon, I clipped the oil/gas well spatial layer to the CHAT Zone polygons spatial layer and viewed the attribute table. I was unable to differentiate oil and gas wells on the landscape. I did not remove plugged, dry, or abandoned wells as retirement of these wells is unknown. I repeated these steps for individual wind turbines and cell phone towers. For transmission lines, I first clipped the spatial layer to the spatial layer with the CHAT Zone polygons. I determined the total length of transmission lines per polygon by joining the attribute table with the lengths of individual transmission lines to the polygon layer. I repeated these for paved/gravel roads. All steps were repeated for the Occupied Areas.

Class and Landscape Metrics

Using Program FRAGSTATS (McGarigal and Marks 1995) and the Ecological Mapping Systems of Kansas landcover layer, I derived class metrics Total Area, Percent Land Cover

(PLAND), Largest Patch Index (LPI), Total Edge (TE), and Edge Density (ED) and landscape metrics Total Area, Number of Patches (NP), Largest Patch Index (LPI), Total Edge (TE), Edge Density (ED), and Contagion for each Focal Area and Occupied Area.

Statistical Analyses

I conducted statistical analyses in Program R to identify differences in landscape variables (grassland, cropland, trees, anthropogenic structures, class and landscape metrics) between Focal Areas and Occupied Areas within each ecoregion and across all ecoregions. I used a nonparametric Kruskal-Wallis test to test differences in land cover variables for Focal Areas across the 3 ecoregions; results are presented with 95% confidence intervals and $\alpha = 0.05$. Following a significant Kruskal-Wallis test, I used a Wilcoxon test for pairwise comparisons. These analyses were repeated for Occupied Areas. I used a Mann-Whitney U test to test for differences in land cover variables between Focal Areas and Occupied Areas within each ecoregion. Descriptive statistics, including means and standard errors, and proportion were calculated for all land cover variables and landscape metrics.

Ranking Focal Areas and Occupied Areas

A ranking system was developed to characterize Focal Areas and Occupied Areas for lesser prairie-chicken habitat conservation and restoration based on current landscape conditions relative to established population thresholds. Additionally, ranking by land cover variables can provide insight into what immediate management actions should be taken (e.g., tree removal). Within each ecoregion, Focal Areas and Occupied Areas were ranked separately. Focal Areas were ranked relative to other Focal Areas in the same ecoregion, as were the Occupied Areas. The first ranking criterium was number of leks above the lek attendance threshold of 10 birds

(Chapter II), followed by percent of total grassland (native grassland + CRP grassland), then by trees/100 ha.

Results

Comparisons Among Ecoregions

Focal Areas

Density of oil/gas wells ($H_2 = 4.65$, $P = 0.10$), cellular towers ($H_2 = 5.80$, $P = 0.06$), wind turbines ($H_2 = 2.08$, $P = 0.35$), or length of roads within 100 ha ($H_2 = 1.67$, $P = 0.43$) did not vary among lesser prairie-chicken ecoregions for WAFWA Focal Areas (CHAT 1; Table 1.4). The average proportion of native grassland within Focal Areas differed among ecoregions ($H_2 = 13.91$, $P < 0.001$; Table 1.4). Focal Areas in the Mixed-Grass Prairie Ecoregion had, on average, 16 percentage points more native grassland than those in the Short-Grass Prairie/CRP Mosaic Ecoregion and 30 percentage points more than those in the Sand Sagebrush Prairie Ecoregion (Table 1.3). The average proportion of CRP grassland varied among ecoregions ($H_2 = 10.73$, $P = 0.005$); Focal Areas in the Sand Sagebrush Prairie Ecoregion contained greater proportions of CRP grassland than those in the Mixed-Grass Prairie and Short-Grass Prairie/CRP Mosaic ecoregions (Table 1.3). Total Grassland (Native grassland + CRP grassland) varied among ecoregions ($H_2 = 7.40$, $P = 0.02$); Focal Areas in the Mixed-Grass Prairie Ecoregion had a greater average proportion of total grassland than those in the Short-Grass Prairie/CRP Mosaic and Sand Sagebrush Prairie ecoregions (Table 1.3). Area of cropland varied among ecoregions ($H_2 = 10.93$, $P = 0.004$); Focal Areas in the Short-Grass Prairie/CRP Mosaic Ecoregion had a greater average proportion of cropland than those in the Mixed-Grass Prairie Ecoregion ($P = 0.002$; Table 1.3). Focal Areas differed in the amount of trees per 100 ha ($H_2 = 16.53$, $P < 0.001$) among ecoregions as the Short-Grass Prairie/CRP Mosaic and Mixed-Grass Prairie ecoregions contained

more trees/100 ha on average compared to Focal Areas in the Sand Sagebrush Prairie Ecoregion (Table 1.4). Lastly, Focal Areas varied in the average length of transmission lines/100 ha ($H_2 = 6.62$, $P = 0.04$), with Focal Areas in the Sand Sagebrush Prairie Ecoregion having greater average length of transmission lines/100 ha than those in the Short-Grass Prairie/CRP Mosaic Ecoregion (Table 1.4).

Occupied Areas

Occupied Areas did not vary in proportion of native grassland ($H_2 = 2.74$, $P = 0.25$), CRP grassland ($H_2 = 5.86$, $P = 0.05$), total grassland ($H_2 = 3.51$, $P = 0.17$), cropland ($H_2 = 4.38$, $P = 0.11$), or density of oil/gas wells ($H_2 = 0.74$, $P = 0.70$), cell towers ($H_2 = 1.16$, $P = 0.56$), transmission lines ($H_2 = 3$, $P = 0.22$), and roads per 100 ha ($H_2 = 0.93$, $P = 0.63$). Occupied Areas varied in trees/100 ha ($H_2 = 7.26$, $P = 0.03$); however, pairwise comparisons did not detect significant differences between any ecoregion pairs (Table 1.4).

Focal Area Landscape Metrics

Focal Areas did not vary in average number of patches ($H_2 = 4.43$, $P = 0.11$), average patch size ($H_2 = 3.05$, $P = 0.22$), or patch density (per 100 ha; $H_2 = 3.05$, $P = 0.22$) among ecoregions. Focal Areas did vary in largest patch index ($H_2 = 16.68$, $P = 0.11$). Focal Areas in the Mixed-Grass Prairie Ecoregion had greater largest patch index values than those in the Short-Grass Prairie/CRP Mosaic Ecoregion (Table 1.5)

Occupied Area Landscape Metrics

Occupied Areas did not vary in average number of patches ($H_2 = 2.91$, $P = 0.23$), average patches size ($H_2 = 2.53$, $P = 0.28$), patch density (per 100 ha; $H_2 = 2.53$, $P = 0.28$), or largest patch index ($H_2 = 1.14$, $P = 0.57$) among ecoregions (Table 1.6).

Comparisons Within Ecoregions

Focal Areas vs. Occupied Areas

In the Short-Grass Prairie/CRP Mosaic Ecoregion, Focal Areas had 39 leks (34.21%) above the attendance threshold (≥ 10 birds) compared to 29 (25.44%) in the Occupied Areas. Focal Areas and Occupied Areas did not differ in the proportion of native grassland ($W = 70.00$, $P = 0.70$), CRP grassland ($W = 75.00$, $P = 0.50$), total grassland ($W = 65.00$, $P = 0.93$), cropland ($W = 66.00$, $P = 0.88$), trees/100 ha ($W = 90.00$, $P = 0.11$), or oil/gas wells ($W = 72.00$, $P = 0.61$) and roads/100 ha ($W = 75.00$, $P = 0.50$). Statistical comparisons were unable to be completed for wind turbines, as there were zero wind turbines within Focal Areas and Occupied Areas. Density of cellular towers/100 ha differed between Focal Areas and Occupied areas ($W = 94.00$, $P = 0.04$), with Focal Areas containing more cellular towers per 100 ha, on average, while Occupied Areas had zero (Table 1.4). Further, Focal Areas differed from Occupied Areas in the average length of transmission lines per 100 ha, with Occupied Areas having zero transmission lines ($W = 94.5$, $P = 0.03$; Table 1.4).

In the Mixed-Grass Prairie Ecoregion, Focal Areas had 3 leks (2.83%) above the attendance threshold (≥ 10 birds) and Occupied Areas had 0 leks with ≥ 10 birds from 2018-2023. Focal areas and Occupied Areas did not differ in proportion of native grassland ($W = 9.00$, $P = 0.57$), CRP grassland ($W = 20$, $P = 0.30$), total grassland ($W = 10.00$, $P = 0.69$), cropland ($W = 17.00$, $P = 0.57$; Table 1.3), trees/100 ha ($W = 11.00$, $P = 0.80$) or density of oil/gas wells ($W = 17.00$, $P = 0.57$), cellular towers ($W = 22.00$, $P = 0.14$), wind turbines ($W = 14.00$, $P = 0.84$), transmission lines ($W = 20.00$, $P = 0.23$), and roads per 100 ha ($W = 13.00$, $P = 1.00$; Table 1.4.). While there were only two Occupied Areas, there were zero cellular towers, wind turbines, and transmission lines present.

In the Sand Sagebrush Prairie Ecoregion, Focal Areas had 11 leks (9.57%) above the attendance threshold (≥ 10 birds), whereas Occupied Areas only had 2 leks (1.74%) above this threshold. Focal Areas and Occupied Areas did not differ in proportion of native grassland ($W = 6.00, P = 0.21$), CRP grassland ($W = 16.00, P = 0.73$), total grassland ($W = 6.00, P = 0.21$), cropland ($W = 22.00, P = 0.15$), or density of oil/gas wells ($W = 13.00, P = 1.00$), cellular towers ($W = 18.00, P = 0.46$), transmission lines ($W = 19.00, P = 0.35$), or roads per 100 ha ($W = 21.00, P = 0.21$). Density of wind turbines could not be compared between Focal Areas and Occupied Areas, as none were present within these areas in this ecoregion. Focal Areas and Occupied Areas varied in the amount of trees/ha ($W = 25.00, P = 0.04$). Focal Areas had approximately 9.35 times as many trees/100 ha compared to Occupied Areas (Table 1.4).

Focal Areas vs. Connectivity Zones

In the Short-Grass Prairie/CRP Mosaic Ecoregion, Focal Areas and Connectivity Zones did not differ in proportion of native grassland ($W = 20.00, P = 0.07$), CRP grassland ($W = 23.00, P = 0.11$), total grassland ($W = 20.00, P = 0.07$), cropland ($W = 68.00, P = 0.09$; Table 1.6), number of trees ($W = 61.00, P = 0.26$), oil/gas wells ($W = 45.00, P = 1.00$), cellular towers ($W = 32.00, P = 0.31$), or length of transmission lines ($W = 49.5, P = 0.75$) and roads within 100 ha ($W = 65.00, P = 0.15$; Table 1.7). Density of wind turbines was unable to be compared, as 0 were present within Focal Areas and Connectivity Zones.

In the Mixed-Grass Prairie Ecoregion, Focal Areas and Connectivity Zones did not differ in the amount of native grassland ($W = 29.00, P = 0.21$), CRP grassland ($W = 54.00, P = 0.54$), total grassland ($W = 35.00, P = 0.44$), cropland ($W = 68.00, P = 0.08$), number of trees ($W = 36.00, P = 0.49$), oil/gas wells ($W = 68.00, P = 0.08$), cellular towers ($W = 29.00, P = 0.18$), wind turbines ($W = 49.00, P = 0.65$), or length of transmission lines per 100 ha ($W = 46.00, P =$

1; Table 1.7). Focal Areas and Connectivity Zones differed in the density of roads per 100 ha ($W = 74.00, P = 0.02$; Table 1.7). Connectivity Zones contained a greater average of roads than Focal Areas. In the Sand Sagebrush Prairie Ecoregion, only one Connectivity Zone was present. This Connectivity Zone had the least total grassland of all Connectivity Zones among the three ecoregions, consisting of approximately 77% cropland.

Landscape Metrics

In the Short-Grass Prairie/CRP Mosaic Ecoregion, Focal Areas and Occupied Areas did not differ in the number of patches ($W = 85.00, P = 0.20$), average patch size ($W = 48.00, P = 0.39$), patch density per 100 ha ($W = 78.00, P = 0.39$), or largest patch index ($W = 38.00, P = 0.14$; Table 1.5). In the Mixed-Grass Prairie Ecoregion, Focal Areas and Occupied Areas did not differ in the number of patches ($W = 22.00, P = 0.14$), average patch size ($W = 12.00, P = 0.93$), patch density per 100 ha ($W = 14.00, P = 0.93$), or largest patch index ($W = 14.00, P = 0.93$; Table 1.5). In the Sand Sagebrush Prairie Ecoregion, Focal Areas and Occupied Areas did not differ in average patch size ($W = 15.00, P = 0.86$), patch density per 100 ha ($W = 12.00, P = 0.86$), or largest patch index ($W = 5.00, P = 0.15$). The average number of patches differed ($W = 26.00, P = 0.02$); Focal Areas had approximately 4.34 times as many patches compared to Occupied Areas (Table 1.5).

Ranking Focal Areas

The top 3 ranking Focal Areas in the Short-Grass Prairie/CRP Mosaic Ecoregion contained a range of 5-12 leks with ≥ 10 birds. Each Focal Area had an average of 56.67% native grassland, and the addition of CRP grassland pushed these areas over the threshold for required native grassland (60%). These areas also had fewer than 2 trees/ha. In the Mixed-Grass Prairie Ecoregion, the top-ranked Focal Area only has 2 leks with ≥ 10 birds. These three Focal Areas

had an average of 57.67% native grassland and 66.67% total grassland. Finally, in the Sand Sagebrush Prairie Ecoregion, the top-ranked Focal Areas had a range of 0-9 leks with ≥ 10 birds. One of these areas was below the threshold for native grassland (60%) but had 31% CRP grassland, the most of all Focal Areas in this study.

Ranking Occupied Areas

The top 3 Occupied Areas in the Short-Grass Prairie/CRP Mosaic Ecoregion contained a range of 5-16 leks with ≤ 10 birds. These had an average of 54% native grassland and 67.33% total grassland. The top-ranked Occupied Area had the most CRP grassland (20%) of all Occupied Areas in this ecoregion. These areas all had fewer than 2 trees/ha. In the Mixed-Grass Prairie Ecoregion, there were only 2 Occupied Areas, one had 1 lek with ≥ 10 birds while the other had 0 observed leks from 2018-2023. In the Sand Sagebrush Prairie Ecoregion, there were only 3 Occupied Areas, ranging from just 0-2 leks with ≥ 10 birds. However, these areas had an average of 83.33% total grassland and minimal trees.

Discussion

The WAFWA Focal Areas (CHAT 1) exhibited differences in ecological threshold and landscape characteristics among defined lesser prairie-chicken ecoregions, suggesting that population threshold concerns varied according to ecoregional landscape conditions. Focal Areas in the Mixed-Grass Prairie Ecoregion had more native and total grassland, yet the lowest amount of CRP grassland on average. In contrast, Focal Areas in the Sand Sagebrush Prairie Ecoregion had the greatest CRP grassland despite having the least total grassland overall. Although both the Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions had low proportions of leks exceeding the attendance threshold of 10 birds (Chapter II), the Sand Sagebrush Prairie Ecoregion had a greater proportion of leks exceeding 10 birds. Contrasting native and CRP

grassland composition suggests that ecoregional differences in lek attendance patterns may be driven not only by quantity and structure of native grassland, but also by the contribution of supplemental grassland, such as CRP. Intact CRP grasslands provide important resources for lesser prairie-chickens, especially in the Sand Sagebrush Prairie and Short-Grass Prairie/CRP Mosaic ecoregions, increasing occupancy, facilitating range expansion, and supporting nesting, dispersal, and roosting behaviors (Hagen et al. 2016; Sullins et al. 2018; Berigan et al. 2022, 2024). Reduced CRP grassland within Focal Areas in the Mixed-Grass Prairie Ecoregion may be a limiting factor for supporting populations of lesser prairie-chickens, despite having greater amount of total grassland when compared to the other two ecoregions. This may be a result of vegetation composition and structure that cannot support lesser prairie-chickens, and presence of woody vegetation. Conversely, although Focal Areas in the Sand Sagebrush Prairie Ecoregion contained the most CRP grassland on average, the ecological benefits of CRP, similar to those supporting populations in the Short-Grass Prairie/CRP Mosaic Ecoregion, may be offset due to altered disturbance regimes (e.g., grazing, fire), presence of cropland, density of anthropogenic structures, and distribution of CRP fields that may be limiting populations of lesser prairie-chickens. For example, lesser prairie-chicken leks in the Sand Sagebrush Prairie Ecoregion were farther from CRP field than leks in the Short-Grass Prairie/CRP Mosaic and Mixed-Grass Prairie ecoregions (Chapter II).

In contrast to Focal Areas, landscape characteristics within Occupied Areas were relatively consistent among ecoregions. Native grassland, CRP grassland, total grassland, cropland, and density of trees and anthropogenic structures per 100 ha did not differ among ecoregions, despite unique landscape vegetation composition and configuration in each ecoregion. This suggests that lesser prairie-chickens may be selecting for similar landscape

characteristics across its occupied range in Kansas. Specifically, Occupied Areas represent areas with sufficient grassland and limited disturbance from woody encroachment and anthropogenic development. This is consistent with literature indicating that for persistence, lesser prairie-chickens require $\geq 60\%$ native grassland (Crawford & Bolen 1976). Furthermore, lesser prairie-chickens will avoid nesting in areas with ≥ 2 trees/ha and exhibit avoidance behaviors in areas with ≥ 2 vertical structures (Lautenbach et al. 2017; Plumb et al. 2019).

I hypothesized that Focal Areas in the Short-Grass Prairie/CRP Mosaic Ecoregion would have more native grassland compared to those in the Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions, as this ecoregion currently supports the greatest proportion of lesser prairie-chickens in Kansas. However, my results did not support this, as Focal Areas in the Mixed-Grass Prairie Ecoregion had a greater proportion of native grassland compared to the other two ecoregions. This suggests that although the Short-Grass Prairie/CRP Mosaic Ecoregion is a stronghold for lesser prairie-chicken populations, factors aside from native grassland may be influencing distribution of lesser prairie-chickens.

Differences in land cover variables between Focal Areas and Occupied Areas were ecoregion-specific and primarily associated with woody encroachment and anthropogenic structure density. Specifically, in the Short-Grass Prairie/CRP Mosaic Ecoregion, the only difference between Focal Areas and Occupied Areas were the number of individual cellular towers and length of transmission lines per 100 ha, both of which were absent in Occupied Areas. These results are consistent with previous findings showing that large structures like cellular towers and transmission lines can evoke a negative response from lesser prairie-chickens (Plumb et al. 2019; Peterson et al. 2020). Even with relatively low densities of anthropogenic

structures within Focal Areas, lesser prairie-chickens may be hesitant to use these areas, potentially further restricting population persistence.

Conversely, in the Mixed-Grass Prairie Ecoregion, Focal Areas and Occupied Areas in the Mixed-Grass Prairie Ecoregion did not vary in any of the land cover variables measured. Notably, only 5.66% of lesser prairie-chicken leks from 2018-2023 in this ecoregion were above the attendance threshold of 10 birds (Chapter II), and none occurred within Occupied Areas. Because Occupied Areas were delineated using lesser prairie-chicken survey data from 1963-2023, this result suggests that some leks have disappeared from the landscape in recent years. Despite the lack of differences in land cover variables between Focal Areas and Occupied Areas, Occupied Areas may not be providing necessary conditions for persistence.

Lastly, Focal Areas and Occupied Areas in the Sand Sagebrush Prairie Ecoregion only differed in tree density; Focal Areas had nearly 10 times more trees per 100 ha than Occupied Areas. This suggests that even in areas with relatively low densities of woody encroachment, lesser prairie-chickens are seeking out landscapes with even less disturbance from trees.

Connectivity Zones were delineated to facilitate movement among Focal Areas by lesser prairie-chickens, while maintaining habitat and minimizing barriers to movement (Van Pelt et al. 2013). No differences in landscape composition were identified between Focal Areas and Connectivity Zones in the Short-Grass Prairie/CRP Mosaic and Mixed-Grass Prairie ecoregions. While there was limited variation in the density of trees and anthropogenic structures, a greater density of roads per 100 ha was reported in Connectivity Zones compared to Focal Areas in the Mixed-Grass Prairie Ecoregion. This suggests that, although anthropogenic disturbance was minimal within Connectivity Zones in each ecoregion, Connectivity Zones in the Mixed-Grass Prairie Ecoregion may face limitations due to increased presence of roads. Throughout their

occupied range, lesser prairie-chickens have been documented performing long-distance dispersal movements exceeding 70 km and exploratory movements among patches of habitat (Earl et al. 2016). Additionally, during long-distance movements, lesser prairie-chickens often avoided taller anthropogenic features (e.g., cellular towers and wind turbines; Peterson et al. 2020). While anthropogenic features may be present in Connectivity Zones in small quantities, it may be hindering lesser prairie-chicken movement. Previous research identified flow potential for lesser prairie-chicken travel between habitat patches during dispersal events. Results suggested higher flow potential between the Short-Grass Prairie/CRP Mosaic and Mixed-Grass Prairie ecoregions, while the Sand Sagebrush Prairie Ecoregion had high flow potential in specific movement corridors only (Schindler et al. 2020). Facilitating connectivity between Focal Areas and throughout the Sand Sagebrush Prairie Ecoregion is especially important, as there is only one established Connectivity Zone. My results, in conjunction with previous lesser prairie-chicken research, highlight the importance of reduced anthropogenic development within areas of connectivity.

Focal Areas and Occupied Areas had little variation in average land cover patch size, patch density, and largest patch index in each ecoregion. While not statistically significant, Occupied Areas often had higher largest patch index values than Focal Areas. This suggests that Occupied Areas may consist of landscapes dominated by a specific patch type (e.g., Mixed-Grass Prairie). Further, these results may indicate that presence of lesser prairie-chickens could be dependent on landscape factors on a smaller scale (e.g., surrounding leks).

Ranking Focal Areas and Occupied Areas provides insight into what portions of the lesser prairie-chicken occupied range in Kansas can be targeted for immediate action, specifically within Occupied Areas. Within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass

Prairie, and Sand Sagebrush Prairie ecoregions, Focal Areas and Occupied Areas were ranked separately based on landscape variables (e.g., presence of leks, native grassland, trees). The highest-ranking Focal Areas in each ecoregion had the most leks with ≥ 10 birds, followed by the most percent total grassland. These areas often had greater proportions of CRP grassland compared to lower ranking areas, emphasizing the importance of CRP grassland on the landscape. In all ecoregions, some Focal Areas had sufficient grassland and minimal trees, but no leks were observed due to lack of survey efforts. Increasing survey efforts to include all Focal Areas can identify the presence/absence of lesser prairie-chicken populations in areas that have not been surveyed before. Management of Focal Areas, Occupied Areas, and Connectivity Zones should include strategies such as increasing native grassland on the landscape (e.g., CRP), woody encroachment removal, and anthropogenic structure consolidation (e.g., removal of abandoned oil/gas wells), with the ultimate goal of improving long-term persistence.

Literature Cited

- Applegate, R. D., and T. Z. Riley. 1998. Lesser prairie-chicken management. *Rangelands* 20:13–15.
- Beck, J. L. 2006. Summary of oil and natural gas development impacts on prairie grouse. Unpublished Report, Colorado Division of Wildlife, Grand Junction, Colorado, USA.
- Bell, L. A., S. D. Fuhlendorf, M. A. Patten, D. H. Wolfe, and S. K. Sherrod. 2010. Lesser prairie-chicken hen and brood habitat use on sand shinnery oak. *Rangeland Ecology & Management* 63:478–486.
- Berigan, L. A., C. S. H. Aulicky, E. C. Teige, D. S. Sullins, D. A. Haukos, K. A. Fricke, J. H. Reitz, L. G. Rossi, K. A. Shultz, and A. M. Ricketts. 2022. Availability of lesser prairie-chicken nesting habitat impairs restoration success. *Wildlife Society Bulletin* 46:e1379.
- Berigan, L. A., C. S. H. Aulicky, E. C. Teige, D. S. Sullins, K. A. Fricke, J. H. Reitz, L. G. Rossi, K. A. Shultz, M. B. Rice, E. Tanner, S. D. Fuhlendorf, and D. A. Haukos. 2024. Lesser prairie-chicken dispersal after translocation: implications for restoration and population connectivity. *Ecology and Evolution* 14:e10871.

- Bidwell, T. G., S. Fuhlendorf, B. Gillen, S. Harmon, R. Horton, R. Manes, R. Rodgers, S. Sherrod, and D. Wolfe. 2003. Ecology and management of the greater prairie-chicken in Oklahoma. Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources. Oklahoma State University, Stillwater, USA.
- Boal, C. W., and D. A. Haukos. 2016. The lesser prairie-chicken: a brief introduction to the grouse of the Southern Great Plains. Pages 1–11 *in* D. A. Haukos and C. W. Boal (editors), Ecology and conservation of lesser prairie-chickens. Studies in Avian Biology (no. 48), CRC Press, Boca Raton, Florida, USA.
- Boyd, C. S., M. K. Creutzburg, A. V. Kumar, J. T. Smith, K. E. Doherty, B. A. Meador, J. B. Bradford, M. Cahill, S. M. Copeland, C. A. Duquette, L. Garner, M. C. Holdrege, B. Sparklin, and T. B. Cross. 2024. A strategic and science-based framework for management of invasive annual grasses in the sagebrush biome. *Rangeland Ecology & Management* 97:67–72.
- Cormen, T. H., Leiserson, C. E., Rivest, R. L., & Stein, C. (2022). Introduction to algorithms. MIT press.
https://books.google.com/books?hl=en&lr=&id=RSMuEAAAQBAJ&oi=fnd&pg=PR13&dq=Minimum+spanning+trees.+Introduction+to+algorithms+cormen%27&ots=a3k9ZX5MUH&sig=WYw5VWntyXD_uHPLR79Xb1XuMMc.
- Courchamp F., T. Clutton-Brock, and B. Grenfell. 1999. Inverse density dependence and the Allee effect. *Trends Ecology and Evolution* 14:405–410.
- Crawford, J. A., and E. G. Bolen. 1976. Effects of land use on lesser prairie-chickens in Texas. *Journal of Wildlife Management* 40:96–104.
- Dahlgren, D. K., R. D. Rodgers, R. D. Elmore, and M. R. Bain. 2016. Grasslands of western Kansas, north of the Arkansas River. Pages 259–279 *in* D. A. Haukos and C. W. Boal, editors. Ecology and conservation of lesser prairie-chickens. Studies in Avian Biology No. 48. CRC Press, Boca Raton, Florida, USA.
- DASC. 2025. Kansas Data Access and Support Center. Kansasgis.org
 <<https://www.kansasgis.org/index.cfm>>.
- Davis, D. M. 2009. Nesting ecology and preproductive success of lesser prairie-chickens in shinnery oak-dominated rangelands. *Wilson Journal of Ornithology* 121:322–327.
- Dhillon, S. S., M. A. McGinley, C. F. Friese, and J.C. Zak. 1994. Construction of sand shinnery oak communities of the Llano Estacado: animal disturbances, plant community structure, and restoration. *Restoration Ecology* 2:51–60.

- Diamond, D. D., L. F. Elliott, G. Steinauer, K. Kindscher, P. Hanberry, D. True, and M. Sunde. 2021. Ecological Systems of Kansas and Nebraska: Final Report. Submitted to Kansas Department of Wildlife, Parks and Tourism, and Nebraska Game and Parks Commission.
- Earl, J. E., S. D. Fuhlendorf, D. Haukos, A. M. Tanner, D. Elmore, and S. A. Carleton. 2016. Characteristics of lesser prairie-chicken (*Tympanuchus pallidicinctus*) long-distance movements across their distribution. *Ecosphere* 7(8):e01441. 10.1002/ecs2.1441
- Environmental Protection Agency. 2016. Climate impacts on ecosystems. EPA.
- Fields, T.L., G. C. White, W. C. Gilgert, and R. D. Rodgers. 2006. Nest and brood survival of lesser prairie-chickens in west central Kansas. *Journal of Wildlife Management* 70:931–938.
- Garton, E. O., C. A. Hagen, G. M. Beauprez, S. C. Kyle, J. C. Pitman, D. D. Schoeling, and W. E. Van Pelt. 2016. Population dynamics of lesser prairie-chickens. Pages 49–76 in D. A. Haukos and C. W. Boal, editors. *Ecology and conservation of lesser prairie-chickens. Studies in Avian Biology* No. 48. CRC Press, Boca Raton, Florida, USA.
- Giesen, K. M. 1994. Movements and nesting habitat of lesser prairie-chicken hens in Colorado. *Southwestern Naturalist* 39:96–98.
- Gilpin, M. E., and M. E. Soulé. 1986. Minimum viable populations: processes of species extinction. Pages 19–34 in M. E. Soule, editor. *Conservation biology: The science of scarcity and diversity*. Sinauer, Sunderland, Massachusetts, USA.
- Green, A.W., C. L. Aldridge, and O'donnell, M.S. 2017. Investigating impacts of oil and gas development on greater sage-grouse. *Journal of Wildlife Management* 81:46–57.
- Grisham, B. A., P. K. Borsdorf, C. W. Boal, and K. K. Boydston. 2014. Nesting ecology and nest survival of lesser prairie-chickens on the Southern High Plains of Texas. *Journal of Wildlife Management* 78:857–866.
- Grisham, B. A. and Boal, C. W. 2015. Causes of mortality and temporal patterns in breeding season survival of lesser prairie-chickens in shinnery oak prairies. *Wildlife Society Bulletin* 39:536–542.
- Gross, A. O. 1928. The heath hen. *Memoirs of the Boston Society of Natural History* 6(4):491–588.
- Hagen, C. A., B. E. Jamison, K. M. Giesen, and T. Z. Riley. 2004. Guidelines for managing lesser prairie-chicken populations and their habitats. *Wildlife Society Bulletin* 32:69–82

- Hagen, C. A., G. C. Salter, J. C. Pitman, R. J. Robel, and R. D. Applegate. 2005. Lesser prairie-chicken brood habitat in sand sagebrush: invertebrate biomass and vegetation. *Wildlife Society Bulletin* 33:1080–1091.
- Hagen, C. A., J. C. Pitman, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2007. Age specific survival and probable causes of mortality in female lesser prairie-chickens. *Journal of Wildlife Management* 71:518–525.
- Hagen, C. A., J. C. Pitman, T. M. Loughin, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2011. Impacts of anthropogenic features on habitat use by lesser prairie-chickens. Pages 63–75 *in* B. K. Sandercock, K. Martin, and G. Segelbacher (editors). *Ecology, conservation, and management of grouse. Studies in Avian Biology* (39), University of California Press, Berkeley, USA.
- Hagen, C. A., B. A. Grisham, C. W. Boal, and D. A. Haukos. 2013. A meta-analysis of lesser prairie-chicken nesting and brood rearing habitats: implications for habitat management. *Wildlife Society Bulletin* 37:750–758.
- Hagen, C. A., D. C. Pavlacky, K. A. Adachi, F. E. Hornsby, T. J. Rintz, and L. L. McDonald. 2016. Multiscale occupancy modeling provides insight into range-wide conservation need of lesser prairie-chicken (*Tympanuchus pallidicinctus*). *Condor* 118:597–612.
- Harryman, S. W., B. A. Grisham, C. W. Boal, S. S. Kahl, R. L. Martin, and C. A. Hagen. 2019. Multiscale habitat selection of lesser prairie-chickens in a row-crop and Conservation Reserve Program land matrix. *Journal of Fish and Wildlife Management* 10:126–136.
- Haukos, D. A., and C. W. Boal. 2016. Ecology and conservation of lesser prairie-chickens. *Studies in Avian Biology* No. 48. CRC Press, Boca Raton, Florida, USA.
- Haukos, D.A., and J.C. Zavaleta. 2016. Habitat. Pages 99-132 *in* D.A. Haukos, and C.W. Boal (editors). *Ecology and conservation of lesser prairie-chickens. Studies in Avian Biology* (no. 48) CRC Press, Boca Raton, Florida, USA.
- Hovick, T. J., R. D. Elmore, D. K. Dahlgren, S. D. Fuhlendorf, and D. M. Engle. 2014. Evidence of negative effects of anthropogenic structures on wildlife: a review of grouse survival and behaviour. *Journal of Applied Ecology* 51:1680–9.
- Jamison, B. E., R. J. Robel, J. S. Pontius, and R. D. Applegate. 2002. Invertebrate biomass: associations with lesser prairie-chicken habitat use and sand sagebrush density in southwestern Kansas. *Wildlife Society Bulletin* 30:517–526.
- Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 61:65–71.

- Kamm, M. 2015. The life and death of the heath hen. *Bird Observer* 43(1):5–14.
- Kansas Department of Labor. 2025. Kansas Counties Feature Layer. ArcGIS Online. <https://www.arcgis.com/home/item.html?id=b912469d52204af98b4a6e475253762a>
- Kansas Department of Wildlife & Parks. 2022. Kansas State Wildlife Action Plan (SWAP). Chapters 4 and 5. Kansas Department of Wildlife & Parks, Pratt, KS, USA. <https://ksoutdoors.com/Services/Kansas-SWAP>. Accessed 1 June 2025.
- Kansas Department of Wildlife and Parks. N.d. Saltcedar. <https://ksoutdoors.gov/Fishing/Aquatic-Invasive-Species/Aquatic-Invasive-Species-List/Saltcedar>. Accessed 27 January 2026.
- Lautenbach, J. M., R. T. Plumb, S. G. Robinson, C. A. Hagen, D. A. Haukos, and J. C. Pitman. 2017. Lesser prairie-chicken avoidance of trees in a grassland landscape. *Rangeland Ecology & Management* 70:78–86.
- Lauver, C. L., K. Kindscher, F. L. Don, and R. Schneider. 1999. A classification of the natural vegetation of Kansas. *Southwestern Naturalist* 44:421–443.
- Lehmann, V. W. 1941. Attwater's prairie-chicken, its life history and management. *North American Fauna* 57.
- Lipp, T. W. 2016. Geospatial analysis of how oil and gas energy development influences lesser prairie-chicken spatial ecology in Kansas. Thesis, Bowling Green State University, Bowling Green, Ohio, USA.
- Maestas, J. D., M. Porter, M. Cahill, and D. Twidwell. 2022. Defend the core: Maintaining intact rangelands by reducing vulnerability to invasive annual grasses. *Rangelands* 44:181–186.
- McDonald, L., G. Beauprez, G. Gardner, J. Griswold, C. Hagen, D. Klute, S. Kyle, J. Pitman, T. Rintz, and B. Van Pelt. 2014. Range-wide population size of the lesser prairie-chicken: 2012 and 2013. *Wildlife Society Bulletin* 38:536–546.
- McGarigal, K., and B.J. Marks. 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. Gen. Tech. Report PNW-GTR-351, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.
- Morrow, M. E., R. S. Adamcik, J. D. Friday, L. B. McKinney. 1996. Factors affecting Attwater's prairie-chicken decline on the Attwater Prairie-Chicken National Wildlife Refuge. *Wildlife Society Bulletin* 24:593–601.
- Nasman, K., T. Rintz, G. DiDonato, and F. Kuzler. 2022. 2012 to 2022 Range-wide population size of the lesser prairie-chicken. Western EcoSystems Technology, Inc., Cheyenne, Wyoming, USA.

- Natural Resources Conservation Service. 2023. Fiscal year 2024 Kansas environmental quality incentives program: working lands for wildlife. U.S. Department of Agriculture. <https://www.nrcs.usda.gov/sites/default/files/2024-01/KS-24-26-Lesser-Prairie-Chicken-Areas.pdf>
- O'Donnell, M. S., Edmunds, D. R., Aldridge, C. L., Heinrichs, J. A., Monroe, A. P., Coates, P. S., Prochazka, B. G., Hanser, S. E., & Wiechman, L. A. (2022). Defining biologically relevant and hierarchically nested population units to inform wildlife management. *Ecology and Evolution*, 12:e9565. <https://doi.org/10.1002/ece3.9565>
- Patten, M.A., Wolfe, D.H., Shochat, E., and S.K. Sherrod. 2005. Habitat fragmentation, rapid evolution and population persistence. *Evolutionary Ecology Research* 7:1–15.
- Peterson, M. J. 1994. Attwater's prairie chicken limiting factors. Thesis, Texas A&M University, College Station, USA.
- Peterson, J. M., J. E. Earl, S. D. Fuhlendorf, R. D. Elmore, D. A. Haukos, A. M. Tanner, and S. A. Carlson. 2020. Estimating response distances of lesser prairie-chickens to anthropogenic features during long-distance movements. *Ecosphere* 11(9): e03202.
- Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2005. Location and success of lesser prairie-chicken nests in relation to vegetation and human disturbance. *Journal of Wildlife Management* 69:1259–1269.
- Plumb, R.T. 2015. Lesser prairie-chicken movement, space use, survival, and response to anthropogenic structures in Kansas and Colorado. Thesis, Kansas State University, Manhattan, USA.
- Plumb, R. T., J. M. Lautenbach, S. G. Robinson, D. A. Haukos, V. L. Winder, C. A. Hagen, D. S. Sullins, J. C. Pitman, and D. K. Dahlgren. 2019. Lesser prairie-chicken space use in relation to anthropogenic structures. *Journal of Wildlife Management* 83:216–230.
- Prim, R. C. 1957. Shortest connection networks and some generalizations. *The Bell System Technical Journal* 36:1389–1401.
- Raynor, E. J., C. E. Whalen, M. B. Brown, and L. A. Powell. 2017. Location matters: evaluating greater prairie-chicken (*Tympanuchus cupido*) boom-chorus propagation. *Avian Conservation and Ecology* 12(2):17.
- Riley, T. Z. 1978. Nesting and brood-rearing habitat of lesser prairie-chickens in southeastern New Mexico. M.S. thesis, New Mexico State University, Las Cruces, New Mexico, USA.

- Riley, T. Z., C. A. Davis, M. Ortiz, and M. J. Wisdom. 1992. Vegetative characteristics of successful and unsuccessful nests of lesser prairie-chickens. *Journal of Wildlife Management* 56(2):383–387.
- Robinson, S. G., D. A., Haukos, R. T. Plumb, J. D. Kraft, D. S. Sullins, J. M. Lautenbach, J. D. Lautenbach, B. K. Sandercock, C. A. Hagen, A. Bartuszevige, and M. A. Rice. 2018. Effects of landscape characteristics on annual survival of lesser prairie-chickens. *American Midland Naturalist* 180:66–86.
- Rodgers, R. D. 2016. A history of lesser prairie-chickens. Pages 15–38 *in* D. A. Haukos and C. W. Boal (editors), *Ecology and conservation of lesser prairie-chickens. Studies in Avian Biology* (no. 48), CRC Press, Boca Raton, Florida, USA.
- Ross, B. E., D. A. Haukos, C. A. Hagen, and J. C. Pitman. 2016. Landscape composition creates a threshold influencing lesser prairie-chicken population resilience to extreme drought. *Global Ecology and Conservation* 6:179–188.
- Schindler, A.R., D.A. Haukos, C.A. Hagen, and B.E. Ross. 2020. A decision-support tool to prioritize candidate landscapes for lesser prairie-chicken conservation. *Landscape Ecology* 35:1417-1434.
- Silber, K. M., T. J. Hefley, H. N. Castro-Miller, Z. Ratajczak, and W. A. Boyle. 2024. The long shadow of woody encroachment: an integrated approach to modeling grassland songbird habitat. *Ecological Applications* 34:e2954.
- Smith, J. A. C. E. Whalen, M. B. Brown, and L. A. Powell. 2016. Indirect effects of an existing wind energy facility on lekking behavior of greater prairie-chickens. *Ethology* 122:419–429.
- Spencer, D., D. A. Haukos, C. A. Hagen, M. Daniels, and D. Goodin. 2017. Conservation reserve program mitigates grassland loss in the lesser prairie-chicken range of Kansas. *Global Ecology and Conservation* 9:21–38.
- Stewart, D. R., S. E. Lehnert, J. A. Moon, S. E. Sesnie, B. E. Burrows, M. A. Kalisek, B. M. Breske, B. R. Sicich, M. F. Small, L. J. Carnes, A. J. Cooper, D. W. Londe, M. J. Butler, J. M. Mueller, and G. M. Harris. 2026. A hierarchical analysis of lek counts: environmental drivers of abundance for an endangered grassland bird. *Journal of Wildlife Management* 90:70148.
- Stevens, B.S., Connelly, J.W. and K. P. Reese. 2012. Multi-scale assessment of greater sage-grouse fence collision as a function of site and broad scale factors. *Journal of Wildlife Management*, 76:1370– 1380.
- Sullins, D. S., J. D. Kraft, D. A. Haukos, S. G. Robinson, J. H. Reitz, R. T. Plumb, J. M. Lautenbach, J. D. Lautenbach, B. K. Sandercock, and C. A. Hagen. 2018. Demographic consequences of

conservation reserve program grasslands for lesser prairie-chickens. *Journal of Wildlife Management* 82:1617–1632.

Sullins, D. S., D. A. Haukos, J. M. Lautenbach, J. D. Lautenbach, S. G. Robinson, M. B. Rice, B. K. Sandercock, J. D. Kraft, R. T. Plumb, J. H. Reitz, J. M. S. Hutchinson, and C. A. Hagen. 2019. Strategic conservation for lesser prairie-chickens among landscapes of varying anthropogenic influence. *Biological Conservation* 238:108213.

Sutton Avian Research Center, n.d. Attwater's Prairie-Chicken.

<https://www.suttoncenter.org/conservation/saving-species/attwaters-prairie-chicken/>

Svedarsky, W. D., R. L. Westemeier, R. J. Robel, S. Gough, and J. E. Toepfer. 2000. Status and management of the greater prairie-chicken *Tympanuchus cupido pinnatus* in North America. *Wildlife Biology* 6:277–284.

Svedarsky, W. D., J. E. Toepfer, R. L. Westemeier, R. J. Robel, L. D. Igl, and J. A. Shaffer. 2022. The effects of management practices on grassland birds—greater prairie-chicken (*Tympanuchus cupido pinnatus*). Chap. C in Johnson, D. H., L. D. Igl, J. A. Shaffer, and J. P. DeLong (editors). *The effects of management practices on grassland birds*. U.S. Geological Survey (no. 1842).

Teige, E. C. 2021. Assessment of lesser prairie-chicken translocation through survival, space use, and resource selection. Thesis, Kansas State University, Manhattan, USA.

U.S. Fish and Wildlife Service. N.d. Attwater's greater prairie chicken. U.S. Fish & Wildlife Service.

<https://www.fws.gov/species/attwaters-greater-prairie-chicken-tympanuchus-cupido-attwateri>

U.S. Fish and Wildlife Service. 2022. Endangered and Threatened Wildlife and Plants; Lesser Prairie-Chicken; Threatened Status with Section 4(d) Rule for the Northern Distinct Population Segment and Endangered Status for the Southern Distinct Population Segment.

<https://www.fws.gov/species-publication-action/endangered-and-threatened-wildlife-and-plants-lesser-prairie-chicken-1>

Van Pelt, W. E., S. Kyle, J. Pitman, D. Klute, G. Beauprez, D. Schoeling, A. Janus, and J. Haufler. 2013. The lesser prairie-chicken range-wide conservation plan. Western Association of Fish and Wildlife Agencies, Cheyenne, Wyoming, USA.

Vhay, M.P. 2022. Retrospective assessment of lesser prairie-chicken habitat in the sand sagebrush prairie ecoregion. Thesis, Kansas State University, Manhattan, USA.

Vhay, M. P., D. A. Haukos, D. S. Sullins, and M. B. Rice. 2024. Broad-scale changes in lesser prairie-chicken habitat. *PLoS ONE* 19(5):e0304452.

Wolfe, D. H., M. A. Patten, E. Shochat, C. L. Pruett, and S. K. Sherrod. 2007. Causes and patterns of mortality in lesser prairie-chickens (*Tympanuchus pallidicinctus*) and implications for management. *Wildlife Biology* 13:95–104.

Tables

Table 1.1. Identified landscape thresholds used to evaluate lesser prairie-chicken persistence within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA.

Variable	Threshold	References
Grassland	Restricted to areas with $\geq 60\%$ native grassland within 5-km radius $\geq 77\%$ native grassland within 5-km	Crawford and Bolen 1976 Sullins et al. 2019
CRP	As CRP in a 57-km ² (5,626 ha) area exceeds 20%, the likelihood of LEPC occupying that landscape increases	Hagen et al. 2016
Cropland	Below 1:10 ratio cropland:grassland <40% for persistence	Ross et al. 2016
Trees	≥ 2 /ha- avoid nesting ≥ 8 /ha- complete avoidance	Lautenbach et al. 2017
Anthropogenic Structures	Display avoidance at 2 vertical structures Decreased probability of use with 2 structures/12.6 km ² (County/paved roads, oil/gas wells, cellular towers, wind turbines, transmission lines)	Plumb et al. 2019 Sullins et al. 2019
Lek Attendance	Leks with <10 birds (males) present at the lek have a high probability of extinction within 5 years, while leks above this threshold (≥ 10) will persist	Whetten et al. <i>In Review</i>

Table 1.2. Description of Western Association of Fish and Wildlife Agencies Critical Habitat Assessment Tool Focal Areas and Connectivity Zones, and Occupied Areas determined by lek survey data within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA.

Category	Purpose	Conservation Goal	Criteria Used for Delineation
CHAT 1 (Focal Areas)	Areas prioritized for conservation containing available lesser prairie-chicken habitat.	70% of the area managed under lesser prairie-chicken conservation plans.	GIS landscape integrity models, aerial photos, soil maps, anthropogenic disturbances, land cover.
CHAT 2 (Connectivity Zones)	Connect Focal Areas and facilitate movement of lesser prairie-chickens.	40% of the area managed under lesser prairie-chicken conservation plans.	GIS landscape integrity models, aerial photos, soil maps, anthropogenic disturbances, land cover.
Occupied Areas	Areas within Focal Areas occupied by lesser prairie-chickens.		Lesser prairie-chicken surveyed lek locations from 1963-2023.

Table 1.3. Comparison of average proportion (ha, $\pm$ SE) of native grassland, CRP grassland, total grassland, and cropland within the boundaries of each lesser prairie-chicken Critical Habitat Assessment Tool (CHAT) Focal Area ($n = 40$) and Occupied Area ($n = 12$) among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.

Ecoregion*	Area Type	Native Grassland	CRP Grassland	Total Grassland	Cropland
SGPR/CRP	Focal Area	0.56 ^a $\pm$ 0.02	0.10 ^a $\pm$ 0.01	0.66 ^a $\pm$ 0.02	0.30 ^a $\pm$ 0.02
	Occupied Area	0.58 ^a $\pm$ 0.08	0.08 ^a $\pm$ 0.03	0.66 ^a $\pm$ 0.06	0.29 ^a $\pm$ 0.06
MGPR	Focal Area	0.72 ^a $\pm$ 0.05	0.07 ^a $\pm$ 0.01	0.79 ^a $\pm$ 0.04	0.15 ^a $\pm$ 0.04
	Occupied Area	0.78 ^a $\pm$ 0.14	0.04 ^a $\pm$ 0.03	0.81 ^a $\pm$ 0.11	0.07 ^a $\pm$ 0.04
SSPR	Focal Area	0.42 ^a $\pm$ 0.06	0.22 ^a $\pm$ 0.05	0.64 ^a $\pm$ 0.05	0.31 ^a $\pm$ 0.05
	Occupied Area	0.64 ^a $\pm$ 0.08	0.19 ^a $\pm$ 0.01	0.83 ^a $\pm$ 0.07	0.13 ^a $\pm$ 0.06

*SGPR/CRP = Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion; MGPR = Mixed-Grass Prairie Ecoregion; SSPR = Sand Sagebrush Prairie Ecoregion

^{a,b} Proportions with the same lowercase letter do not differ ($P > 0.05$) between Focal Area and Occupied Area within ecoregions

Table 1.4. Average number of individual trees, oil/gas wells, cellular towers, wind turbines, length of transmission lines, and length of roads per 100 ha within the boundaries of each lesser prairie-chicken Critical Habitat Assessment Tool (CHAT) Focal Area ($n = 40$) and Occupied Area ($n = 12$) among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.

Ecoregion*	Area Type	Trees	Oil/Gas Wells	Cellular Towers	Wind Turbines	Length (km) of Transmission Lines	Length km) of Roads
SGPR/CRP	Focal Area	114.246 ^a $\pm$ 24.277	0.962 ^a $\pm$ 0.182	0.003 $\pm$ 0.001	0 $\pm$ 0	0.022 $\pm$ 0.007	0.840 ^a $\pm$ 0.043
	Occupied Area	60.427 ^a $\pm$ 17.305	0.838 ^a $\pm$ 0.317	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0.784 ^a $\pm$ 0.071
MGPR	Focal Area	238.128 ^a $\pm$ 51.755	0.868 ^a $\pm$ 0.128	0.004 $\pm$ 0.001	0.003 $\pm$ 0.003	0.035 $\pm$ 0.015	0.887 ^a $\pm$ 0.048
	Occupied Area	231.201 ^a $\pm$ 104.561	0.651 ^a $\pm$ 0.057	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0.900 ^a $\pm$ 0.086
SSPR	Focal Area	30.305 ^a $\pm$ 12.269	1.691 ^a $\pm$ 0.340	0.007 ^a $\pm$ 0.001	0 $\pm$ 0	0.083 ^a $\pm$ 0.031	1.028 ^a $\pm$ 0.116
	Occupied Area	3.241 ^b $\pm$ 2.529	1.652 ^a $\pm$ 0.773	0.005 ^a $\pm$ 0.005	0 $\pm$ 0	0.066 ^a $\pm$ 0.066	0.662 ^a $\pm$ 0.304

*SGPR/CRP = Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion; MGPR = Mixed-Grass Prairie Ecoregion; SSPR = Sand Sagebrush Prairie Ecoregion

^{a,b} Proportions with the same lowercase letter do not differ ($P > 0.05$) between Focal Area and Occupied Area within ecoregions

Table 1.5. Comparison of average number of land cover patches, average patch size, patch density per 100/ha, and largest patch index within the boundaries of each lesser prairie-chicken Critical Habitat Assessment Tool (CHAT) Focal Area ($n = 40$) and Occupied Areas ($n = 12$) among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.

Ecoregion*	Area Type	Number of Patches	Average Patch Size	Patch Density per 100 ha	Largest Patch Index
SGPR/CRP	Focal Area	5,355.44 ^a ± 512.07	8.62 ^a ± 0.59	12.55 ^a ± 0.86	10.57 ^a ± 0.94
	Occupied Area	4,261.86 ^a ± 1,536.46	10.09 ^a ± 1.61	11.48 ^a ± 1.78	18.34 ^a ± 5.84
MGPR	Focal Area	4,218.23 ^a ± 795.52	9.44 ^a ± 0.83	11.87 ^a ± 1.27	28.12 ^a ± 4.69
	Occupied Area	1,520 ^a ± 233	9.42 ^a ± 1.62	10.94 ^a ± 1.88	31.36 ^a ± 22.03
SSPR	Focal Area	6,369.44 ^a ± 1,040.78	7.42 ^a ± 0.61	14.11 ^a ± 0.99	14.59 ^a ± 2.82
	Occupied Area	1,467 ^b ± 166.77	6.79 ^a ± 0.44	14.85 ^a ± 0.98	36.07 ^a ± 11.81

*SGPR/CRP = Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion; MGPR = Mixed-Grass Prairie Ecoregion; SSPR = Sand Sagebrush Prairie Ecoregion

^{a,b} Landscape metric values with the same letter do not differ ($P < 0.05$) between Focal Areas and Occupied Areas within ecoregion

Table 1.6. Average proportion (ha, $\pm$ SE) of native grassland, CRP grassland, total grassland, and cropland within the boundaries of each lesser prairie-chicken Critical Habitat Assessment Tool (CHAT) Focal Area ($n = 40$) and Connectivity Zone ($n = 13$) among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.

Ecoregion [*]	Area Type	Native Grassland	CRP Grassland	Total Grassland	Cropland
SGPR/CRP	Focal Area	0.56 $\pm$ 0.02	0.10 $\pm$ 0.01	0.66 $\pm$ 0.02	0.30 $\pm$ 0.02
	Connectivity Zone	0.42 $\pm$ 0.07	0.05 $\pm$ 0.02	0.47 $\pm$ 0.08	0.47 $\pm$ 0.09
MGPR	Focal Area	0.72 $\pm$ 0.05	0.07 $\pm$ 0.01	0.79 $\pm$ 0.04	0.15 $\pm$ 0.04
	Connectivity Zone	0.60 $\pm$ 0.09	0.08 $\pm$ 0.02	0.68 $\pm$ 0.08	0.28 $\pm$ 0.08
SSPR ⁺	Focal Area	0.42 $\pm$ 0.06	0.22 $\pm$ 0.05	0.64 $\pm$ 0.05	0.31 $\pm$ 0.05
	Connectivity Zone	0.06 $\pm$ 0	0.13 $\pm$ 0	0.19 $\pm$ 0	0.77 $\pm$ 0

^{*}SGPR/CRP = Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion; MGPR = Mixed-Grass Prairie Ecoregion; SSPR = Sand Sagebrush Prairie Ecoregion

⁺Only one Connectivity Zone was present in the Sand Sagebrush Prairie Ecoregion

Table 1.7. Average number of individual trees, oil/gas wells, cellular towers, wind turbines, length of transmission lines, and length of roads per 100 ha within the boundaries of each lesser prairie-chicken Critical Habitat Assessment Tool (CHAT) Focal Area ($n = 40$) and Occupied Area ($n = 12$) among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.

Ecoregion*	Area Type	Trees	Oil/Gas Wells	Cellular Towers	Wind Turbines	Length (km) of Transmission Lines	Length km) of Roads
SGPR/CRP	Focal Area	114.246 $\pm$ 24.277	0.962 $\pm$ 0.182	0.003 $\pm$ 0.001	0 $\pm$ 0	0.022 $\pm$ 0.007	0.840 $\pm$ 0.043
	Connectivity Zone	212.739 $\pm$ 86.463	1.124 $\pm$ 0.558	0.002 $\pm$ 0.002	0 $\pm$ 0	0.059 $\pm$ 0.040	1.233 $\pm$ 0.202
MGPR	Focal Area	238.128 $\pm$ 51.755	0.868 $\pm$ 0.128	0.004 $\pm$ 0.001	0.003 $\pm$ 0.003	0.035 $\pm$ 0.015	0.887 $\pm$ 0.048
	Connectivity Zone	160.159 $\pm$ 32.788	1.368 $\pm$ 0.252	0.001 $\pm$ 0.001	0.005 $\pm$ 0.005	0.040 $\pm$ 0.021	1.095 $\pm$ 0.080
SSPR ⁺	Focal Area	30.305 $\pm$ 12.269	1.691 $\pm$ 0.340	0.007 $\pm$ 0.001	0 $\pm$ 0	0.083 ^a $\pm$ 0.031	1.028 $\pm$ 0.116
	Connectivity Zone	13.34 $\pm$ 0	1.528 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	1.408 $\pm$ 0

*SGPR/CRP = Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion; MGPR = Mixed-Grass Prairie Ecoregion; SSPR = Sand Sagebrush Prairie Ecoregion

⁺Only one Connectivity Zone was present in the Sand Sagebrush Prairie Ecoregion

Table 1.8. Ranking list of Western Association of Fish and Wildlife Agencies Critical Habitat Assessment Tool Zones (Focal Areas) and Occupied Areas determined by survey data within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA. Areas were ranked by the number of leks with ≥ 10 birds in attendance, followed by percentage of total grassland. ID corresponds to ID in Figures 1.2 and 1.3.

ID	Focal Area/occupied Area	Ecoregion	Leks with ≥ 10 Birds	Leks with < 10 Birds	Extinct Leks	Total Area (ha)	Native Grassland	CRP Grassland	Total Grassland	Cropland	Trees/ha
1*	Focal Area	SGPR/CRP	12	6	10	34,964	51%	19%	70%	22%	0.56
2*	Focal Area	SGPR/CRP	5	5	0	60,864	62%	6%	68%	29%	0.60
3*	Focal Area	SGPR/CRP	5	7	12	34,965	57%	8%	65%	31%	0.93
4	Focal Area	SGPR/CRP	4	3	1	51,541	56%	16%	71%	25%	0.65
5*	Focal Area	SGPR/CRP	3	6	6	52,318	65%	8%	73%	24%	1.68
6	Focal Area	SGPR/CRP	3	2	0	40,921	56%	2%	58%	39%	1.15
7	Focal Area	SGPR/CRP	2	1	0	51,282	46%	19%	65%	32%	0.71
8	Focal Area	SGPR/CRP	2	1	0	49,210	66%	5%	71%	25%	2.14
9	Focal Area	SGPR/CRP	1	1	0	33,411	56%	14%	71%	28%	1.70
10	Focal Area	SGPR/CRP	1	0	0	56,461	47%	5%	52%	44%	1.36
11	Focal Area	SGPR/CRP	1	1	0	25,381	53%	3%	56%	39%	4.62
12	Focal Area	SGPR/CRP	N/A	N/A	N/A	25,381	79%	4%	83%	14%	0.27
13	Focal Area	SGPR/CRP	N/A	N/A	N/A	34,188	68%	10%	79%	17%	0.44
14	Focal Area	SGPR/CRP	N/A	N/A	N/A	39,109	57%	15%	72%	27%	0.18
15	Focal Area	SGPR/CRP	N/A	N/A	N/A	45,324	54%	15%	69%	29%	0.68
16	Focal Area	SGPR/CRP	N/A	N/A	N/A	52,577	51%	12%	63%	36%	1.05
17	Focal Area	SGPR/CRP	N/A	N/A	N/A	29,266	56%	4%	60%	34%	1.50
18	Focal Area	SGPR/CRP	N/A	N/A	N/A	40,662	35%	12%	47%	49%	0.35
1.10	Occupied Area	SGPR/CRP	16	9	11	44,675	49%	20%	69%	25%	0.54
1.9	Occupied Area	SGPR/CRP	5	5	0	21,427	63%	6%	69%	28%	0.57
1.12	Occupied Area	SGPR/CRP	5	2	0	112,674	50%	15%	64%	32%	1.08
1.11	Occupied Area	SGPR/CRP	3	0	0	37,969	45%	4%	48%	47%	1.35
1.8	Occupied Area	SGPR/CRP	N/A	N/A	N/A	11,104	88%	1%	89%	7%	0.08
1.6	Occupied Area	SGPR/CRP	N/A	N/A	N/A	8,331	78%	0%	78%	12%	0.42
1.7	Occupied Area	SGPR/CRP	N/A	N/A	N/A	27,653	30%	11%	41%	53%	0.20
19*	Focal Area	MGPR	2	10	19	41,304	61%	8%	69%	19%	1.32
20*	Focal Area	MGPR	1	5	8	24,605	34%	8%	42%	55%	0.67
21	Focal Area	MGPR	0	0	9	5,574	78%	10%	89%	8%	0.63
22	Focal Area	MGPR	0	2	9	38,850	84%	2%	86%	9%	4.31
23	Focal Area	MGPR	0	1	0	48,951	80%	8%	88%	9%	0.90
24*	Focal Area	MGPR	0	3	14	28,324	72%	15%	87%	8%	0.93
25	Focal Area	MGPR	N/A	N/A	N/A	30,303	73%	14%	87%	9%	1.00
26*	Focal Area	MGPR	0	4	5	39,627	80%	7%	87%	8%	4.16

ID	Focal Area/occupied Area	Ecoregion	Leks with ≥ 10 Birds	Leks with < 10 Birds	Extinct Leks	Total Area (ha)	Native Grassland	CRP Grassland	Total Grassland	Cropland	Trees/ha
27*	Focal Area	MGPR	0	3	0	52,318	87%	0%	87%	3%	6.33
28	Focal Area	MGPR	N/A	N/A	N/A	37,555	58%	3%	61%	24%	3.06
29*	Focal Area	MGPR	N/A	N/A	N/A	34,447	51%	7%	58%	34%	4.15
30	Focal Area	MGPR	N/A	N/A	N/A	42,217	91%	2%	94%	5%	0.87
31	Focal Area	MGPR	N/A	N/A	N/A	13,502	87%	2%	89%	7%	2.60
1.4	Occupied Area	MGPR	0	9	28	19,357	64%	6%	70%	11%	1.27
1.5	Occupied Area	MGPR	N/A	N/A	N/A	10,041	92%	1%	93%	3%	3.36
32*	Focal Area	SSPR	9	14	31	66,656	58%	21%	79%	15%	0.30
33*	Focal Area	SSPR	2	1	0	31,449	20%	31%	51%	46%	0.07
34*	Focal Area	SSPR	0	2	23	56,714	64%	14%	78%	19%	0.54
35*	Focal Area	SSPR	0	21	0	43,771	43%	4%	47%	45%	0.14
36	Focal Area	SSPR	0	2	0	16,846	36%	22%	89%	7%	0.09
37*	Focal Area	SSPR	0	5	0	46,879	13%	25%	38%	50%	0.08
38	Focal Area	SSPR	N/A	N/A	N/A	44,807	51%	18%	68%	28%	0.21
39	Focal Area	SSPR	N/A	N/A	N/A	39,627	57%	6%	63%	30%	1.20
40	Focal Area	SSPR	N/A	N/A	N/A	39,109	39%	21%	60%	36%	0.11
1.2	Occupied Area	SSPR	2	9	31	8,671	80%	18%	98%	2%	0.01
1.1	Occupied Area	SSPR	0	21	0	13,491	56%	20%	76%	20%	0.01
1.3	Occupied Area	SSPR	0	3	0	8,054	55%	21%	76%	18%	0.08

*Survey route within area

N/A = Area was not surveyed

Figures

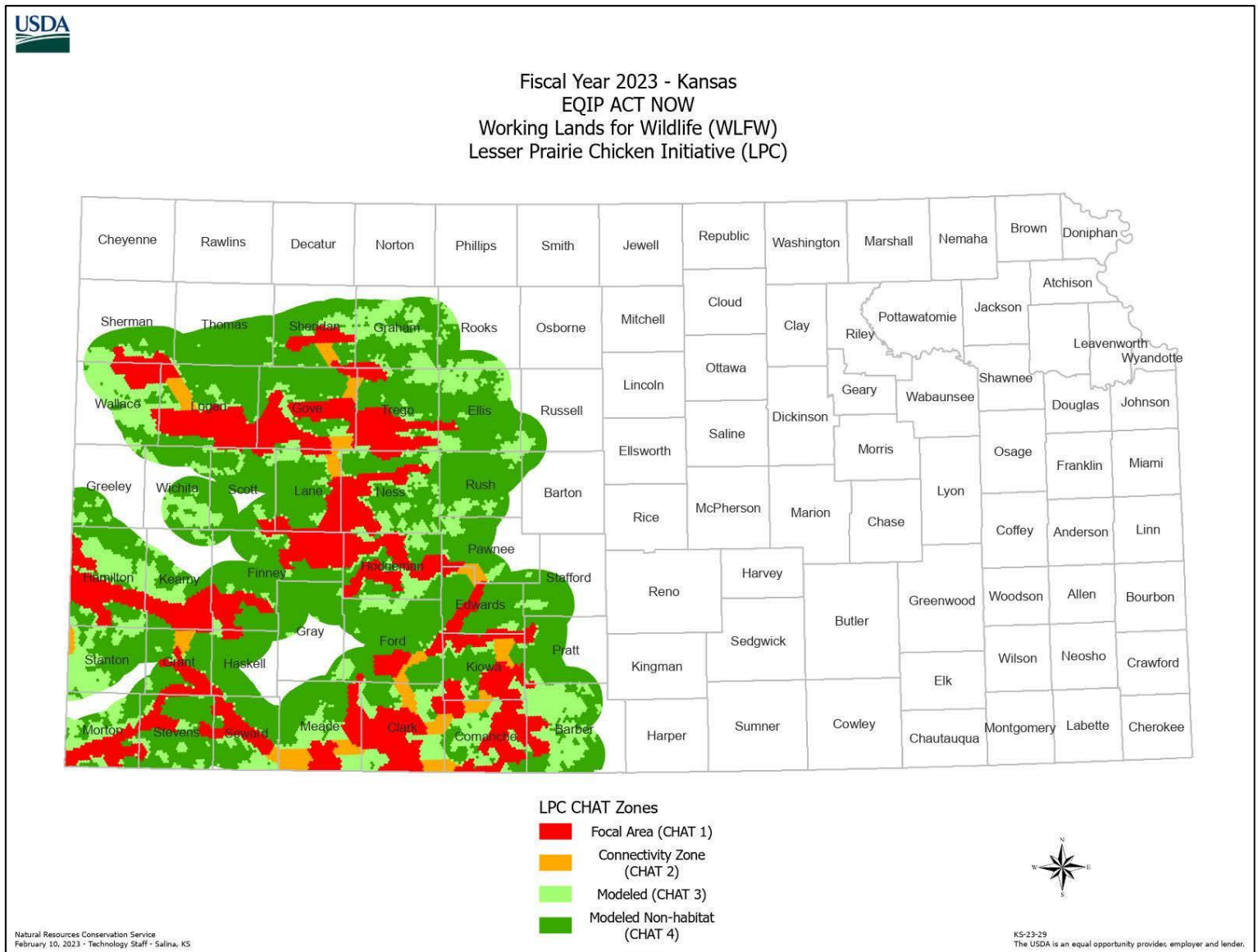


Figure 1.1. Distribution of lesser prairie-chicken focal areas, connectivity zones, current and potential habitat, and non-habitat in Kansas, USA, designated by the Western Association of Fish and Wildlife Agencies using the Critical Habitat Assessment Tool (USDA NRCS 2023).

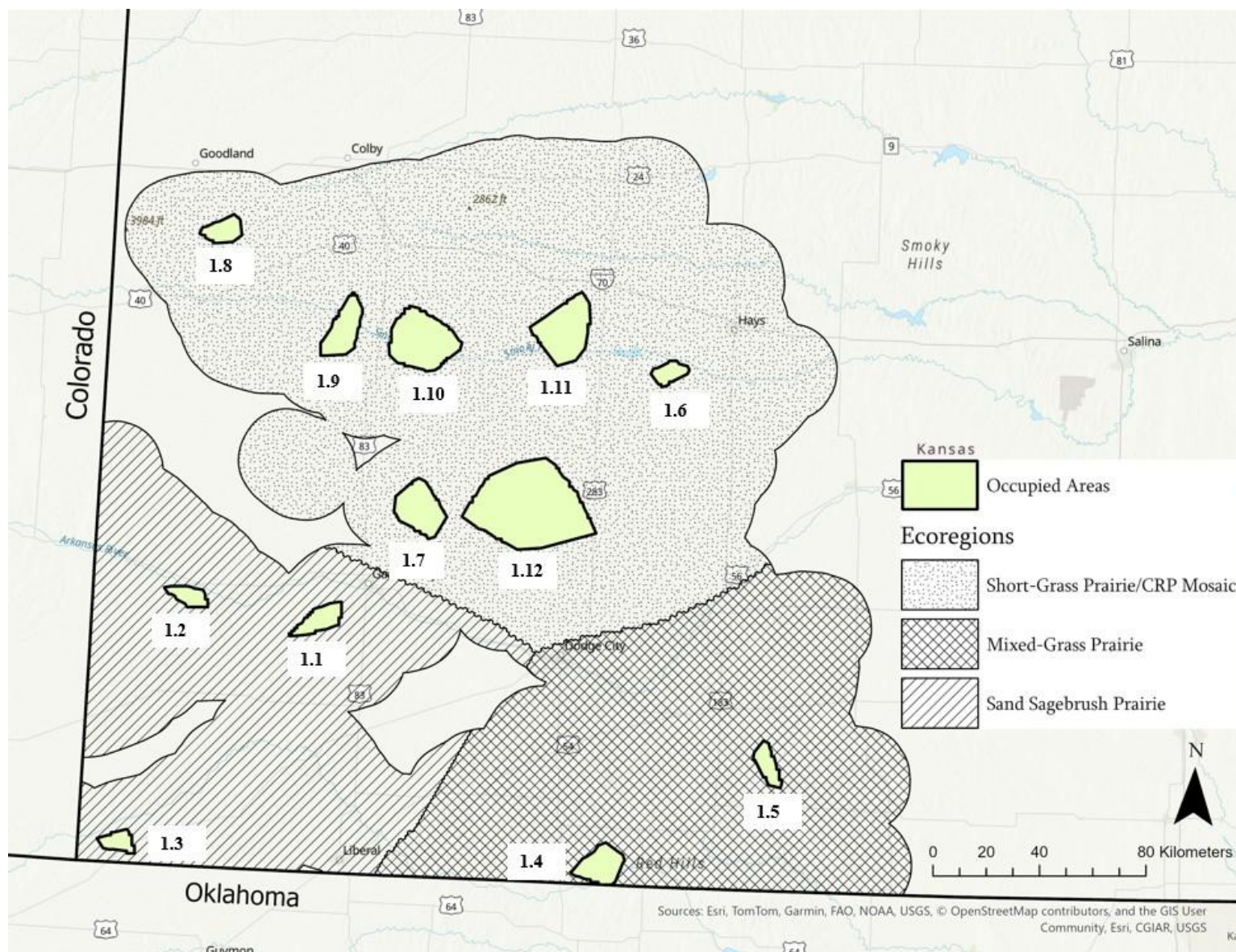


Figure 1.2. Distribution of lesser prairie-chicken Occupied Areas determined by lek survey data within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA. Numbering corresponds with ranking in Table 1.8.

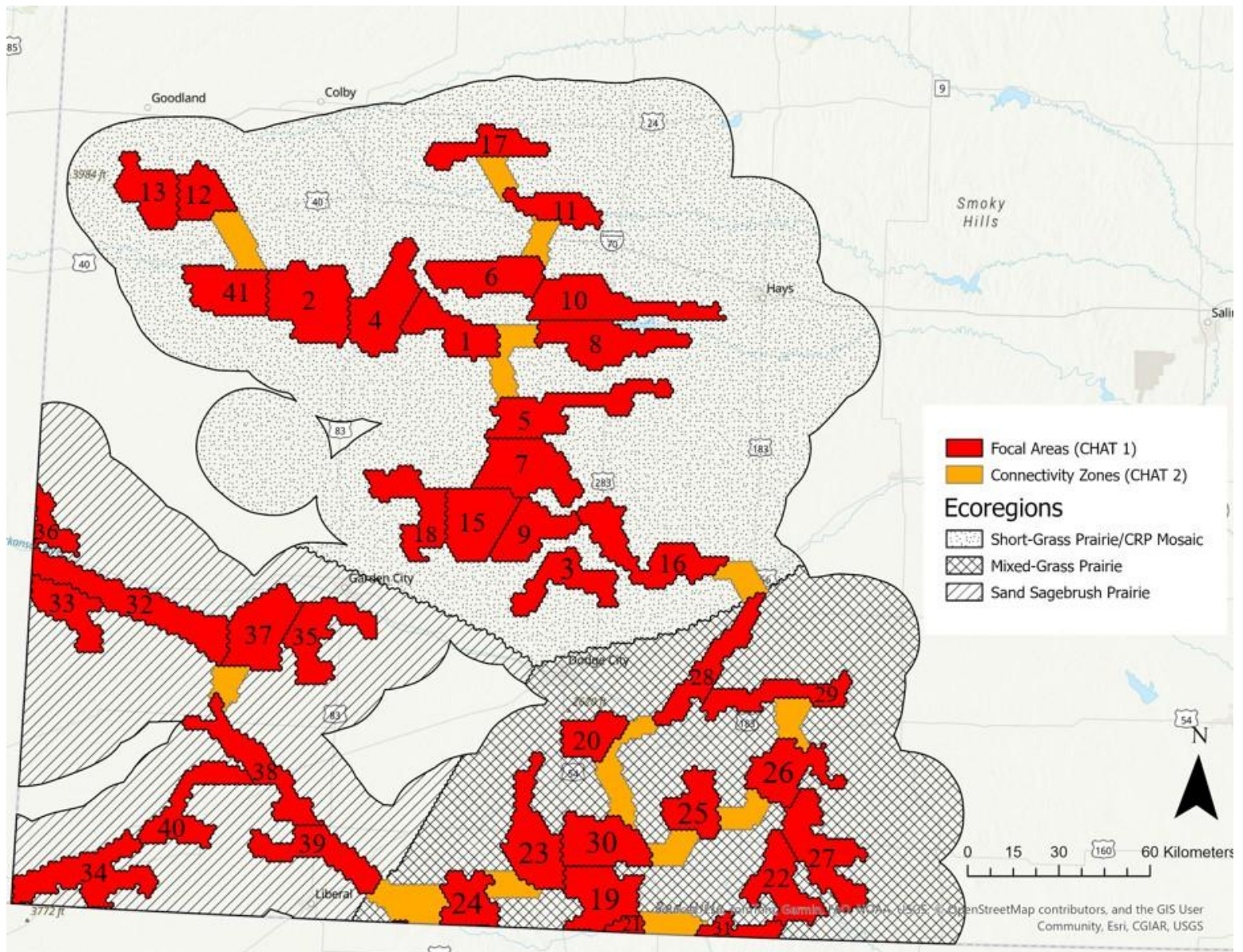


Figure 1.3. Distribution of Western Association Fish and Wildlife Agencies Critical Habitat Assessment Tool Focal Areas (CHAT 1) and Connectivity Zones (CHAT 2) within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA. Numbering corresponds with ranking in Table 1.8.

Chapter 2 - Landscape composition surrounding stable and vulnerable lesser prairie-chicken leks in Kansas

Introduction

During the past century, several species of prairie grouse in North America including (but not limited to) the extinct heath hen (*Tympanuchus cupido cupido*), greater prairie-chicken (*T. c. pinnatus*), endangered Attwater's prairie-chicken (*T. c. attwateri*), and lesser prairie-chicken (*T. pallidicinctus*) have endured significant habitat loss, reduced occupied range, and population declines. Prairie grouse are crucial indicators of the health of the prairie ecosystem; they aid in sustaining ecological balance by relying on a wide variety of native plants and insects, thus serving as indicators of habitat loss, degradation, or recovery. Ecological and anthropogenic factors such as changes in disturbance regimes, woody encroachment, conversion of grassland for agriculture, disease, overharvest, herbicide/pesticide use, and energy development are contributing to these declines (Gross 1928; Svedarsky et al. 2000; Bidwell et al. 2003; Kamm 2015; Rodgers 2016; Lautenbach et al. 2017; Spencer et al. 2017).

Of foremost concern is the loss and degradation of native grasslands that have resulted in isolation and localized extinction of many populations of prairie grouse species in North America (Lehmann 1941; Crawford and Bolen 1976; Morrow et al. 1996; Ross et al. 2016). As grasslands (e.g., the Great Plains) are reduced in quality and area, prairie grouse, such as the lesser prairie-chicken, face restricted movement and increasing isolation; absence of vegetation for breeding, brood-rearing, and nonbreeding stages; and overall significant decline in population abundance. Furthermore, lesser prairie-chickens require expansive grassland landscapes for population persistence and resilience. For example, populations of lesser prairie-chickens in Texas, USA, are restricted to landscapes with $\geq 60\%$ native grassland (Crawford and Bolen

1976). Additionally, in Kansas, USA, the probability of use of an area was greatest at $\geq 77\%$ native grassland with contiguous patches of grassland (Sullins et al. 2018). Because habitat requirements vary for each life stage (e.g., breeding, brood-rearing, nonbreeding), large, contiguous grasslands have been a central component of research and conservation efforts.

As grasslands (e.g., the Great Plains) are reduced in quality and area, isolation of populations and small population size can result in failure for the species to rebound in numbers (e.g., Allee effect), leading to localized extinction. The Allee effect describes a phenomenon where low population density decreases population growth rates and reproductive viability (Courchamp et al. 1999). As a result, once populations reach a critical abundance threshold, the likelihood of extinction greatly increases. Small or isolated populations are also subject to an “extinction vortex” where lack of genetic diversity allows deleterious mutations to dominate the population, also increasing the likelihood of local extinction (Gilpin and Soule 1986). These conditions have contributed to previous extinctions of prairie grouse populations and are likely contributing to contemporary trends of prairie grouse range-wide population trends.

The heath hen was the first species of grouse in North America documented to go extinct. Before the remaining individuals were restricted to Martha’s Vineyard, an island off the coast of Massachusetts, USA, heath hens were believed to breed in coastal prairies from Massachusetts south to Virginia with populations in New York, Pennsylvania, and New Jersey, USA. It is hypothesized that in addition to a decreased range, predators, disease, and imbalance of males and females led to extinction of the heath hen (i.e., Allee effect; Gross 1928; Kamm 2015). Hunted extensively by Native Americans and then Europeans following settlement, the heath hen was extirpated from mainland Massachusetts in the 1830s and Connecticut by the 1840s. No wild heath hens were found in the mainland United States after 1870. On Martha’s Vineyard, the

remaining 120 to 200 individuals were presumed to be gone following a fire in 1894.

Fortunately, the population rebounded to an estimated 800-2,000 birds. Another fire on the island in 1916 decimated the population, with surviving heath hens experiencing limited access to food resources and cover (Kamm 2015). While the exact number of birds that died in the second fire is unknown, few young birds were found during a succeeding survey, suggesting that most nests and eggs were likely destroyed. A surge of northern goshawks (*Accipiter gentilis*) on the island preyed on remaining heath hens and American crows (*Corvus brachyrhynchos*) predated poorly concealed nests. Goshawks, feral cats, and rats were consistently hunted by land managers to try and control their effects on heath hens. The risk of diseases such as poultry blackhead disease increased due to domestic geese foraging in the same areas; the disease was confirmed in one male heath hen in 1923 (Gross 1928). A survey after the second fire estimated fewer than 100 birds remained on the island. Despite this, the species rebounded again and reached upwards of 400 birds in 1920. Attempts to save the heath hen through translocation and captive breeding failed. During the 1920s, cold and wet weather conditions during the breeding seasons limited productivity and increased chick mortality. By 1928 only one heath hen remained, and the species was declared extinct in 1932 (Kamm 2015).

Prior to European settlement, greater prairie-chickens were abundant across tallgrass prairies of the eastern Great Plains of North America (Svedarsky et al. 2000). Habitat for greater prairie-chickens includes short herbaceous cover for lek sites, tall residual grasses for nesting, and disturbed areas with adequate vegetation regrowth for foraging, movement, and shelter of broods (Svedarsky et al. 2022). With settlement, anthropogenic influences such as logging, wetland drainage, burning, and cultivation had a positive effect, facilitating expansion of the greater prairie-chicken's occupied range into parts of Minnesota, Wisconsin, and Michigan,

USA, and Ontario, Canada. From the mid-1960s to the late 1990s, there were relatively large populations of greater prairie-chickens in Kansas, Nebraska, South Dakota, and Oklahoma, USA, and these states allowed hunting. Harvest of smaller populations in Colorado, Minnesota, Wisconsin, Missouri, North Dakota, Iowa, and Illinois, USA, was prohibited, though Minnesota recently reinstated the hunting season (Svedarsky et al. 2000; Minnesota Department of Natural Resources, n.d.). Currently, greater prairie-chickens have been extirpated from several provinces in Canada, and Michigan, Indiana, Ohio, Arkansas, Tennessee, Kentucky, Texas, and Wyoming, USA (Svedarsky et al. 2022).

Increasing anthropogenic development has resulted in wide-spread declines in population abundance and occupied range of greater prairie-chickens (Hovick et al. 2014; Londe et al. 2022). Across the species range, populations vacated landscapes consisting of >20-30% cropland, and areas with woody vegetation regrowth (Svedarsky et al. 2000). Specifically in Oklahoma, herbicide and pesticide use and burning during spring negatively affected nesting, loafing, and roosting cover (Svedarsky et al. 2000; Bidwell et al. 2003). In Nebraska, female greater prairie-chicken lek attendance remained unaffected by the presence of a wind facility, but males at leks closer to the facility spent less time exhibiting nonbreeding behaviors such as feeding, walking, or preening (Johnson et al. 2011; Smith et al. 2016). Another study in Nebraska found that audible area of greater prairie-chicken boom chorus decreased with increased background noise (e.g., wind turbines, roads), while leks in open grasslands experienced less background noise (Raynor et al. 2017). Together, these factors reflect a substantial and continuing reduction in great prairie-chicken population abundance throughout their occupied range.

Attwater's prairie-chicken is an endangered subspecies of the heath hen (Lehmann 1941). Historically, nearly a million birds occupied the coastal prairies of western Louisiana and southeastern Texas, USA (U.S. Fish and Wildlife Service, n.d.). Habitat for this species can be described as well-drained grassland with some weeds or shrubs, cover varying from light to heavy density, and available water during summer (Lehmann 1941). Quality habitat results from the presence of diversified grassland types, as emphasized by Lehmann (1941). Extensive harvest in the late 1800s to early 1900s resulted in significant population decline, prompting Texas to ban hunting of Attwater's prairie-chicken in 1937 (U.S. Fish and Wildlife Service n.d.). Other influences such as agricultural conversion, unmanaged grazing, urban and industrial expansion, energy development, and woody expansion have exacerbated habitat and population declines.

However, like other grouse species, loss of the prairie ecosystem played the biggest role in the decline of Attwater's prairie-chicken populations (Lehmann 1941; Morrow et al. 1996). By 1937, only 185,000 ha of habitat remained, and populations had declined to approximately 8,700 individuals. By 1992, approximately 80,000 ha of habitat remained (Peterson 1994). To combat these losses, the Attwater's Prairie Chicken Recovery Team initiated a captive-breeding program that would supplement the wild population with pen-reared individuals (Seal 1994). In Oklahoma, the George Miksch Sutton Avian Research Center began raising Attwater's prairie-chickens in 2019. In collaboration with several Texas zoos including Houston Zoo, Caldwell Zoo, and Fossil Rim Wildlife Center, the Sutton Center raises and releases chicks at the Attwater Prairie Chicken National Wildlife Refuge in Texas, and private ranch properties in Goliad County, Texas (U.S. Fish and Wildlife Service n.d.; Sutton Avian Research Center n.d.). Recent research suggests a mean annual population growth rate of 3%, with peak abundance at

intermediate levels of perennial forb and grass cover under moderate drought conditions (Stewart et al. 2026). Overgrowth of vegetation and excessive moisture resulted in declines in population. Additionally, these results emphasize the importance of re-establishing prescribed fire at an interval of 2-3 years (Stewart et al. 2026).

Whereas the heath hen, greater prairie-chicken, and Attwater's prairie-chicken historically occupied broader and more geographically dispersed ranges in the United States and Canada, the lesser prairie-chicken has been restricted to the southwestern Great Plains. Lesser prairie-chickens were believed to occupy much broader areas than the currently estimated occupied range (Boal and Haukos 2016). Uncertainty about the true historical range lies in a lack of documented observations, confusion regarding species identification, and uncertainty with exact locations from anecdotal sightings (Boal and Haukos 2016; Rodgers 2016). In 2014, four ecoregions supporting lesser prairie-chickens were officially established: Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic, Mixed-Grass Prairie, Sand Sagebrush Prairie, and Sand Shinnery Oak Prairie. These ecoregions span across Texas, New Mexico, Oklahoma, Colorado, and Kansas, USA (Figure 2.1; McDonald et al. 2014). With the exception of the Sand Shinnery Oak Prairie Ecoregion (northwest Texas and eastern New Mexico), all or portions of these ecoregions occur in Kansas. Historically, lesser prairie-chickens did not occupy the Short-Grass Prairie/CRP Mosaic Ecoregion north of the Arkansas River until the mid-to-late 1990s (Rodgers 2016). After establishment of U.S. Department of Agriculture, Conservation Reserve Program (CRP) grasslands that provided taller and reliably available grassland structure for nesting, lesser prairie-chickens were enticed to disperse north of the Arkansas River into northwest Kansas.

Because greater prairie-chickens and lesser prairie-chickens share similar life histories, habitat requirements, and sensitivity to ecological changes, population declines observed in greater prairie-chickens can provide insight into mechanisms likely shaping lesser prairie-chicken population dynamics. In greater prairie-chickens, population declines and loss of occupied range followed extensive grassland conversion, woody encroachment, and anthropogenic development (Svedarsky et al. 2000; Bidwell et al. 2003; Hovick et al. 2014; Londe et al. 2022). This suggests that lesser prairie-chicken populations may experience similar declines once habitat requirements fall below critical proportions within their occupied range. It can be hypothesized that small, spatially constrained populations experience reduced reproductive success due to Allee effects, increasing the likelihood of localized extinction.

Prior to European settlement, lesser prairie-chicken habitat consisted of mixed-grass prairie and tall and mixed-grasses within sand sagebrush (*Artemisia filifolia*) and sand-shinnery oak (*Quercus havardii*) prairie in the eastern and western portions of the species range, respectively. These habitats were primarily associated with sandy soils within the short-grass prairie matrix of the High Plains region of the southwestern Great Plains (Boal and Haukos 2016). Habitat requirements of lesser prairie-chicken populations consist of large areas of grassland within expansive landscapes (i.e., >20,000 ha) comprised of specific vegetation composition and structure for each life stage (Haukos and Zavaleta 2016). For example, ideal lek locations have short grassland vegetation and good visibility at sites of relatively high elevation (Bidwell et al. 2003). Nest site characteristics consist of greater visual obstruction, horizontal cover, residual grass cover, and litter cover (Riley 1978; Riley et al. 1992; Giesen 1994; Pitman et al. 2005; Davis 2009; Hagen et al. 2013; Grisham et al. 2014). Brood-rearing habitat is characterized by sparse and short vegetation to allow for movement (Haukos and Zavaleta 2016).

Additionally, female lesser prairie-chickens with broods often select areas that have greater food resources and thermoregulatory capacity (e.g., forb-dominated patches; Jamison et al. 2002; Hagen et al. 2005; Bell et al. 2010). To close out the annual life cycle, lesser prairie-chickens require denser grass cover during winter, with grassland being used for roosting and loafing and grain fields for foraging (Hagen et al. 2004; Haukos and Zavaleta 2016).

Lesser prairie-chickens evolved in prairie landscapes without trees, a result of limited precipitation, periodic grazing by native herbivores, and fire. Post settlement, areas of extant prairies were cultivated and domestic livestock were introduced throughout the lesser prairie-chicken occupied range. The development and establishment of center-pivot irrigation systems in the High Plains during the 1960s-1980s altered landscapes and accelerated loss of native prairies (Spencer et al. 2017; Vhay et al. 2024). These technological advancements provided reliable irrigation from the Ogallala/High Plains aquifer but also contributed to widespread cultivation of prairie in the sandy soils at the core of lesser prairie-chicken distribution.

The U.S. Department of Agriculture introduced the - CRP in 1985, encouraging land restoration by initially planting perennial introduced (New Mexico, Texas, and Oklahoma) and native (Kansas and Colorado) mid- and tall grasses on highly erodible soils in exchange for annual rental payments. In northwest Kansas, the presence of CRP grasslands provides reliable nesting habitat that was not present previously for lesser prairie-chickens during periods of drought (Sullins et al. 2018). As a result, lesser prairie-chickens dispersed north of the Arkansas River and established populations in previously unoccupied landscapes (Dalgren et al. 2016). Currently, the Short-Grass Prairie/CRP Mosaic Ecoregion has become the species stronghold, supporting >70% of extant lesser prairie-chickens (Nasman et al. 2022). The lesser prairie-chicken is a boom-bust species in a semi-arid region with dynamic and unpredictable

environmental conditions (e.g., drought). Because of this, population fluctuations are both normal and common, but population recovery is becoming hindered by increasing occurrence and intensity of drought (Haukos and Zavaleta 2016; Ross et al. 2016). During the 1960s-1980s, population estimates throughout the lesser prairie-chicken occupied range reported stable numbers, with ~150,000 birds (Garton et al. 2016). Unfortunately, following a contemporary peak in abundance during the mid-late 1980s, a steep range-wide decline through the mid 1990s dropped to ~25,000 birds by approximately 1995. Populations increased to ~80,000 birds by 2008 but dipped again to ~37,000 birds in 2012 (Garton et al. 2016). A decade later, aerial surveys estimated ~26,591 birds, with >90% of extant lesser prairie-chickens occurring in Kansas (Nasman et al. 2022). The Short-Grass Prairie/CRP Mosaic Ecoregion had the largest number of lesser prairie-chickens, with an estimated 19,847 individuals. Populations in the Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions were much smaller with an estimated 4,512 and 1,713 individuals, respectively (Nasman et al. 2022). There has not been a range-wide population estimate since 2022.

As a result of population declines and conservation concerns, the legal status of the lesser prairie-chicken has been under continual review since being petitioned for listing in 1995 under the 1973 Endangered Species Act (Rodgers 2016). Initially listed as threatened range wide under the Endangered Species Act in 2014, the ruling was vacated in 2015, with the species officially removed from the list in 2016 (Boal and Haukos 2016). However, in 2022, the U.S. Fish and Wildlife Service proposed listing two Distinct Population Segments (DPS). In 2023, the Northern DPS (Kansas, Oklahoma, and Colorado) was listed as threatened, while the Southern DPS (Texas and New Mexico) was listed as endangered (U.S. Fish and Wildlife Service 2022). In 2025, a federal judge vacated the rule establishing the Distinct Population Segments,

effectively leading to an eventual delisting of the species once again in 2026 (<https://www.federalregister.gov/documents/2026/02/26/2026-03883/endangered-and-threatened-wildlife-and-plants-removal-of-northern-and-southern-distinct-population>).

Despite the ongoing challenges surrounding the listing of the lesser prairie-chicken, established conservation practices have remained in place. In 2013, the Western Association of Fish and Wildlife Agencies (WAFWA) developed the Lesser Prairie-Chicken Range-Wide Plan, a conservation plan to address threats to lesser prairie-chickens across their historic and current occupied range (<https://wafwa.org/initiative-programs/lesser-prairie-chicken/>). Objectives of this plan included identifying Focal Areas (CHAT 1) and Movement Corridors (CHAT 2) using the Crucial Habitat Assessment Tool (CHAT; <https://www.sgpchat.org/>), prioritizing landscapes with existing populations and high-quality habitat for conservation. Additionally, available, or potential habitat (Modeled Habitat, CHAT 3) and the estimated occupied range with an added 10 miles buffer (Modeled Non-Habitat, CHAT 4) are designated within this plan. These CHAT designations were based on the assumption of available habitat or expert opinion, rather than the presence of lesser prairie-chickens. This tool incorporates multiple criteria related to habitat quality, landscape composition, and potential threats to categorize areas based on their conservation value (Van Pelt et al. 2013). Monitoring leks, along with habitat conditions and characteristics of Focal Areas (CHAT 1) and Movement Corridors (CHAT 2), allows for detection of population declines, assessment of factors potentially influence population demography, and initiation of proactive conservation actions.

Conservation-focused programs such as the CRP and Conservation Banking have provided critical support for lesser prairie-chicken populations by protecting and restoring habitat across their occupied range. Conservation Banking is a market-based approach to species

and habitat conservation that involves partnerships among landowners, government agencies, and developers. Landowners permanently protect and manage habitat for a target species in exchange for U.S. Fish and Wildlife Service-approved credits, which can be sold to developers to offset negative effects to the same species elsewhere. Like the CRP, this program provides financial incentives for landowners while promoting habitat conservation for species of concern (U.S. Fish and Wildlife Service n.d.). However, effectiveness of these programs depends on a clear understanding of which landscape features most strongly influence lesser prairie-chicken lek occurrence and persistence.

Importantly, ecological thresholds, critical points at which relatively small changes in landscape features result in rapid declines in population abundance and occupied area, influencing lesser prairie-chicken occupancy and persistence have been identified in recent decades (Hagen et al. 2007; Environmental Protection Agency 2016). Landscape-level thresholds have been linked to grassland extent, tree density, and anthropogenic structures (Crawford and Bolen 1976; Ross et al. 2016; Lautenbach et al. 2017; Sullins et al. 2018; Plumb et al. 2019; Table 2.1). Within the lesser prairie-chicken occupied range, specifically surrounding leks, assessing thresholds can identify areas at heightened risk of population decline or local extinction. This knowledge will enable more effective conservation prioritization and management strategies.

Grasslands are critical for each life stage of lesser prairie-chickens, providing required cover to meet life history requirements, food resources, protection from predators, and can improve population resilience to intensive drought. At least 60% grassland in a landscape supporting lesser prairie-chickens is required for population persistence and long-term occupancy (Crawford and Bolen 1976). Research in Kansas found that lesser prairie-chickens are

constrained to areas with >70% grasslands within a 5-km radius (Sullins et al. 2019). Like other grouse species (e.g., greater prairie-chicken), lesser prairie-chickens will use cropland for food resources. In Texas, lesser prairie-chicken populations were found in areas with 63-95% native grassland; the remaining area was grain sorghum. No lesser prairie-chicken leks were recorded in areas with >37% cultivation (Crawford and Bolen 1976). Similarly, in Kansas, as the proportion of cropland exceeded approximately 23%, available grassland decreased along with the probability of use by lesser prairie-chickens (Ross et al. 2016; Sullins et al. 2018). Further, a cropland-to-grassland ratio of 1:10 (~9.6% cropland) was defined for resilience to intensive drought, with population persistence of lesser prairie-chickens declining if this ratio was exceeded (Ross et al. 2016).

Lesser prairie-chickens are most likely to use CRP grasslands when landscapes are ~77% native prairie, and where CRP fields are in areas of contiguous patches of native grassland (Sullins et al. 2018). The probability of lesser prairie-chickens occupying a landscape increases considerably when the land is managed by prescribed grazing or enrolled in CRP (Hagen et al. 2016). On a different scale, as the percentage of CRP enrolled in a 57-km² area exceeds 20%, the likelihood of lesser prairie-chickens occupying that landscape increases (Hagen et al. 2016). In the western portion of their occupied range, CRP grasslands have supported lesser prairie-chickens during nesting and roosting periods (Sullins et al. 2018; Berigan et al. 2022). In the Sand Sagebrush Prairie Ecoregion, translocated lesser prairie-chickens selected CRP grasslands at the end of dispersal steps (Berigan et al. 2024).

Historically, lesser prairie-chickens evolved in prairie landscapes with few to no trees. Fueled by precipitation and a lack of fire, trees located in the sand prairies of central Kansas (i.e., Mixed-Grass Prairie Ecoregion) flourished, causing a major loss of lesser prairie-chicken habitat

(Rodgers 2016). Further, incentives (e.g., living snow fences) for planting trees in the western Great Plains were implemented in the late 1800s, contributing to loss of habitat throughout the occupied range. The encroachment of woody vegetation, particularly eastern red cedar (*Juniperus virginiana*), elicits avoidance behaviors in lesser prairie-chickens and other grassland birds in Kansas (Lautenbach et al. 2017). An increase in woody vegetation prompts declines in grasshopper sparrow (*Ammodramus savannarum*), dickcissel (*Spiza americana*), and eastern meadowlark (*Sturnella magna*) populations (Silber et al. 2024). Despite normally selecting for different vegetation types and varying amounts of herbaceous cover, each species selected for relatively flat areas, <6% shrub cover, and <1% tree cover (Silber et al. 2024). Lesser prairie-chickens were 40 times more likely to use habitats with 0 trees/ha when compared to landscapes with 5 trees/ha (Lautenbach et al. 2017). Additionally, lesser prairie-chickens were 19 times more likely to use habitats that were >1 km from the nearest tree compared to habitats <100 m away from the nearest tree (Lautenbach et al. 2017). Female lesser prairie-chickens selected for habitats with <2 trees/ha and distances >300 m from a tree when placing nests. Thresholds were established as no nests were observed in areas with >2 trees/ha and habitat use ceases completely with 8 trees/ha (Lautenbach et al. 2017).

Lesser prairie-chickens will avoid multiple types of anthropogenic structures, such as transmission lines, distribution power lines, oil wells, gas wells, wind turbines, and cellular towers (Plumb et al. 2019). Roads and oil/gas energy development, along with associated noise, are a potential threat to this species (Hagen et al. 2011; Lipp 2016). High densities of anthropogenic structures negatively affect lesser prairie-chickens; thus, they often select areas with minimal structures within a 2-km radius (Sullins et al. 2019). Avoidance of these structures varies with the density at the landscape scale, life-stage of individuals, and availability of high-

quality habitat, with some lesser prairie-chickens reducing avoidance distance when there is sufficient access to high-quality habitat (Lautenbach et al. 2017; Plumb et al. 2019). Several grouse species, including lesser prairie-chickens, are negatively affected by power lines (e.g., transmission and distribution power lines). These structures influence movement, nest-site selection, and general habitat use (Patten et al. 2005; Beck et al. 2006; Hagen et al. 2007; Wolfe et al. 2007; Stevens et al. 2012). Plumb et al. (2019) reported that in all analyses, lesser prairie-chickens consistently avoided distribution power lines. While distribution lines were not differentiated from transmission lines in many studies due to lack of transmission lines, results suggest negative effects on lesser prairie-chickens. Additionally, lesser prairie-chickens established home ranges and placed nests farther from powerlines than what would be expected at random (Plumb et al. 2019). It was reported that the probability of use of an area decreases at a powerline density of 0.15 km per 12.6 km² (Sullins et al. 2019). Further, transmission lines and distribution power lines can elicit a negative response to the newness (neophobia) and size of the structure. A different study suggested that the tallest features on the landscape (e.g., towers, windmills, and transmission lines) were avoided at greater distances (Peterson et al. 2020).

Oil and gas well development affects not only lesser prairie-chickens, but other species of grouse. Greater sage-grouse (*Centrocercus urophasianus*) have been documented avoiding both oil and gas wells; similar avoidance behaviors have been observed in lesser prairie-chickens (Green et al. 2017). Areas with >2 wells/12.6 km² have 8 times lower rate of use (Sullins et al. 2019). Additionally, space use declines with greater well density, as female lesser prairie-chickens avoided areas containing 23 wells/250 ha (Plumb 2015). However, effects of oil and gas wells can vary among scales of selection (i.e., second and third order of selection; Johnson 1980), with distance to wells not being a significant predictor of home range or nest placement at

the second-order selection scale. Despite this, lesser prairie-chickens selected areas farther away from oil and gas wells than what was available within their home range (Plumb et al. 2019).

While gravel and paved roads may not be as problematic as other anthropogenic structures, there are still some risks associated with these features. Gravel and paved roads, and noise produced from cars may trigger avoidance behaviors in lesser prairie-chickens, resulting in potential deterrence from the area (Plumb et al. 2019). Female lesser prairie-chickens established nesting sites farther from paved roads than what would be expected (Hagen et al. 2011). Positively, the effect of county roads appears lower than that of other anthropogenic features, as avoidance was not observed when road density was below 15 km per 12.6 km² (Sullins et al. 2019). These patterns of habitat use may have cascading effects on reproductive behavior, including lek establishment.

The lekking period is the first stage in the breeding season, followed by nesting and brood-rearing. Leks are often established on slightly elevated ground in areas with sparse vegetation (Boal and Haukos 2016). In addition to grassland sites, lesser prairie-chicken leks have been observed in green wheat fields, bare corn fields, cut hay fields, livestock holding or watering areas, abandoned oil pads, and roadsides. Male lesser prairie-chickens arrive at leks in early spring (late February – early March) to establish territories with females visiting a few weeks later. Males attract females with an exhilarating courtship display consisting of booming, fanning their tails, and rapidly stomping around on the lek (Applegate and Riley 1998). Females may visit multiple leks before choosing a mate and typically nesting within 3.2 km of the nearest lek (Boal and Haukos 2016). Additionally, male lesser prairie-chickens often return to the same lek year after year. Thus, prevention of lek isolation and maintaining connectivity among leks is important for persistence of the local populations (Applegate and Riley 1998; Boal and Haukos

2016). An intrinsic threshold regarding lek attendance, determined using aerial and ground lek survey data, has been recently established. This threshold suggests that lesser prairie-chicken leks with <10 males present at the lek have a much greater probability of extinction within 5 years, while leks above this threshold (≥ 10) have a greater probability of persistence (Whetten et al. *In Review*). This threshold and trends in lek attendance may hint at future population declines that can be attributed to Allee effects, such as those that greatly diminished populations of heath hen and Attwater's prairie-chicken.

The establishment of ecological thresholds, a result of sensitivity to environmental changes and influences by lesser prairie-chickens, has increased the risk of localized extinction due to habitat loss, decreased habitat quality, and low population level. Failure to meet habitat requirements (e.g., $>60\%$ grassland) and surpassing other thresholds of features surrounding leks will likely result in decreased attendance or lek abandonment. Monitoring thresholds can identify populations of lesser prairie-chickens at risk of localized extinction, highlight areas with relatively greater conservation need, and inform conservation efforts of potential risks of future landscape changes (e.g., anthropogenic development).

The goal of my research project was to use identified ecological thresholds to further understand dynamics between lesser prairie-chicken leks and the surrounding landscape. My specific objective was to compare the composition and configuration of landscapes surrounding lesser prairie-chicken leks with attendance counts above and below the survival threshold of 10 birds, and Extinct leks (historical leks with no males in attendance during the 2018-2023 survey period). Specifically, I 1) quantified each lek type (<10 , ≥ 10 , Extinct) within each ecoregion, noting which ecoregion had the greatest proportion of each lek type and 2) determined the similarities and differences in landscape condition among the three lek attendance groups and

compared those metrics among the lesser prairie-chicken ecoregions in Kansas. I predicted that 1) anthropogenic structures (e.g., wind farms, oil/gas wells, transmission lines, and cellular towers) and land-use development negatively influence lek attendance; thus, leks with ≥ 10 males would be established further from roads and transmission lines, compared to leks with counts of < 10 males and Extinct leks; 2) the Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion would have a greater proportion of leks above the survival threshold (≥ 10 males) and a lower proportion of leks below the threshold (< 10) and Extinct leks, compared to the Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions; and 3) within 5 km of leks with ≥ 10 males in attendance, there are greater proportions of native grassland cover, CRP grasslands, and less tree cover, compared to leks with < 10 males and Extinct leks. Frequent evaluation of current landscape conditions within the lesser prairie-chicken occupied range in Kansas, specifically within the established dispersal radius (~ 5 km) around active and abandoned leks, is necessary to identify areas that have passed or are approaching established persistence thresholds. This information will provide the necessary information to improve habitat and promote population persistence.

Study Area

Three defined ecoregions of the lesser prairie-chicken occupied range in Kansas were of focus for this study. The Short-Grass Prairie/CRP Mosaic Ecoregion is a semi-arid climatic zone north of the Arkansas River with a range of 25-51 cm annual precipitation. This ecoregion is dominated by fine, sandy loam soil and primary land use includes CRP grasslands, livestock grazing, and row-crop agriculture (Robinson et al. 2018; Kansas Department of Wildlife and Parks 2022). Grasses present in this ecoregion include big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), hairy grama (*Bouteloua hirsuta*), sideoats grama (*B.*

curtipendula), blue grama (*B. gracilis*), and buffalograss (*B. dactyloides*). The forb community is comprised of Illinois bundleflower (*Desmanthus illinoensis*), prairie sunflower (*Helianthus petiolaris*), annual buckwheat (*Eriogonum annuum*), sand milkweed (*Asclepias arenaria*), nine-anther dalea (*Dalea enneandra*), and western ragweed (*Ambrosia psilostachya*; Lauver et al., 1999). The CRP fields were planted with native grasses species including big bluestem, little bluestem, sideoats grama, blue grama, buffalograss, switchgrass (*Panicum virgatum*), and golden feather grass (*Sorghastrum nutans*). Starting in the mid-1990s, CRP fields were interseeded with forbs such as white sweet clover (*Melilotus albus*), yellow sweet clover (*M. officinalis*), Maximillian sunflower (*Helianthus maximiliani*), Illinois bundleflower, purple prairie clover (*Dalea purpurea*), and prairie coneflower (*Ratibida columnifera*; Fields et al. 2006). Woody species found in this ecoregion include bur oak (*Quercus macrocarpa*), green ash (*Fraxinus pennsylvanica*), american elm (*Ulmus americana*), eastern cottonwood (*Populus deltoids*), sugar maple (*Acer saccharum*), river birch (*Betula nigra*), and hackberry (*Celtis occidentalis*; Kansas Department of Wildlife and Parks 2022). Salt cedar (*Tamarix* spp.) is a non-native species and eastern red cedar (*Juniperus virginiana*) is native; both of these invasive woody species are rapidly encroaching in this ecoregion.

The Mixed-Grass Prairie Ecoregion has a dry, sub-humid to semi-arid climate with a range of 51-76 cm of annual precipitation (Kansas Department of Wildlife and Parks 2022). Soil in this ecoregion is loamy. Primary land uses are livestock grazing, oil/gas extraction, and row-crop agriculture (Robinson et al. 2018). Grasses include big bluestem, little bluestem, blue grama, hairy grama, sideoats grama, western wheatgrass (*Pascopyrum smithii*), buffalograss, switchgrass, golden feather grass, sand lovegrass (*Eragrostis trichodes*), tall dropseed (*Sporobolus compositus*), and alkali sacaton (*Sporobolus airoides*). Forbs in this ecoregion

include purple coneflower (*Echinacea purpurea*), leadplant (*Amorpha canescens*), dotted blazing star (*Liatris punctata*), heath aster (*Symphyotrichum ericoides*), hairy sunflower (*Helianthus hirsutus*), round leaf bladderpod (*Lesquerella ovalifolia*), western ragweed, lamb's quarters (*Chenopodium album*), Russian thistle (*Salsola tragus*), annual sunflower (*Helianthus annuus*), kochia (*Bassia scoparia*), and Patagonian plantain (*Plantago patagonica*). Native woody species include southern hackberry (*Celtis laevigata*), western snowberry (*Symphoricarpos occidentalis*), eastern cottonwood (*Populus deltoides*), eastern red cedar, honey mesquite (*Prosopis glandulosa*), and green ash (*Fraxinus pennsylvanica*; Robinson et al. 2018). Invasive woody species include salt cedar, with native species such as eastern red cedar also exhibiting rapid encroachment (Kansas Department of Wildlife and Parks n.d.).

The Sand Sagebrush Prairie Ecoregion is a semi-arid, drought-prone region with a range of 41-53 cm of annual precipitation. This ecoregion has sandy soil with dunes found throughout, associated with river drainages (e.g., Cimarron, Arkansas). Grassland with irrigated row-crop agriculture, livestock grazing, and oil/gas extraction are the predominant land uses for this ecoregion. Sand dropseed (*Sporobolus cryptandrus*), sideoats grama, hairy grama, blue grama, big bluestem, little bluestem, sand bluestem (*Andropogon hallii*), buffalograss, prairie sandreed (*Calamovilfa longifolia*), and alkali sacaton are commonly occurring grasses. The forb community includes annual buckwheat, dotted blazing star, western ragweed, prairie sunflower, annual sunflower, Russian thistle, camphorweed (*Heterotheca subaxillaris*), Indian blanket flower (*Gaillardia pulchella*), tansy aster (*Machaeranthera tanacetifolia*), buffalo bur (*Solanum rostratum*), buffalo gourd (*Cucurbita foetidissima*), wax goldenweed (*Grindelia papposa*), prickly lettuce (*Lactuca serriola*), and marestail (*Conzya canadensis*). Woody and shrubby

vegetation includes cottonwood, elm (*Ulmus* spp.), eastern red cedar, salt cedar, and sand sagebrush (*Artemisia filifolia*; Vhay 2022).

Methods

Lek Survey Dataset

A multi-decadal dataset (1960-2023) of lesser prairie-chicken lek surveys was used for this research, however, analyses in this study were restricted to surveys conducted from 2018-2023 to identify lek locations and classify leks based on counts of attending birds. In Kansas, ground surveys were implemented and served as an index to lesser prairie-chicken population trends in the early 1960s. This dataset included established annual ground surveys and opportunistic reporting of identified leks. Originating with single transects in six counties, efforts increased to 17 transects in 15 counties by 2014. Ideally, surveys were conducted twice each season between March 20 and April 20, starting between 0500 and 0700. When conducting a survey, observers drove a 16-km transect, stopping every 1.6 km to listen for three minutes to detect leks. Once the route was completed, the observer would return to identified leks, flush the birds, and count any lesser prairie-chickens (Ross et al. 2016). A lek observation was labeled opportunistic when it was located >1.6 km from an established survey route. Similar data were collected for these leks as those found along established survey routes. Additional opportunistic leks were submitted to an online database by conservation managers, biologists, researchers, and landowners (Pitman 2014).

This dataset was reformatted to organize data by individual lek with the male lesser prairie-chicken count per survey year, rather than all lek observations without unique identifiers. Additionally, we used data from 2018-2023 for our analyses as this time frame reflected the most recent available data, represented contemporary landscape characteristics, and captured variation

in precipitation conditions that may have influenced vegetation characteristics. Results will be more informative for conservation efforts compared to using the entire dataset.

Lek Attendance Groups

Lesser prairie-chicken leks were categorized as <10 birds, ≥ 10 birds, or Extinct based on average lek attendance during 2018-2023. A lek was considered Extinct if there were zero males observed at a previously identified lek during annual survey efforts across the five-year time frame. I started with a total of 343 individual leks in my analyses. I checked for duplicates or observations with missing data (e.g., coordinates). Eight leks were removed from the data set; five due to not being consistently surveyed across the five-year period. I removed one lek from the data set because it had identical coordinates as another lek, keeping the lek with the highest male count. I removed an opportunistic lek from the data set because it had the same coordinates as a lek found via survey. The last lek I removed was an Extinct lek within 500 m of another Extinct lek. These changes resulted in a final total of 335 leks for analyses.

I calculated the average male attendance from 2018-2023 for each lek observation, rounding as necessary. Some leks were inconsistently surveyed during this time frame, but because it was not confirmed that zero males were present during each survey attempt, there was still a possibility of presence. For example, a lek might have zero males in attendance for three of the five years and “N/A” for the remaining two years. Despite not being surveyed, this lek was treated as a consistently surveyed lek rather than an Extinct lek, to account for the possibility of males being present. In the dataset, the male count was entered as “N/A”; these leks were still used in my analyses. For each lek attendance category, I included the survey route (if applicable), county, and ecoregion for each lek. I overlaid established survey routes for lesser prairie-chickens with lek locations to identify the survey route associated with each lek. I

determined which county and ecoregion for each lek using Kansas counties and lesser prairie-chicken occupied range ecoregion maps (Lesser Prairie Chicken Interstate Working Group 2022; Kansas Department of Labor 2025).

Establishment of Lek Locations

I uploaded lek locations to ArcGIS Pro 3.2 using latitude and longitude coordinates for each lek observation. I reprojected these spatial layers to change the coordinate system to “NAD 1983 UTM Zone 14N”. Using a specific UTM zone can limit distortion and improve accuracy, as latitude and longitude coordinates are not ideal for measuring distances and area due to the Earth’s shape. Map projections using UTM coordinates minimizes distortion within each zone (e.g., Zone 14), making the distance and area calculations within my study area more accurate (Geography Realm 2020).

I defined boundaries of Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions and used the Select by Location map tool to identify the number of known leks per attendance group per ecoregion (Lesser Prairie Chicken Interstate Working Group 2022). Additionally, this tool allowed me to highlight all leks within each ecoregion and provided a count in an attribute table. Following previous lesser prairie-chicken research that suggests a 5-km scale of selection, I generated a 5-km buffer around each lek (Sullins et al. 2019). Land cover type did not change for the few 5-km buffers of leks in the Sand Sagebrush Prairie and Mixed-Grass Prairie ecoregions that crossed into Colorado or Oklahoma. I calculated the total area (ha) of each landcover variable within all 5-km buffers and the average area per 5-km buffer for each lek attendance category using the SUM and AVERAGE functions; values of 0 were included in all calculations.

Estimation of Landcover Variables

Grassland

Kansas land cover data was retrieved from the Ecological Mapping Systems of Kansas (Diamond et al. 2021). This layer contains 49 land cover classes for Kansas including short-grass prairie, mixed-grass prairie, and sand sagebrush prairie. To estimate the proportion of native grassland cover types within a 5-km radius buffer surrounding each lek, I joined the Ecological Mapping Systems of Kansas grassland layer to the lek buffers in ArcGIS PRO 3.2. I then quantified the area of each grassland cover type within each buffer. The area of each cover type per buffer was displayed in the attribute table; the sum of each landcover class was calculated using the SUM function in Excel. I combined the following cover types for the native grassland category: mixed-grass prairie, mixed-grass prairie breaks grassland, sand sagebrush prairie, sandhills prairie, shortgrass prairie, chalkflat mixed-grass prairie, and western lowland grassland. To prevent over-estimation of the native grassland variable, I converted the CRP spatial layer into a raster, merged the grassland layer with the CRP layer, and erased native grassland where it overlapped with CRP grassland. I then added the CRP variable to the native grassland variable for an estimate of total grassland. I derived the mean, standard error, and percentage for each grassland variable (native grassland, CRP, total grassland) for each lek category in each ecoregion. I retained all other cover types included in this spatial layer (e.g., playa, barren, urban grasses, etc.) for thoroughness, but no statistical analyses were done for those attributes.

Cropland

Cropland was included in the Ecological Mapping Systems of Kansas land cover layer, so I estimated this variable in the same manner as the grassland variable. I then calculated the mean,

standard error, and percentage of cropland per 5-km radius buffer for each lek category in each ecoregion using the corresponding functions in Excel.

Conservation Reserve Program (CRP)

Conservation Reserve Program data from 2021 were provided by the United States Department of Agriculture Farm Service Agency. The 2021 data represents the mid-point of the study's time frame (2018-2023). This variable was treated as a binomial variable (present or absent); Conservation Practice was not recorded. I quantified the proportion of CRP within a 4.23 km radius (56.25 km²; 5,625 ha) for each lek location, using a scale identified by Hagen et al. (2016) where the probability of lesser prairie-chickens occupying a landscape increases as CRP exceeds 20%. I estimated the area of CRP within each buffer and reported this as a standalone metric from native grassland. The mean, standard error, and percentage of CRP for each lek was derived for each lek category in each ecoregion. For leks that were in a CRP field, I measured the area in hectares of the field using the Measure Features tool in ArcGIS Pro. I reported the number of CRP fields (partial or whole) within 5 km of each lek. Additionally, the distance to the nearest CRP field from each lek was determined using the Near tool.

Trees

I obtained 2021 Kansas tree data from EarthDefine (<https://www.earthdefine.com/treemap/>). This spatial layer was presented as a binary raster (1 = tree, 0 = no tree) with 5-m resolution. I developed an index to estimate the number of individual trees within 5-km of each lek. I randomly selected 10 leks and generated 500 random points in each 5-km buffer. I generated 1-ha buffers around each random point, and randomly selected 10 points, each with varying proportions of trees. I then estimated what proportion of a tree was covered by each 25-m² pixel in the spatial layer (e.g., 0.25, 0.50, 0.75, 1.0). To determine the

approximate number of trees per pixel, I counted the total number of pixels covering 0.25% of a tree and multiplied that by 25 (ex: 60 pixels x 0.25). I repeated this for the remaining categories of coverage (0.50%, 0.75%, and 1%). I then divided the total number of tree coverage by the total number of pixels to get a value of 0.49 trees per pixel when trees were indicated in a pixel.

To estimate trees/ha, I first converted the EarthDefine tree raster into polygons and clipped the tree polygons to each 5-km buffer. I then used Zonal Statistics to retrieve the number of individual tree pixels per buffer. The value of 0.49 trees per pixel was multiplied by the total number of pixels in each 5-km buffer, resulting in an estimated count of trees per buffer. The number of trees per 5-km buffer was then divided by the area in hectares of the 5-km buffer to get trees/ha. Additionally, I estimated the distance from each lek to the nearest tree polygon using the Near tool.

Anthropogenic Structures

Anthropogenic structure spatial layers were obtained from several sources. Data for Kansas oil and gas wells, cellular towers, and paved/gravel roads were gathered from the Kansas Data Access and Support Center. Locations of individual wind turbines in Kansas were from the U.S. Geological Survey Wind Turbine Database; transmission line locations were obtained from the U.S. Department of Homeland Security open data site via ArcGIS.com. I quantified each anthropogenic structure type within 5 km of all recorded lesser prairie-chicken leks. To retrieve the count of oil/gas wells per buffer, I clipped the oil/gas well spatial layer to the lek spatial layer and viewed the attribute table. Oil and gas wells on the landscape were not differentiated, and I did not remove plugged, dry, or abandoned wells as these may have been active at some point from 2018-2023. I repeated these steps for individual wind turbines and cell phone towers. For transmission lines, I first clipped the spatial layer to the spatial layer with the lek locations. I then

visually confirmed if a transmission line crossed through the buffer. I determined the total length of transmission lines per buffer by joining the attribute table with the lengths of individual transmission lines to the lek spatial layer. I derived the distance from each lek to the nearest road using the Near tool and calculated the total length of roads within each buffer.

Statistical Analyses

Statistical analyses were conducted in Program R to identify relationships and test for differences among leks per ecoregion, three lek attendance groups (i.e., <10 , ≥ 10 , and Extinct) across all ecoregions, and lek attendance groups within each of the three ecoregions. I used a non-parametric Kruskal-Wallis test for comparisons. Results are presented with 95% confidence intervals, and statistical significance was defined as $\alpha = 0.05$. A Wilcoxon test was used for pairwise comparisons following a significant ($P < 0.05$) Kruskal-Wallis Test. Descriptive statistics, including means and standard errors, were calculated for all landcover variables.

Results

Of the 335 total leks, 114 were in the Short-Grass Prairie/CRP Mosaic Ecoregion, 106 in the Mixed-Grass Prairie Ecoregion, and 115 in the Sand Sagebrush Prairie Ecoregion (Table 2.2). The Short-Grass Prairie/CRP Mosaic Ecoregion had the greatest proportion of surveyed leks above the attendance threshold of ≥ 10 males (39.47%) and lowest proportion of Extinct leks (26.32%). Conversely, the Mixed-Grass Prairie Ecoregion had the lowest proportion of surveyed leks above the ≥ 10 bird attendance threshold (5.66%) and greatest proportion of Extinct leks (64.15%). Greater than 80% of surveyed leks in the Sand Sagebrush Prairie Ecoregion were either below the attendance threshold of 10 males (42.61%) or Extinct (46.96%; Table 2.2).

Ecoregions

Within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions, landcover variables were measured within 5 km of lesser prairie-chicken leks. Statistical tests revealed that all ecoregions varied in the amount of native grassland, total grassland, CRP grassland at the 5-km and 4.23-km scales, cropland, and trees/ha (Tables 2.3-2.4). The amount of native grassland differed among ecoregions ($H_2 = 17.55$, $P < 0.001$). Native grassland surrounding leks in the Short-Grass Prairie/CRP Mosaic Ecoregion differed from those in the Sand Sagebrush Prairie Ecoregion ($P < 0.001$), whereas leks in the Mixed-Grass Prairie Ecoregion did not statistically differ from the other ecoregions. Leks in the Sand Sagebrush Prairie Ecoregion contained the greatest average native grassland within 5 km (Table 2.3). Total grassland varied among ecoregions ($H_2 = 22.98$, $P < 0.001$), with leks in the Sand Sagebrush Prairie Ecoregion surrounded by more total grassland on average, when compared to the Mixed-Grass Prairie Ecoregion ($P < 0.001$) and Short-Grass Prairie/CRP Mosaic Ecoregion ($P < 0.001$; Table 2.3). The amount of cropland within 5 km of leks differed among ecoregions ($H_2 = 24.47$, $P < 0.001$), with leks in the Short-Grass Prairie/CRP Mosaic Ecoregion containing greater average area of cropland than those in the Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions ($P < 0.001$; Table 2.3). Area of CRP grassland varied among ecoregions as at the 5-km scale ($H_2 = 34.70$, $P < 0.001$). Differences in area of CRP grasslands were reported between the Short-Grass Prairie/CRP Mosaic and Mixed-Grass Prairie ecoregions ($P < 0.001$) and Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions ($P < 0.001$). The lowest average area of CRP grassland (581.1 ha) was reported within 5 km of leks in the Mixed-Grass Prairie Ecoregion (Table 2.3). Additionally, area of CRP grassland varied at the 4.23-km scale ($H_2 = 31.71$, $P < 0.001$). Differences were reported between leks in the Mixed-Grass Prairie and Short-

Grass Prairie/CRP Mosaic ($P < 0.001$) ecoregions and Sand Sagebrush Prairie Ecoregion ($P = 0.004$). Leks within the Mixed-Grass Prairie Ecoregion contained the lowest average area of CRP grasslands within 4.23 km (428.47 ha; Table 2.4). Lastly, the amount of trees/ha varied across ecoregions ($H_2 = 108.61$, $P < 0.001$). Leks in the Sand Sagebrush Prairie Ecoregion had the fewest trees/ha on average, whereas leks in the Mixed-Grass Prairie Ecoregion contained the most trees/ha. Additionally, leks in the Mixed-Grass Prairie Ecoregion contained more trees/ha than leks in the Short-Grass Prairie/CRP Mosaic Ecoregion (Table 2.5). On average, the nearest tree in the Mixed-Grass Prairie Ecoregion was located 0.54 km away from a lek, whereas the nearest tree was approximately 0.88 km and 1.87 km from a lek in the Short-Grass Prairie/CRP Mosaic and Sand Sagebrush Prairie ecoregions, respectively (Table 2.5).

Across the three ecoregions, each lek contained oil/gas wells within 5 km (Table 2.6). Approximately 16% of leks in the Short-Grass Prairie/CRP Mosaic Ecoregion contained individual cell towers within 5 km. The proportion of leks with cellular towers was largest in the Sand Sagebrush Prairie Ecoregion (18%) and smallest in the Mixed-Grass Prairie Ecoregion (7%; Table 2.6). Approximately 4% of sampled leks in both the Short-Grass Prairie/CRP Mosaic and Mixed-Grass Prairie ecoregions contained individual wind turbines, while 0% of sampled leks in the Sand Sagebrush Prairie Ecoregion contained individual wind turbines (Table 2.6).

The average distance from a lek to the nearest road was similar between the Mixed-Grass Prairie and Short-Grass Prairie/CRP Mosaic ecoregions (0.49 km and 0.54 km, respectively), while leks in the Sand Sagebrush Prairie Ecoregion were further from the nearest road (0.81 km; Table 2.7). The average distance from a lek to the nearest transmission line was also similar between the Mixed-Grass Prairie and Short-Grass Prairie/CRP Mosaic ecoregions (9.62 km and

9.47 km, respectively), while transmission lines in the Sand Sagebrush Prairie Ecoregion were closest to a lek (7.89 km; Table 2.7).

Lek Attendance Groups per Ecoregion

Within the Short-Grass Prairie/CRP Mosaic Ecoregion, there was no significant difference among lek attendance groups (<10 , ≥ 10 , Extinct) for native grassland ($H_2 = 1.71$, $P = 0.43$), total grassland ($H_2 = 4.37$, $P = 0.11$), cropland ($H_2 = 3.63$, $P = 0.16$), CRP grassland within 5 km ($H_2 = 3.70$, $P = 0.16$; Table 2.8), CRP grassland at the 4.23- km scale ($H_2 = 4.19$, $P = 0.12$; Table 2.9), and trees/ha ($H_2 = 0.05$, $P = 0.98$; Table 2.10). The distance from a lek to the nearest tree varied among lek attendance groups ($H_2 = 8.47$, $P = 0.01$), with Extinct leks differing from leks with ≥ 10 males ($P = 0.016$). Trees were closer to Extinct leks, with the nearest tree being 0.40 km from a lek (Table 2.10). The average number of CRP fields within 5 km of a lek did not vary between lek attendance groups ($H_2 = 2.78$, $P = 0.25$). Also, distance from a lek to the nearest CRP field did not vary between lek attendance groups ($H_2 = 0.74$, $P = 0.69$; Table 2.11).

Within the Mixed-Grass Prairie Ecoregion, there was no difference among lek attendance groups for native grassland ($H_2 = 0.27$, $P = 0.87$), total grassland ($H_2 = 0.35$, $P = 0.84$), cropland ($H_2 = 4.76$, $P = 0.09$), CRP grassland at the 5-km scale ($H_2 = 0.96$, $P = 0.62$ Table 2.12), and CRP grassland at the 4.23-km scale ($H_2 = 0.96$, $P = 0.62$; Table 2.13). Trees/ha varied among lek attendance groups ($H_2 = 8.46$, $P = 0.01$; Table 2.14). Leks with ≥ 10 males had fewer trees/ha on average (0.55 trees/ha), whereas leks with <10 males and Extinct leks did not differ ($P = 1.000$). Within 5 km, leks with <10 males had 1.80 trees/ha and Extinct leks had 1.64 trees/ha, respectively (Table 2.14). The distance from a lek to the nearest tree did not differ among lek attendance groups ($H_2 = 5.45$, $P = 0.07$; Table 2.15). The average number of CRP fields within 5 km did not vary; however, leks with ≥ 10 males had the greatest average of CRP fields.

Additionally, the distance from a lek to the nearest CRP field did not vary among the lek attendance groups ($H_2 = 0.24$, $P = 0.89$; Table 2.15).

In the Sand Sagebrush Prairie Ecoregion, native grassland varied among lek attendance groups ($H_2 = 39.61$, $P < 0.001$; Table 2.16). Extinct leks differed from leks with <10 and ≥ 10 birds; Extinct leks contained more native grassland on average than the other lek attendance groups. Total grassland area varied among lek attendance groups as well ($H_2 = 48.05$, $P < 0.001$; Table 2.16); Extinct leks differed from leks with <10 birds ($P < 0.001$). Specifically, Extinct leks contained more total grassland on average (Table 2.16). Cropland varied among lek attendance groups ($H_2 = 43.46$, $P < 0.001$), with leks with <10 males and Extinct leks differing ($P < 0.001$). Leks with <10 males contained more cropland within 5 km (Table 2.16). No differences were reported in lek attendance groups for area of CRP grasslands at the 5-km scale ($H_2 = 2.82$, $P = 0.24$; Table 2.16). No differences were reported for CRP grasslands at the 4.23-km scale ($H_2 = 2.58$, $P = 0.28$; Table 2.17). Trees/ha varied among lek attendance groups in the Sand Sagebrush Prairie Ecoregion ($H_2 = 27.40$, $P < 0.001$). Extinct leks differed from leks with <10 ($P < 0.001$) and ≥ 10 males ($P = 0.05$; Table 2.18). Extinct leks contained an average of 0.57 trees/ha, while leks with <10 and ≥ 10 males contained 0.19 and 0.26 trees/ha, respectively. Distance from a lek to the nearest tree did not differ between lek attendance groups ($H_2 = 4.21$, $P = 0.12$; Table 2.18). No differences were reported among lek attendance groups for the distance from a lek to the nearest CRP field ($H_2 = 3.28$, $P = 0.19$; Table 2.19).

Discussion

To assess the relative status of landscape thresholds affecting lesser prairie-chicken lek persistence and attendance, I estimated the amount of native grassland, CRP grassland, total grassland, cropland, trees/ha, and proportion of anthropogenic structures within 5 km of 335

surveyed lesser prairie-chicken leks within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas during 2018-2023. Each ecoregion varies greatly in proportion of dominant vegetation cover type, vegetation structure, anthropogenic development, land use, and populations of lesser prairie-chickens (Haukos and Boal 2016). For example, the Short-Grass Prairie/CRP Mosaic Ecoregion had the most CRP grassland, whereas the Mixed-Grass Prairie Ecoregion had the least CRP grassland and greatest density of trees. The Sand Sagebrush Prairie Ecoregion had the most total grassland and lowest density of trees, but high density of oil/gas wells. Thus, tailoring conservation and management strategies to each ecoregion based on knowledge of landscape factors influencing lek persistence may yield the most effective results towards lesser prairie-chicken population recovery.

As I hypothesized, the Short-Grass Prairie/CRP Mosaic Ecoregion had the greatest proportion of leks with ≥ 10 males (39.47%) and the least proportion of Extinct leks (26.32%). Within the Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions, >80% of surveyed leks were either below the attendance threshold of 10 males or Extinct. Historically, the Sand Sagebrush Prairie and Mixed-Grass Prairie ecoregions supported the greatest density of lesser prairie-chickens (Garton et al. 2016). However, declines in population in both ecoregions have been observed through multiple research efforts and lesser prairie-chicken surveys (Hagen et al. 2011; McDonald et al. 2014; Sullins et al. 2019; Nasman et al. 2022). As a result, the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas has become the stronghold for lesser prairie-chicken populations, with an estimated 19,847 individuals reported in the 2022 population estimate (Nasman et al. 2022). In the Short-Grass Prairie/CRP Mosaic Ecoregion, leks were surrounded by more CRP grassland and fewer trees within 5 km than other ecoregions. Leks in the Mixed-Grass Prairie Ecoregion had the greatest density of trees, followed by the lowest

proportion of CRP grassland within 5 km. Lastly, leks in the Sand Sagebrush Prairie Ecoregion contained the fewest trees within 5 km, but high density of anthropogenic development and agriculture operations surrounded concentrations of leks.

I predicted that lesser prairie-chicken leks with ≥ 10 birds in attendance would have more native grassland within 5 km. Within the Short-Grass Prairie/CRP Mosaic Ecoregion, lek attendance groups did not differ in the average native grassland; each lek contained an average 53.67% native grassland. By itself, the amount of native grassland on the landscape is not enough to support populations, as lesser prairie-chickens are restricted to areas with $\geq 60\%$ native grassland within 5 km (Crawford and Bolen 1976). The addition of CRP grasslands increased the average total grassland to 70.60%. Position of CRP in the landscape was important as leks with ≥ 10 males contained the greatest average of CRP fields (39.68 fields) within 5 km and were closer to CRP fields on average (0.71 km). Previous research has suggested that although nest success did not vary between CRP grassland and native working grassland, lesser prairie-chickens in the Short-Grass Prairie/CRP Mosaic Ecoregion had greater nesting densities in CRP when compared to native working grasslands (Sullins et al. 2018). Reliability of CRP as nesting cover during intensive drought is a primary factor contributing to the expansion of lesser prairie-chicken range into the Short-Grass Prairie/CRP Mosaic Ecoregion. The presence of CRP grassland on the landscape and the number of leks established in and near CRP fields may represent selection over native working grassland in the Short-Grass Prairie/CRP Mosaic Ecoregion.

In the Mixed-Grass Prairie Ecoregion, an average of 58.39% native grassland surrounded leks, an insufficient amount for carrying out lesser prairie-chicken life stages. The least CRP grassland was present within 5 km of leks in this ecoregion, but the addition of CRP grassland

resulted in an average of 65.80% total grassland per lek. Despite sparse CRP grassland surrounding leks, without it, lek landscapes could remain below the threshold for required grassland. In addition to the lack of CRP grassland, leks in the Mixed-Grass Prairie Ecoregion contained the most trees/ha. This may result in a lack of functional connectivity among patches of grassland, thus reducing movement of lesser prairie-chickens, resulting in isolation and populations declines.

Leks in the Sand Sagebrush Prairie had the greatest area of native grassland of the three ecoregions, with an average of 59.82% per lek. Within 5 km, CRP grassland accounted for an average of 14.76% of grassland. With the addition of CRP grassland, each lek had an average total grassland of 74.59%, the most of all ecoregions. Leks in this ecoregion had the greatest average of oil/gas wells within 5 km. In the Sand Sagebrush Prairie Ecoregion, three relatively large concentrations of leks were observed; two concentrations of Extinct leks and one consisting of leks with <10 males, with few leks above the attendance threshold scattered throughout (Figures 2.4 and 2.5). Without CRP grassland to supplement native grassland on the landscape within 5 km of leks, leks with <10 and ≥ 10 birds in the Sand Sagebrush Prairie Ecoregion would not have enough grassland to support lesser prairie-chickens. Despite Extinct leks having the most grassland, most trees/ha were present in this attendance group. This emphasizes the importance of grassland with minimal trees.

The Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions varied in density of trees/ha; leks in the Sand Sagebrush Prairie Ecoregion had the fewest trees/ha surrounding surveyed leks, whereas leks in the Mixed-Grass Prairie Ecoregion had the most. Moreover, lek attendance groups varied in density of trees/ha. Extinct leks in all ecoregions were on average closest to a tree, whereas leks with ≥ 10 birds were farthest. This

suggests the presence and proximity of trees influence lek persistence, placement, and attendance.

Encroachment of tree species such as salt cedar and eastern red cedar has contributed to the decline in prairie landscape integrity (Lautenbach 2015). Grassland production, decline of perennial grasses and forbs, herbaceous species richness and productivity, reduced soil water availability, increased erosion, and loss of topsoil are just some of the consequences of woody encroachment (Twidwell et al. 2013, 2016; Lautenbach 2015). Other species of grouse, such as the greater prairie-chicken, have experienced restrictions of habitat availability in portions of their occupied range due to encroaching woody vegetation (McKee et al. 1998; Gehrt et al. 2022). Such consequences include reduced reproduction and overall habitat loss. Lesser prairie-chickens have shown avoidance behaviors associated with trees during nesting, refraining from nesting in areas with as few as 2 trees/ha and completely avoiding an area with ≥ 8 trees/ha (Lautenbach et al. 2017). Implementation of woody encroachment removal around all leks, potentially beginning with those that are more likely to persist (≥ 10 birds in attendance), could improve lek persistence and reduce isolations of populations.

The density of anthropogenic structures (oil/gas wells, cellular towers, wind turbines, transmission lines) differed among ecoregions. Across all ecoregions, 99% of anthropogenic structures within 5 km of leks were oil/gas wells. The presence of oil and gas wells reduces availability of native grassland, connectivity between patches of existing grassland, and removes potential areas of CRP grassland placement. Lesser prairie-chickens often avoid anthropogenic structures. Consolidating oil and gas wells where possible, plugging wells no longer in service, and removing the larger well components once plugged may reduce negative effects for lesser prairie-chickens. Most importantly, avoiding establishment of oil and gas wells within 5 km of a

lek will be the best way to prevent abandonment of the area and further loss of lesser prairie-chicken habitat. If lesser prairie-chickens cannot navigate among patches of grassland and leks cannot be established or maintained on the landscape, populations are not sustainable with the likelihood of declines in abundance and eventual localized extinctions.

In Kansas, a large portion of the lesser prairie-chicken range occurs on private land, so incentive-based conservation programs (e.g., CRP, Conservation Banking) have been crucial in spreading awareness about threatened and endangered species, grassland health and restoration, and gaining support from landowners (U.S. Fish and Wildlife Service 2003; Van Pelt et al. 2013). The CRP has been proven to be a necessary factor in facilitating lesser prairie-chicken persistence through protection, enhancement, and restoration of habitat across the species range (Spencer et al. 2017; Sullins et al. 2018). On a smaller scale (approximately 4.23 km radius or 5,621 ha), as CRP increases beyond 20%, the likelihood of lesser prairie-chickens occupying the landscape increases (Hagen et al. 2016). Leks in the Short-Grass Prairie/CRP Mosaic Ecoregion were closest to this threshold, with leks containing an average of 17.36% CRP grassland within 4.23 km, followed by leks in the Sand Sagebrush Prairie Ecoregion (14.76%) and Mixed-Grass Prairie Ecoregion (7.62%). Presence of CRP grassland can increase connectivity and movement, provide access to more resources, and support larger, persistent populations of lesser prairie-chickens (Hagen et al. 2016; Sullins et al. 2018; Berigan et al. 2022, 2024). Within the lesser prairie-chicken occupied range in Kansas, croplands often near established CRP fields were targeted for future CRP enrollment (Sullins et al. 2018). Continuing to prioritize CRP enrollment in all ecoregions, specifically near the Sandhills Prairie and Sand Sagebrush Prairie in the Sand Sagebrush Prairie Ecoregion, may provide refugia for remaining lesser prairie-chickens in those areas. Similarly, in the Mixed-Grass Prairie, conversion of cropland to CRP grasslands can

connect existing habitat patches and increase available habitat. Continuous maintenance of these grasslands (i.e., woody encroachment removal) and encouragement to re-enroll once the contract expires, is important as well to manage lesser prairie-chickens effectively.

The distribution of leks within each lek attendance group (<10 , ≥ 10 , Extinct) varied among ecoregions; thus persistence of established leks and potential colonization of new leks likely varies by ecoregion due to differences in landscape factors. In the Short-Grass Prairie/CRP Mosaic Ecoregion, leks above the attendance threshold (≥ 10 males) were farther from trees compared to leks below the threshold (<10 and Extinct). This suggests that trees closer to leks may elicit avoidance behaviors, resulting in reduced attendance or lek abandonment. In the Mixed-Grass Prairie Ecoregion, the greatest density of trees was reported within 5 km of leks. Additionally, leks in this ecoregion contained the least CRP grassland within 5 km. Leks in the Sand Sagebrush Prairie Ecoregion contained the most total grassland and the second greatest amount of CRP. Factors like anthropogenic development and conversion of native grassland for agriculture are likely contributing to the declining persistence of lesser prairie-chicken populations in this ecoregion. Further, agricultural development can increase isolation of populations, resulting in localized extinction. The Short-Grass Prairie/CRP Mosaic and Sand Sagebrush Prairie ecoregions contained the most CRP grassland within 5 km of leks. The Short-Grass Prairie/CRP Mosaic Ecoregion, which has the most leks above the attendance threshold and the least Extinct leks, contained the largest proportions of CRP grassland within 5 km of leks. However, the area of CRP grassland did not differ compared to the Sand Sagebrush Prairie which has large proportion of leks that are either below the threshold or are Extinct. This suggests that while CRP grassland is important, it alone cannot facilitate lek persistence or establishment in the absence of native grassland.

Assessing landscape metrics around leks using currently established ecological thresholds that have been derived from lesser prairie-chicken movement and demographic information could further explain lek extinction and colonization. Within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions, I quantified each lek type (<10 , ≥ 10 , Extinct) and determined the proportion of each lek attendance group in each ecoregion. I identified similarities and differences in landscape condition among the three lek attendance groups, further comparing those metrics among the three ecoregions in Kansas to further understand the ecoregional differences. The Short-Grass Prairie/CRP Mosaic supported the most leks above the attendance threshold and least proportion of Extinct leks. Only 5% of leks in the Mixed-Grass Prairie Ecoregion had ≥ 10 males present, and 10% of leks in the Sand Sagebrush Prairie were above the attendance threshold. These results suggest that landscape thresholds influencing lesser prairie-chicken persistence differ among ecoregions. Therefore, implementation of management practices should be ecoregion specific to yield the most effective results and improve the persistence of the lesser prairie-chicken in Kansas.

Literature Cited

- Ahlborn, G. G. 1980. Brood-rearing habitat and fall-winter movements of lesser prairie chickens in eastern New Mexico. Thesis, New Mexico State University, Las Cruces, USA.
- Applegate, R. D., and T. Z. Riley. 1998. Lesser prairie-chicken management. *Rangelands* 20: 13–15.
- Beck, J. L. 2006. Summary of oil and natural gas development impacts on prairie grouse. Unpublished Report, Colorado Division of Wildlife, Grand Junction, Colorado, USA.
- Bell, L. A., S. D. Fuhlendorf, M. A. Patten, D. H. Wolfe, and S. K. Sherrod. 2010. Lesser prairie-chicken hen and brood habitat use on sand shinnery oak. *Rangeland Ecology and Management* 63:478–486.
- Berigan, L. A., C. S. H. Aulicky, E. C. Teige, D. S. Sullins, D. A. Haukos, K. A. Fricke, J. H. Reitz, L. G. Rossi, K. A. Shultz, and A. M. Ricketts. 2022. Availability of lesser prairie-chicken nesting habitat impairs restoration success. *Wildlife Society Bulletin* 46:e1379.

- Berigan, L. A., C. S. H. Aulicky, E. C. Teige, D. S. Sullins, K. A. Fricke, J. H. Reitz, L. G. Rossi, K. A. Shultz, M. B. Rice, E. Tanner, S. D. Fuhlendorf, and D. A. Haukos. 2024. Lesser prairie-chicken dispersal after translocation: implications for restoration and population connectivity. *Ecology and Evolution* 14:e10871.
- Bidwell, T. G., S. Fuhlendorf, B. Gillen, S. Harmon, R. Horton, R. Manes, R. Rodgers, S. Sherrod, and D. Wolfe. 2003. Ecology and management of the greater prairie-chicken in Oklahoma. Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources. Oklahoma State University, Stillwater, USA.
- Boal, C. W., and D. A. Haukos. 2016. The lesser prairie-chicken: a brief introduction to the grouse of the Southern Great Plains. Pages 1–11 *in* D. A. Haukos and C. W. Boal (editors), *Ecology and conservation of lesser prairie-chickens*. Studies in Avian Biology (no. 48), CRC Press, Boca Raton, Florida, USA.
- Courchamp F., T. Clutton-Brock, and B. Grenfell. 1999. Inverse density dependence and the Allee effect. *Trends Ecology and Evolution* 14:405–410.
- Crawford, J. A., and E. G. Bolen. 1976. Effects of land use on lesser prairie-chickens in Texas. *Journal of Wildlife Management* 40:96–104.
- Dahlgren, D. K., R. D. Rodgers, R. D. Elmore, and M. R. Bain. 2016. Grasslands of Western Kansas, North of the Arkansas River. Pages 259–279 *in* D. A. Haukos and C. W. Boal, editors. *Ecology and conservation of lesser prairie-chickens*. Studies in Avian Biology No. 48. CRC Press, Boca Raton, Florida, USA.
- DASC. 2025. Kansas Data Access and Support Center. [Kansasgis.org](https://www.kansasgis.org)
<<https://www.kansasgis.org/index.cfm>>.
- Davis, C. A., T. Z. Riley, R. A. Smith, H. R. Suminski, and M. J. Wisdom. 1979. Habitat evaluation of lesser prairie chickens in eastern Chaves County, New Mexico. Department of Fish and Wildlife Science, New Mexico Agriculture Experiment Station, Las Cruces, USA.
- Davis, D. M. 2009. Nesting ecology and preproductive success of lesser prairie-chickens in shinnery oak-dominated rangelands. *Wilson Journal of Ornithology* 121:322–327.
- Diamond, D. D., L. F. Elliott, G. Steinauer, K. Kindscher, P. Hanberry, D. True, and M. Sunde. 2021. *Ecological Systems of Kansas and Nebraska: Final Report*. Submitted to Kansas Department of Wildlife, Parks and Tourism, and Nebraska Game and Parks Commission.
- Environmental Protection Agency. 2016. Climate impacts on ecosystems. EPA.

- Fields, T.L., G. C. White, W. C. Gilgert, and R. D. Rodgers. 2006. Nest and brood survival of lesser prairie-chickens in west central Kansas. *Journal of Wildlife Management* 70:931–938.
- Garton, E. O., C. A. Hagen, G. M. Beauprez, S. C. Kyle, J. C. Pitman, D. D. Schoeling, and W. E. Van Pelt. 2016. Population dynamics of lesser prairie-chickens. Pages 49–76 in D. A. Haukos and C. W. Boal, editors. *Ecology and conservation of lesser prairie-chickens. Studies in Avian Biology* No. 48. CRC Press, Boca Raton, Florida, USA.
- Geography Realm. 2020. Universal Transverse Mercator (UTM). *Geography Realm*. Accessed 2025 Jul 22. <https://www.geographyrealm.com/universal-transverse-mercator/>.
- Giesen, K. M. 1994. Movements and nesting habitat of lesser prairie-chicken hens in Colorado. *Southwestern Naturalist* 39:96–98.
- Gilpin, M. E., and M. E. Soulé. 1986. Minimum viable populations: processes of species extinction. Pages 19–34 in M. E. Soule, editor. *Conservation biology: The science of scarcity and diversity*. Sinauer, Sunderland, Massachusetts, USA.
- Green, A.W., C. L. Aldridge, and O'donnell, M.S. 2017. Investigating impacts of oil and gas development on greater sage-grouse. *Journal of Wildlife Management* 81: 46–57.
- Grisham, B. A., P. K. Borsdorf, C. W. Boal, and K. K. Boydston. 2014. Nesting ecology and nest survival of lesser prairie-chickens on the Southern High Plains of Texas. *Journal of Wildlife Management* 78:857–866.
- Gross, A. O. 1928. The heath hen. *Memoirs of the Boston Society of Natural History* 6(4):491–588.
- Hagen, C. A., B. E. Jamison, K. M. Giesen, and T. Z. Riley. 2004. Guidelines for managing lesser prairie-chicken populations and their habitats. *Wildlife Society Bulletin* 32:69–82
- Hagen, C. A., G. C. Salter, J. C. Pitman, R. J. Robel, and R. D. Applegate. 2005. Lesser prairie-chicken brood habitat in sand sagebrush: invertebrate biomass and vegetation. *Wildlife Society Bulletin* 33:1080–1091.
- Hagen, C. A., J. C. Pitman, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2007. Age specific survival and probable causes of mortality in female lesser prairie-chickens. *Journal of Wildlife Management* 71:518–525.
- Hagen, C. A., J. C. Pitman, T. M. Loughin, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2011. Impacts of anthropogenic features on habitat use by lesser prairie-chickens. Pages 63–75 in B. K. Sandercock, K. Martin, and G. Segelbacher (editors). *Ecology, conservation, and management of grouse. Studies in Avian Biology* (39), University of California Press, Berkeley, USA.

- Hagen, C. A., B. A. Grisham, C. W. Boal, and D. A. Haukos. 2013. A meta-analysis of lesser prairie-chicken nesting and brood rearing habitats: implications for habitat management. *Wildlife Society Bulletin* 37:750–758.
- Hagen, C. A., D. C. Pavlacky, K. A. Adachi, F. E. Hornsby, T. J. Rintz, and L. L. McDonald. 2016. Multiscale occupancy modeling provides insight into range-wide conservation need of lesser prairie-chicken (*Tympanuchus pallidicinctus*). *Condor* 118:597–612.
- Haukos, D. A., and C. W. Boal. 2016. Ecology and conservation of lesser prairie-chickens. *Studies in Avian Biology* No. 48. CRC Press, Boca Raton, Florida, USA.
- Haukos, D.A., and J.C. Zavaleta. 2016. Habitat. Pages 99-132 in D.A. Haukos, and C.W. Boal (editors). *Ecology and Conservation of Lesser Prairie-Chickens. Studies in Avian Biology* (no. 48) CRC Press, Boca Raton, FL.
- Hovick, T. J., R. D. Elmore, D. K. Dahlgren, S. D. Fuhlendorf, and D. M. Engle. 2014. Evidence of negative effects of anthropogenic structures on wildlife: a review of grouse survival and behaviour. *Journal of Applied Ecology* 51:1680–9.
- Jamison, B. E., R. J. Robel, J. S. Pontius, and R. D. Applegate. 2002. Invertebrate biomass: associations with lesser prairie-chicken habitat use and sand sagebrush density in southwestern Kansas. *Wildlife Society Bulletin* 30:517–526.
- Johnson, J. A., M. A. Schroeder, and L. A. Robb. 2020. Greater prairie-chicken (*Tympanuchus cupido*) version 1.0. *in* *Birds of the world* (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithica, NY, USA. <https://doi.org/10.2173/bow.grpchi.01>
- Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 61:65–71.
- Kamm, M. 2015. The life and death of the heath hen. *Bird Observer* 43(1):9 5–14.
- Kansas Department of Labor. 2025. Kansas Counties Feature Layer. ArcGIS Online. <https://www.arcgis.com/home/item.html?id=b912469d52204af98b4a6e475253762a>
- Kansas Department of Wildlife & Parks. 2022. Kansas State Wildlife Action Plan (SWAP). Chapters 4 and 5. Kansas Department of Wildlife & Parks, Pratt, KS, USA. <https://ksoutdoors.com/Services/Kansas-SWAP>. Accessed 1 June 2025.
- Kansas Department of Wildlife and Parks. N.d. Saltcedar. <https://ksoutdoors.gov/Fishing/Aquatic-Invasive-Species/Aquatic-Invasive-Species-List/Saltcedar>. Accessed 27 January 2026.

Kansas Oil and Gas Wells Download. n.d.

<https://hub.kansasgis.org/datasets/514428df866b46c893b6834ff0bf303d_0/explore?location=37.246124,-100.285813,12.00>. Accessed 28 May 2025.

Lautenbach, J. M. 2015. Lesser prairie-chicken reproductive success, habitat selection, and response to trees. Thesis, Kansas State University, Manhattan, USA.

Lautenbach, J. M., R. T. Plumb, S. G. Robinson, C. A. Hagen, D. A. Haukos, and J. C. Pitman. 2017. Lesser prairie-chicken avoidance of trees in a grassland landscape. *Rangeland Ecology & Management* 70:78–86.

Lauver, C. L., K. Kindscher, F. L. Don, and R. Schneider. 1999. A classification of the natural vegetation of Kansas. *Southwestern Naturalist* 44:421–443.

Lehmann, V. W. 1941. Attwater's prairie-chicken, its life history and management. *North American Fauna* 57.

Lesser Prairie-Chicken Interstate Working Group (LPCIWG). 2022. Lesser prairie-chicken estimated occupied range 2022 Update. LCPIWG, Western Association of Fish and Wildlife Agencies, Boise, USA.

Lipp, T. W. 2016. Geospatial analysis of how oil and gas energy development influences lesser prairie-chicken spatial ecology in Kansas. Thesis, Bowling Green State University, Bowling Green, Ohio, USA.

Locke, B. A. 1992. Lek hypothesis and the location, dispersion, and size of lesser prairie chicken leks. Thesis. New Mexico State University, Las Cruces, USA.

Londe, D. W., R. D. Elmore, C. A. Davis, T. J. Hovick, S. D. Fuhlendorf, and J. Rutledge. 2022. Why did the chicken not cross the road? Anthropogenic development influences the movement of a grassland bird. *Ecological Applications* 32:e2543.

McDonald, L., J. Griswold, and T. Rintz. 2011. Range-wide population estimation and monitoring for lesser prairie-chickens: sampling design and pilot implementation. Western EcoSystems Technology, Inc., Cheyenne, Wyoming, USA.

McDonald, L., G. Beauprez, G. Gardner, J. Griswold, C. Hagen, D. Klute, S. Kyle, J. Pitman, T. Rintz, and B. Van Pelt. 2014. Range-wide population size of the lesser prairie-chicken: 2012 and 2013. *Wildlife Society Bulletin* 38:536–546.

McKee, G., M. R. Ryan, and L. M. Mechlin. 1998. Predicting greater prairie-chicken nest success from vegetation and landscape characteristics. *Journal of Wildlife Management* 62:314–321.

- Minnesota Department of Natural Resources. (n.d.). Greater prairie-chicken hunting.
<https://www.dnr.state.mn.us/hunting/prairiechicken/index.html>
- Morrow, M. E., R. S. Adamcik, J. D. Friday, L. B. McKinney. 1996. Factors affecting Attwater's prairie-chicken decline on the Attwater Prairie-Chicken National Wildlife Refuge. *Wildlife Society Bulletin* 24:593–601.
- Nasman, K., T. Rintz, G. DiDonato, and F. Kuzler. 2022. 2012 to 2022 Range-wide population size of the lesser prairie-chicken. Western EcoSystems Technology, Inc., Cheyenne, Wyoming, USA.
- Patten, M.A., Wolfe, D.H., Shochat, E., and S.K. Sherrod. 2005. Habitat fragmentation, rapid evolution and population persistence. *Evolutionary Ecology Research* 7: 1–15.
- Peterson, M. J. 1994. Attwater's prairie chicken limiting factors. Thesis, Texas A&M University, College Station, USA.
- Peterson, J. M., J. E. Earl, S. D. Fuhlendorf, R. D. Elmore, D. A. Haukos, A. M. Tanner, and S. A. Carlson. 2020. Estimating response distances of lesser prairie-chickens to anthropogenic features during long-distance movements. *Ecosphere* 11(9): e03202.
- Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2005. Location and success of Lesser Prairie-Chicken nests in relation to vegetation and human disturbance. *Journal of Wildlife Management* 69:1259–1269.
- Pitman, J. C. 2014. Prairie chicken lek survey: performance report, statewide wildlife research and surveys. Kansas Department of Wildlife, Parks, and Tourism. Pittman-Robertson Federal Aid in Wildlife Restoration. Grant W39- R-20, Emporia, USA.
- Plumb, R.T. 2015. Lesser prairie-chicken movement, space use, survival, and response to anthropogenic structures in Kansas and Colorado. Thesis, Kansas State University, Manhattan, USA.
- Plumb, R. T., J. M. Lautenbach, S. G. Robinson, D. A. Haukos, V. L. Winder, C. A. Hagen, D. S. Sullins, J. C. Pitman, and D. K. Dahlgren. 2019. Lesser prairie-chicken space use in relation to anthropogenic structures. *Journal of Wildlife Management* 83:216–230.
- Pruett, C. L., M. A. Patten, and D. H. Wolfe. 2009. Avoidance behavior by prairie grouse: implications for wind energy development. *Conservation Biology* 23:1253–1259.
- Raynor, E. J., C. E. Whalen, M. B. Brown, and L. A. Powell. 2017. Location matters: evaluating greater prairie-chicken (*Tympanuchus cupido*) boom-chorus propagation. *Avian Conservation and Ecology* 12(2):17.

- Riley, T. Z. 1978. Nesting and brood-rearing habitat of lesser prairie-chickens in southeastern New Mexico. M.S. thesis, New Mexico State University, Las Cruces, NM.
- Riley, T. Z., C. A. Davis, M. Ortiz, and M. J. Wisdom. 1992. Vegetative characteristics of successful and unsuccessful nests of lesser prairie-chickens.
- Riley, T. Z., C. A. Davis, M. A. Candelaria, and R. Suminski. 1994. Lesser prairie-chicken movements and home ranges in New Mexico. *Prairie Naturalist* 26:183–186.
- Robinson, S. G., D. A., Haukos, R. T. Plumb, J. D. Kraft, D. S. Sullins, J. M. Lautenbach, J. D. Lautenbach, B. K. Sandercock, C. A. Hagen, A. Bartuszevige, and M. A. Rice. 2018. Effects of landscape characteristics on annual survival of lesser prairie-chickens. *American Midland Naturalist* 180:66–86.
- Rodgers, R. D. 2016. A history of lesser prairie-chickens. Pages 15–38 *in* D. A. Haukos and C. W. Boal (editors), *Ecology and conservation of lesser prairie-chickens*. Studies in Avian Biology (no. 48), CRC Press, Boca Raton, Florida, USA.
- Ross, B. E., D. A. Haukos, C. A. Hagen, and J. C. Pitman. 2016. Landscape composition creates a threshold influencing lesser prairie-chicken population resilience to extreme drought. *Global Ecology and Conservation* 6:179–188.
- Sandercock, B. K., K. Martin, and G. Segelbacher (editors). *Ecology, conservation, and management of grouse*. Studies in Avian Biology (no. 39), University of California Press, Berkeley, USA.
- Seal, U.S. 1994. Attwater's prairie chicken population and habitat viability assessment. Captive Breeding Specialist Group, Apple Valley, Minnesota, USA.
- Sell, D. L. 1979. Spring and summer movements and habitat use by lesser prairie chickens in Yoakum County, Texas. Thesis. Texas Tech University, Lubbock, USA.
- Silber, K. M., T. J. Hefley, H. N. Castro-Miller, Z. Ratajczak, and W. A. Boyle. 2024. The long shadow of woody encroachment: An integrated approach to modeling grassland songbird habitat. *Ecological Applications* 34:e2954.
- Smith, J. A. C. E. Whalen, M. B. Brown, and L. A. Powell. 2016. Indirect effects of an existing wind energy facility on lekking behavior of greater prairie-chickens. *Ethology* 122:419–429.
- Spencer, D., D. A. Haukos, C. A. Hagen, M. Daniels, and D. Goodin. 2017. Conservation reserve program mitigates grassland loss in the lesser prairie-chicken range of Kansas. *Global Ecology and Conservation* 9:21–38.

- Stevens, B.S., Connelly, J.W. and K. P. Reese. 2012. Multi-scale assessment of greater sage-grouse fence collision as a function of site and broad scale factors. *The Journal of Wildlife Management*, 76: 1370-1380.
- Stewart, D. R., S. E. Lehnen, J. A. Moon, S. E. Sesnie, B. E. Burrows, M. A. Kalisek, B. M. Breske, B. R. Sicich, M. F. Small, L. J. Carnes, A. J. Cooper, D. W. Londe, M. J. Butler, J. M. Mueller, and G. M. Harris. 2026. A hierarchical analysis of lek counts: environmental drivers of abundance for an endangered grassland bird. *Journal of Wildlife Management* 90:70148.
- Sullins, D. S., J. D. Kraft, D. A. Haukos, S. G. Robinson, J. H. Reitz, R. T. Plumb, J. M. Lautenbach, J. D. Lautenbach, B. K. Sandercock, and C. A. Hagen. 2018. Demographic consequences of conservation reserve program grasslands for lesser prairie-chickens. *Journal of Wildlife Management* 82:1617–1632.
- Sullins, D. S., D. A. Haukos, J. M. Lautenbach, J. D. Lautenbach, S. G. Robinson, M. B. Rice, B. K. Sandercock, J. D. Kraft, R. T. Plumb, J. H. Reitz, J. M. S. Hutchinson, and C. A. Hagen. 2019. Strategic conservation for lesser prairie-chickens among landscapes of varying anthropogenic influence. *Biological Conservation* 238:108213.
- Sutton Avian Research Center, n.d. Attwater's Prairie-Chicken.
<https://www.suttoncenter.org/conservation/saving-species/attwaters-prairie-chicken/>
- Svedarsky, W. D., R. L. Westemeier, R. J. Robel, S. Gough, and J. E. Toepfer. 2000. Status and management of the greater prairie-chicken *Tympanuchus cupido pinnatus* in North America. *Wildlife Biology* 6:277–284.
- Svedarsky, W. D., J. E. Toepfer, R. L. Westemeier, R. J. Robel, L. D. Igl, and J. A. Shaffer. 2022. The effects of management practices on grassland birds—greater prairie-chicken (*Tympanuchus cupido pinnatus*). Chap. C in Johnson, D. H., L. D. Igl, J. A. Shaffer, and J. P. DeLong (editors). *The effects of management practices on grassland birds*. U.S. Geological Survey (no. 1842).
- Taylor, M. A. 1979. Lesser prairie chicken use of man-made leks. *Southwest Naturalist* 24:706–707.
- Twidwell, D., W. E. Rogers, S. D. Fuhlendorf, C. L. Wonkka, D. M. Engle, J. R. Weir, U. P. Kreuter, and C. A. Taylor Jr. 2013. The rising Great Plains fire campaign: citizens' response to woody plant encroachment. *Frontiers in Ecology and the Environment* 11:64–71.
- Twidwell, D., A. S. West, W. B. Hiatt, A. L. Ramirez, J. T. Winter, D. M. Engle, S. D. Fuhlendorf, and J. D. Carlson. 2015. Plant invasions or fire policy: which has altered fire behavior more in the tallgrass prairie? *Ecosystems* 19:356–368.
- U.S. Department of Homeland Security [DHS]. Homeland infrastructure foundation-level data. Transmission lines. <https://hifld-geoplatform.hub.arcgis.com/datasets/>

bd24d1a282c54428b024988d32578e59_0/explore?location=38.447254%2C-98.278099%2C7.13. Accessed 25 May 2025.

- U.S. Fish and Wildlife Service. N.d. Attwater's greater prairie chicken. U.S. Fish & Wildlife Service. <https://www.fws.gov/species/attwaters-greater-prairie-chicken-tympanuchus-cupido-attwateri>
- U.S. Fish and Wildlife Service. 2003. Conservation Banking. <https://www.fws.gov/service/conservation-banking>
- U.S. Fish and Wildlife Service. 2022. Endangered and Threatened Wildlife and Plants; Lesser Prairie-Chicken; Threatened Status with Section 4(d) Rule for the Northern Distinct Population Segment and Endangered Status for the Southern Distinct Population Segment. <https://www.fws.gov/species-publication-action/endangered-and-threatened-wildlife-and-plants-lesser-prairie-chicken-1>
- U.S. Wind Turbine Database. 2016. Usgs.gov. <https://energy.usgs.gov/uswtodb/>
- Vhay, M.P. 2022. Retrospective assessment of lesser prairie-chicken habitat in the sand sagebrush prairie ecoregion. Thesis, Kansas State University, Manhattan, USA.
- Vhay, M. P., D. A. Haukos, D. S. Sullins, and M. B. Rice. 2024. Broad-scale changes in lesser prairie-chicken habitat. PLoS ONE 19(5):e0304452.
- Wolfe, D. H., M. A. Patten, E. Shochat, C. L. Pruett, and S. K. Sherrod. 2007. Causes and patterns of mortality in lesser prairie-chickens (*Tympanuchus pallidicinctus*) and implications for management. Wildlife Biology 13:95–104.

Tables

Table 2.1. Identified landscape thresholds associated with lesser prairie-chicken (LEPC) persistence within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA.

Variable	Threshold	References
Grassland	Restricted to areas with $\geq 60\%$ native grassland	Crawford and Bolen 1976
	$\geq 77\%$ native grassland and contiguous patches of native grassland at 5-km radius scale (7,854 ha)	Sullins et al. 2018
CRP	As CRP in a 57-km ² (5,626 ha) area exceeds 20%, the likelihood of LEPC occupying that landscape increases	Hagen et al. 2016
Cropland	Below 1:10 ratio cropland:grassland <40% cropland for persistence	Ross et al. 2016
Trees	$\geq 2/\text{ha}$ - avoid nesting $\geq 8/\text{ha}$ - complete avoidance	Lautenbach et al. 2017
Anthropogenic Structures	Display avoidance at 2 vertical structures Decreased probability of use with 2 structures/12.6 km ² (County/paved roads, oil/gas wells, cellular towers, wind turbines, transmission lines)	Plumb et al. 2019 Sullins et al. 2019
Lek Attendance	Leks with <10 birds (males) present at the lek have a high probability of extinction within 5 years, while leks above this threshold (≥ 10) will persist	Whetten et al. <i>In Review</i>

Table 2.2. Total number (%) of lesser prairie-chicken leks evaluated for status relative to established landscape thresholds in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, within each lek attendance group. Leks were grouped based on average male attendance during 2018-2023.

Ecoregion ^a	Lek Attendance Group			Total
	<10 Bird	≥10 Bird	Extinct	
SGPR/CRP	39 (34.2%)	45 (39.5%)	30 (26.3%)	114 (34.0%)
MGPR	32 (30.2%)	6 (5.7%)	68 (64.2%)	106 (31.6%)
SSPR	49 (42.6%)	12 (10.4%)	54 (47%)	115 (34.3%)

^a SGPR/CRP = Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion; MGPR = Mixed-Grass Prairie Ecoregion; SSPR = Sand Sagebrush Prairie Ecoregion

Table 2.3. Comparison of average area (ha $\pm$ SE) of native grassland, CRP grassland, total grassland, and cropland within a 5-km (7,854 ha) buffer around surveyed leks ($n = 335$) among the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.

Ecoregion*	Native Grassland	CRP Grassland	Total Grassland	Cropland
SGPR/CRP	4,215.87 ^a $\pm$ 86.73	1,329.20 ^a $\pm$ 91.47	5,545.08 ^a $\pm$ 70.67	2,060.72 ^a $\pm$ 72.88
MGPR	4,586.34 ^{ab} $\pm$ 134.76	581.06 ^b $\pm$ 42.83	5,167.40 ^b $\pm$ 126.48	1,680.46 ^b $\pm$ 151.12
SSPR	4,698.92 ^b $\pm$ 143.22	1,159.60 ^a $\pm$ 95.42	5,858.52 ^c $\pm$ 107.32	1,584.80 ^b $\pm$ 96.61

*SGPR/CRP = Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion; MGPR = Mixed-Grass Prairie Ecoregion; SSPR = Sand Sagebrush Prairie Ecoregion

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.4. The average area (ha $\pm$ SE) of Conservation Reserve Program grasslands within a 4.23-km radius (5,621 ha) for surveyed leks ($n = 335$) in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.

Ecoregion*	CRP (ha)	# of CRP fields	Distance to nearest field
SGPR/CRP	975.56 ^a $\pm$ 67.54	29.88 $\pm$ 1.25	0.71 $\pm$ 0.08
MGPR	428.47 ^b $\pm$ 33.95	18.07 $\pm$ 1.72	1.78 $\pm$ 0.18
SSPR	829.80 ^a $\pm$ 77.05	15.85 $\pm$ 1.48	2.17 $\pm$ 0.20

* SGPR/CRP = Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion; MGPR = Mixed-Grass Prairie Ecoregion; SSPR = Sand Sagebrush Prairie Ecoregion

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.5. The average count ($\pm$ SE) of trees per hectare and distance (km) to nearest tree within a 5-km (7,854 ha) buffer around surveyed leks ($n = 335$) in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.

Ecoregion*	Trees (per ha)	Distance to nearest tree (km)
SGPR/CRP	1.26 ^a $\pm$ 0.10	0.88 ^a $\pm$ 0.04
MGPR	1.62 ^b $\pm$ 0.11	0.54 ^b $\pm$ 0.03
SSPR	0.38 ^c $\pm$ 0.04	1.87 ^c $\pm$ 0.07

* SGPR/CRP = Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion; MGPR = Mixed-Grass Prairie Ecoregion; SSPR = Sand Sagebrush Prairie Ecoregion

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.6. The proportion of lesser prairie-chicken leks containing individual cellular towers, individual wind turbines, and oil/gas wells within a 5-km (7,854 ha) buffer around surveyed leks ($n = 335$) in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023.

Ecoregion^a	Total Leks	Cellular Towers	Wind Turbines	Oil/Gas Wells
SGPR/CRP	114	0.16	0.04	1
MGPR	106	0.07	0.04	1
SSPR	115	0.18	0	1

^a SGPR/CRP = Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion; MGPR = Mixed-Grass Prairie Ecoregion; SSPR = Sand Sagebrush Prairie Ecoregion

Table 2.7. The average length (km $\pm$ SE) of paved/gravel roads and transmission lines, average distance (km $\pm$ SE) to the nearest paved/gravel road, transmission line, CRP field, and number of CRP fields within 5-km (7,854 ha) of each lek in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas.

Ecoregion^a	Length of roads	Distance to road	Length of transmission lines	Distance to transmission line	# of CRP fields	Distance to nearest field
SGPR/CRP	66.91 $\pm$ 1.82	0.54 $\pm$ 0.04	1.58 $\pm$ 0.32	9.47 $\pm$ 0.47	39.68 $\pm$ 1.50	0.71 $\pm$ 0.08
MGPR	71.45 $\pm$ 1.68	0.49 $\pm$ 0.03	1.81 $\pm$ 0.44	9.62 $\pm$ 0.51	23.47 $\pm$ 2.10	1.78 $\pm$ 0.18
SSPR	53.88 $\pm$ 2.23	0.81 $\pm$ 0.05	7.10 $\pm$ 1.39	7.89 $\pm$ 0.41	22.20 $\pm$ 1.80	2.17 $\pm$ 0.20

^a SGPR/CRP = Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion; MGPR = Mixed-Grass Prairie Ecoregion; SSPR = Sand Sagebrush Prairie Ecoregion

Table 2.8. The average (ha $\pm$ SE) of native grassland, CRP grassland, total grassland, and cropland within a 5-km (7,854 ha) buffer around surveyed leks (n = 114) in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA, during 2018-2023.

Lek Attendance Group	Native Grassland	CRP Grassland	Total Grassland	Cropland
<10 Bird	4,316.41 ^a $\pm$ 144.46	1,138.44 ^a $\pm$ 149.54	5,454.85 ^a $\pm$ 114.31	2,182.28 ^a $\pm$ 117.62
>10 Bird	4,076.06 ^a $\pm$ 125.39	1,387.12 ^a $\pm$ 153.31	5,463.18 ^a $\pm$ 122.07	2,107.20 ^a $\pm$ 126.06
Extinct	4,294.89 ^a $\pm$ 195.87	1,490.32 ^a $\pm$ 172.10	5,785.21 ^a $\pm$ 123.24	1,833.01 ^a $\pm$ 127.85

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.9. The average area (ha $\pm$ SE) of Conservation Reserve Program grasslands within a 4.23-km radius (5,621 ha) for surveyed lesser prairie-chicken leks ($n = 114$) in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA.

Lek Attendance Group	CRP (ha)	# of CRP fields	Distance to nearest field
<10 Bird	592.03 ^a $\pm$ 112.83	27.26 ^a $\pm$ 2.42	0.79 ^a $\pm$ 0.17
>10 Bird	1,019.52 ^a $\pm$ 109.01	31.89 ^a $\pm$ 1.91	0.69 ^a $\pm$ 0.10
Extinct	1,107.06 ^a $\pm$ 130.74	30.27 ^a $\pm$ 2.08	0.61 ^a $\pm$ 0.16

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.10. The average count ($\pm$ SE) of trees per hectare and distance (km) to nearest tree within a 5-km (7,854 ha) buffer around surveyed leks in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA, during 2018-2023.

Lek Attendance Group	Trees (per ha)	Distance to nearest tree (km)
<10 Bird	1.31 ^a $\pm$ 0.19	0.82 $\pm$ 0.07 ^{ab}
>10 Bird	1.24 ^a $\pm$ 0.18	1.05 $\pm$ 0.08 ^a
Extinct	1.23 ^a $\pm$ 0.20	0.40 $\pm$ 0.09 ^b

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.11. The average length (km $\pm$ SE) of paved/gravel roads and transmission lines, average distance (km $\pm$ SE) to the nearest paved/gravel road, transmission line within, CRP field, and number of CRP fields within 5-km (7,854 ha) of each lek ($n = 114$) in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA during 2018-2023.

Lek Attendance Group	Length of roads	Distance to road	Length of transmission lines	Distance to transmission line	# of CRP fields	Distance to nearest CRP field
<10 Bird	72.06 $\pm$ 3.23	0.42 $\pm$ 0.05	2.35 $\pm$ 0.70	8.34 $\pm$ 0.74	36.21 ^a $\pm$ 2.84	0.79 ^a $\pm$ 0.17
>10 Bird	62.40 $\pm$ 2.81	0.60 $\pm$ 0.06	1.24 $\pm$ 0.44	10.97 $\pm$ 0.85	41.56 ^a $\pm$ 2.25	0.69 ^a $\pm$ 0.10
Extinct	66.99 $\pm$ 3.37	0.28 $\pm$ 0.07	1.09 $\pm$ 0.47	3.36 $\pm$ 0.75	41.30 ^a $\pm$ 2.43	0.61 ^a $\pm$ 0.16

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.12. The average (ha $\pm$ SE) of native grassland, CRP grassland, total grassland, and cropland within a 5-km (7,854 ha) buffer around surveyed leks ($n = 106$) in the Mixed-Grass Prairie Ecoregion in Kansas, USA, during 2018-2023.

Lek Attendance Group	Native Grassland	CRP Grassland	Total Grassland	Cropland
<10 Bird	4,414.46 ^a $\pm$ 278.59	611.40 ^a $\pm$ 77.10	5,025.85 ^a $\pm$ 270.20	2,072.50 ^a $\pm$ 316.78
>10 Bird	4,592.41 ^a $\pm$ 794.92	678.60 ^a $\pm$ 114.34	5,271.00 ^a $\pm$ 748.16	2,371.15 ^a $\pm$ 769.90
Extinct	4,666.69 ^a $\pm$ 151.65	558.20 ^a $\pm$ 55.50	5,224.86 ^a $\pm$ 138.90	1,435.01 ^a $\pm$ 165.62

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.13. The average area (ha $\pm$ SE) of Conservation Reserve Program grasslands within a 4.23-km radius (5,621 ha) for surveyed lesser prairie-chicken leks ($n = 106$) in the Mixed-Grass Prairie Ecoregion in Kansas, USA.

Lek Attendance Group	CRP (ha)	# of CRP fields	Distance to nearest field
<10 Bird	476.38 ^a $\pm$ 63.00	18.66 $\pm$ 3.05	1.92 $\pm$ 0.40
$\geq$ 10 Bird	469.03 ^a $\pm$ 87.49	13.00 $\pm$ 2.62	1.29 $\pm$ 0.43
Extinct	402.35 ^a $\pm$ 43.28	18.24 $\pm$ 2.27	1.76 $\pm$ 0.21

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.14. The average count ($\pm$ SE) of trees per hectare and distance (km) to nearest tree within a 5-km (7,854 ha) buffer around surveyed leks in the Mixed-Grass Prairie Ecoregion in Kansas, USA, during 2018-2023.

Lek Attendance Group	Trees (per ha)	Distance to nearest tree (km)
<10 Bird	1.80 ^b $\pm$ 0.20	0.59 ^a $\pm$ 0.05
$\geq$ 10 Bird	0.55 ^a $\pm$ 0.19	0.68 ^a $\pm$ 0.15
Extinct	1.64 ^b $\pm$ 0.14	0.49 ^a $\pm$ 0.04

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.15. The average length (km $\pm$ SE) of paved/gravel roads and transmission lines, average distance (km $\pm$ SE) to the nearest paved/gravel road, transmission line within, CRP field, and number of CRP fields within 5-km (7,854 ha) of each lek ($n = 106$) in the Mixed-Grass Prairie Ecoregion in Kansas, USA during 2018-2023.

Lek Attendance Group	Length of roads	Distance to road	Length of transmission lines	Distance to transmission line	# of CRP fields	Distance to nearest CRP field
<10 Bird	73.35 $\pm$ 3.93	0.48 $\pm$ 0.07	3.36 $\pm$ 1.01	8.17 $\pm$ 1.08	24.09 ^a $\pm$ 3.60	1.90 ^a $\pm$ 0.40
$\geq$ 10 Bird	81.83 $\pm$ 4.05	0.34 $\pm$ 0.16	4.97 $\pm$ 2.69	4.80 $\pm$ 0.72	25.83 ^a $\pm$ 9.37	1.30 ^a $\pm$ 0.40
Extinct	69.64 $\pm$ 1.79	0.51 $\pm$ 0.04	0.81 $\pm$ 0.38	10.74 $\pm$ 0.56	23.5 ^a $\pm$ 2.70	1.80 ^a $\pm$ 0.20

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.16. The average (ha $\pm$ SE) of native grassland, CRP grassland, total grassland, and cropland within a 5-km (7,854 ha) buffer around surveyed leks ($n = 115$) in the Sand Sagebrush Prairie Ecoregion in Kansas, USA, during 2018-2023.

Lek				
Attendance	Native	CRP	Total	
Group	Grassland	Grassland	Grassland	Cropland
<10 Bird	3,813.75 ^{ab} $\pm$ 217.74	1,257.00 ^a $\pm$ 196.86	5,070.74 ^{ab} $\pm$ 163.60	2,278.94 ^a $\pm$ 143.28
$\geq$ 10 Bird	4,296.64 ^a $\pm$ 545.77	1,528.24 ^a $\pm$ 247.97	5,824.87 ^a $\pm$ 342.57	1,568.84 ^{ab} $\pm$ 350.43
Extinct	5,591.54 ^b $\pm$ 110.15	989.30 ^a $\pm$ 75.82	6,580.83 ^b $\pm$ 69.80	958.49 ^b $\pm$ 67.60

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.17. The average area (ha $\pm$ SE) of Conservation Reserve Program grasslands within a 4.23-km radius (5,621 ha) for surveyed lesser prairie-chicken leks ($n = 115$) in the Sand Sagebrush Prairie Ecoregion in Kansas, USA.

Lek Attendance Group	CRP (ha)	# of CRP fields	Distance to nearest field
<10 Bird	960.27 ^a $\pm$ 154.91	17.57 $\pm$ 3.16	3.06 $\pm$ 0.41
$\geq$ 10 Bird	1,098.37 ^a $\pm$ 207.93	19.58 $\pm$ 3.79	1.22 $\pm$ 0.38
Extinct	651.71 ^a $\pm$ 65.49	13.46 $\pm$ 0.97	1.58 $\pm$ 0.14

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.18. The average count ($\pm$ SE) of trees per hectare and distance (km) to nearest tree within a 5-km (7,854 ha) buffer around surveyed leks in the Sand Sagebrush Ecoregion in Kansas, USA, during 2018-2023.

Lek Attendance Group	Trees (per ha)	Distance to nearest tree (km)
<10 Bird	0.19 ^a $\pm$ 0.04	1.73 ^a $\pm$ 0.09
$\geq$ 10 Bird	0.26 ^a $\pm$ 0.12	2.27 ^a $\pm$ 0.25
Extinct	0.57 ^b $\pm$ 0.07	1.91 ^a $\pm$ 0.11

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Table 2.19. The average length (km $\pm$ SE) of paved/gravel roads and transmission lines, average distance (km $\pm$ SE) to the nearest paved/gravel road, transmission line within, CRP field, and number of CRP fields within 5-km (7,854 ha) of each lek ($n = 115$) in the Sand Sagebrush Prairie Ecoregion in Kansas, USA during 2018-2023.

Lek Attendance Group	Length of roads	Distance to road	Length of transmission lines	Distance to transmission line	# of CRP fields	Distance to nearest field
<10 Bird	57.91 $\pm$ 3.44	0.79 $\pm$ 0.07	16.27 $\pm$ 2.76	5.42 $\pm$ 0.69	23.16 $\pm$ 3.96	3.06 ^a $\pm$ 0.41
$\geq$ 10 Bird	43.08 $\pm$ 6.07	1.57 $\pm$ 0.27	0.67 $\pm$ 0.67	12.14 $\pm$ 1.06	26.58 $\pm$ 4.86	1.22 ^a $\pm$ 0.38
Extinct	52.62 $\pm$ 3.25	0.67 $\pm$ 0.05	0.20 $\pm$ 0.09	9.19 $\pm$ 0.35	20.39 $\pm$ 1.07	1.58 ^a $\pm$ 0.14

^{a,b} Means with the same lowercase letter do not differ ($P > 0.05$)

Figures

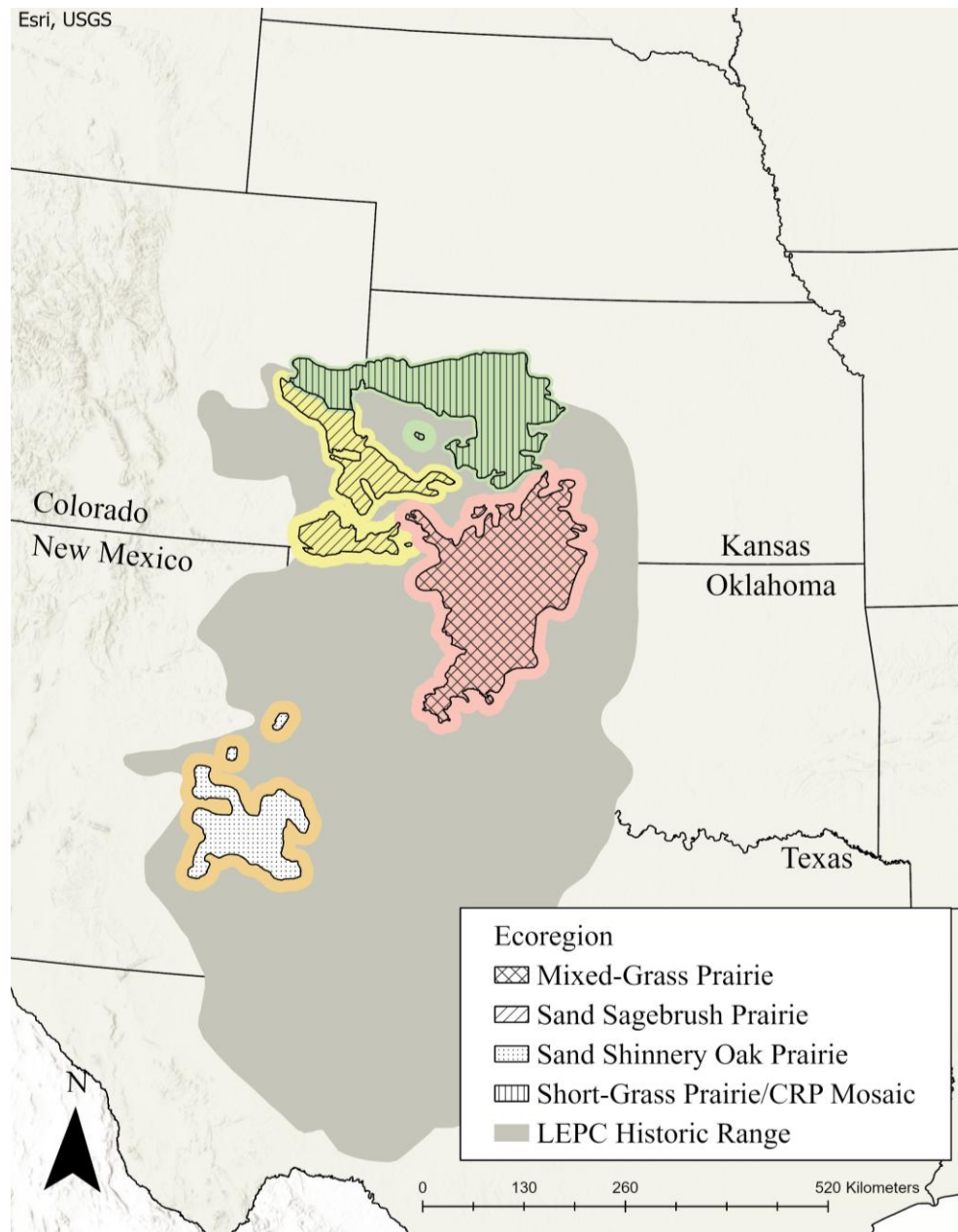


Figure 2.1. The four defined ecoregions in lesser prairie-chicken occupied range in Kansas, Colorado, Oklahoma, New Mexico, and Texas, USA.

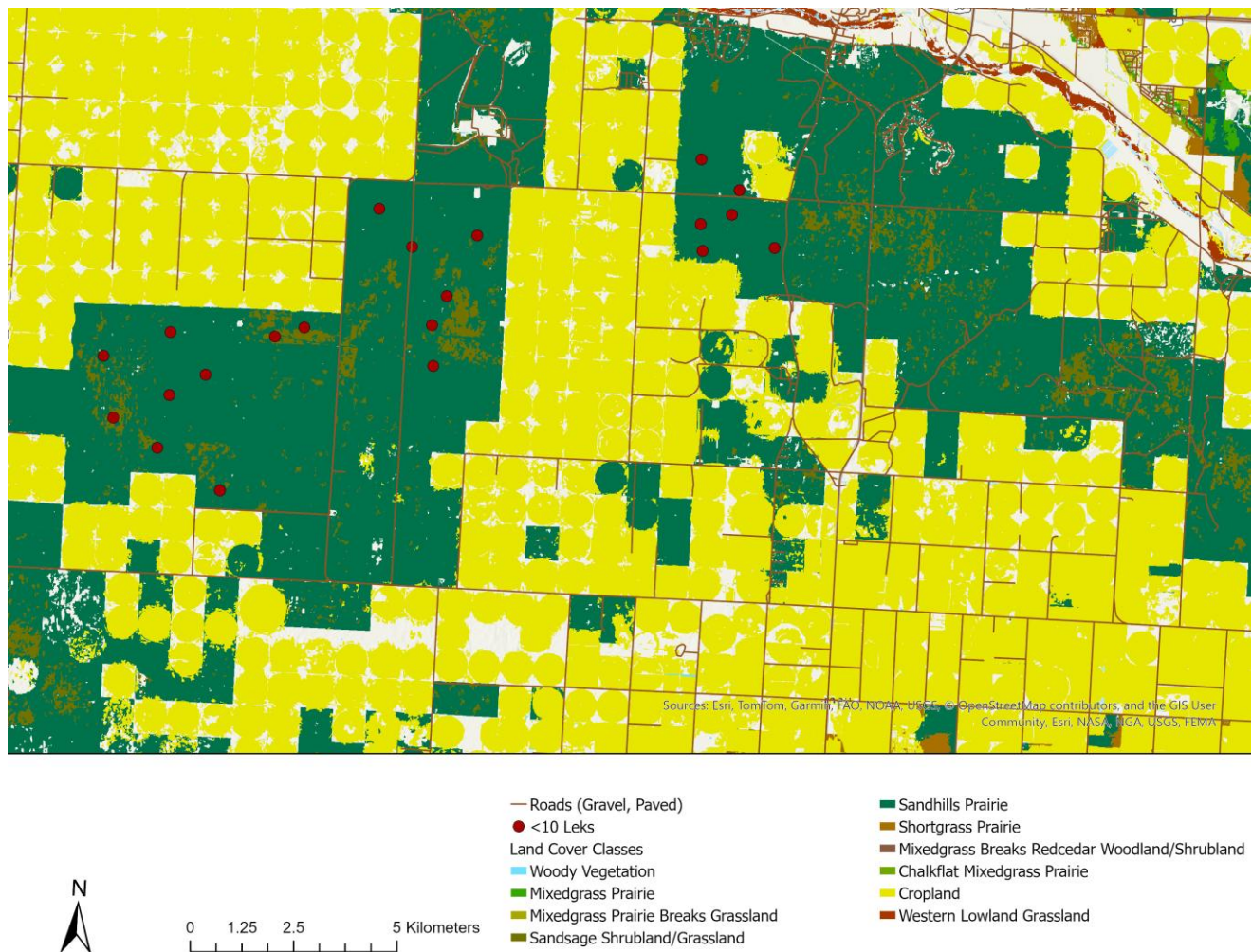


Figure 2.2. Example of land cover variables (native grassland, cropland, woody vegetation, anthropogenic features) measured within 5 km of each lesser prairie-chicken lek in the Sand Sagebrush Prairie Ecoregion in Kansas, USA, during 2018-2022. Leks below the lek attendance threshold of 10 males (<10), represented by the red points, were surrounded by cropland, woody vegetation, and gravel/paved roads.

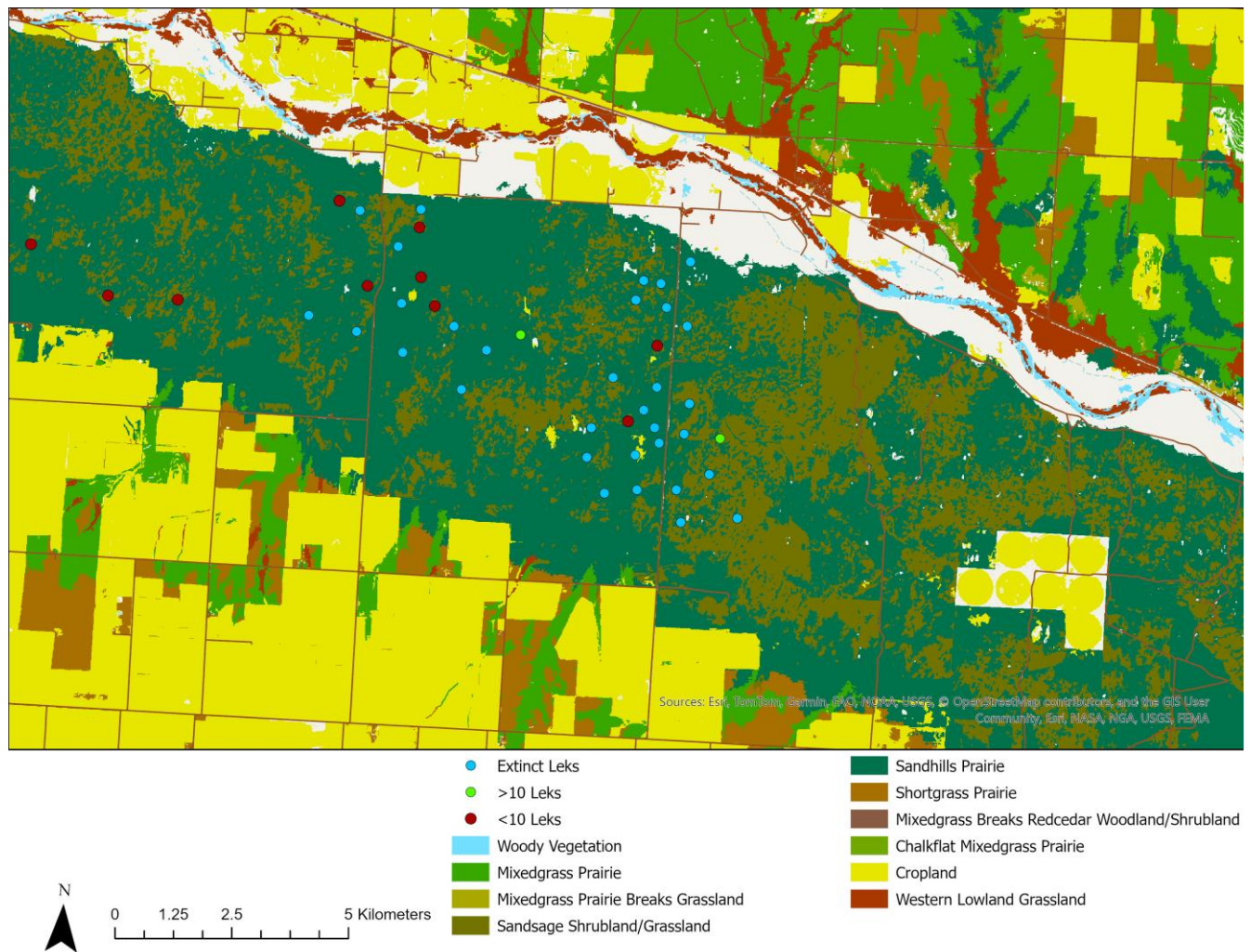


Figure 2.3. Example of land cover variables (native grassland, cropland, woody vegetation, anthropogenic features) measured within 5 km of each lesser prairie-chicken lek in the Sand Sagebrush Prairie Ecoregion in Kansas, USA, during 2018-2023. Extinct leks, represented by the light blue points, were surrounded by cropland, woody vegetation, and gravel/paved roads. Additionally, only two leks above the lek attendance threshold of 10 males (≥ 10) were observed in this portion of the Sand Sagebrush Prairie Ecoregion.

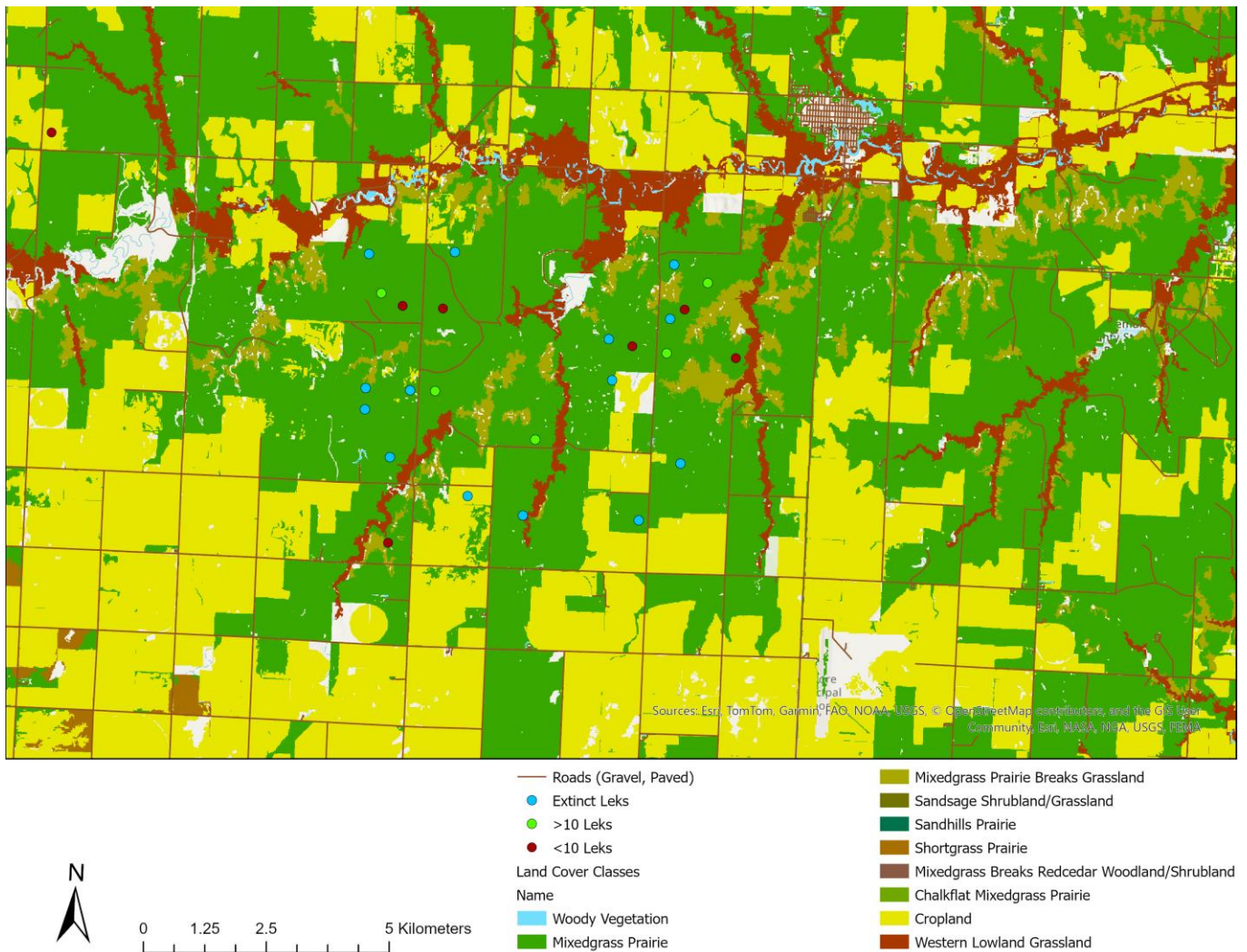


Figure 2.4. Example of land cover variables (native grassland, cropland, woody vegetation, anthropogenic features) measured within 5 km of each lesser prairie-chicken lek in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA, during 2018-2023. Leks with <10 males, ≥ 10 males, and Extinct leks were surrounded by cropland, woody vegetation, and gravel/paved roads.

Chapter 3 - Determining Status of Lesser Prairie-Chicken Leks in Kansas Relative to Ecological Thresholds

Introduction

Prairie grouse are crucial indicators of the health of prairie ecosystems. They aid in sustaining ecological balance by relying on large, intact grassland landscapes with a wide variety of native plants and insects; thus, serving as umbrella species of prairie loss, degradation, or recovery. During the past century, several species of prairie grouse in North America such as the extinct heath hen (*Tympanuchus cupido cupido*), greater prairie-chicken (*T. c. pinnatus*), endangered Attwater's prairie-chicken (*T. c. attwateri*), and lesser prairie-chicken (*T. pallidicinctus*) have suffered extensive habitat loss and degradation, reduced occupied range, and population declines. Ecological and anthropogenic factors such as changes in disturbance regimes, woody encroachment, conversion of grassland for agriculture, disease, overharvest, herbicide/pesticide use, and energy development are contributing to these population and habitat declines (Gross 1928; Svedarsky et al. 2000; Bidwell et al. 2003; Kamm 2015; Rodgers 2016; Lautenbach et al. 2017; Spencer et al. 2017). Concern for the status of the lesser prairie-chicken has been on-going for several decades (Boal and Haukos 2016). However, recent regulatory actions related to the 1973 Endangered Species Act have elevated those concerns to development of management strategies to conserve the lesser prairie-chicken.

Initial conservation efforts involved delineating four ecoregions in 2012 describing the occupied area of lesser prairie-chickens: Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic, Mixed-Grass Prairie, Sand Sagebrush Prairie, and Sand Shinnery Oak Prairie (Figure 2.1; McDonald et al. 2014). These ecoregions span the southwestern Great Plains across Texas, New Mexico, Oklahoma, Colorado, and Kansas, USA. The Sand Shinnery Oak Prairie

Ecoregion is restricted to northwest Texas and eastern New Mexico, whereas the remaining ecoregions occur wholly or partially within Kansas. However, historical occupancy of these ecoregions differs across the species' range as lesser prairie-chickens did not occupy the Short-Grass Prairie/CRP Mosaic Ecoregion north of the Arkansas River until the mid- to late-1990s (Rodgers 2016). These ecoregions have served as the basis for contemporary population monitoring and implementation of established management plans.

Following the extensive, intensive drought of the 1950s in the Great Plains, population estimates throughout the lesser prairie-chicken occupied range reported stable numbers with ~150,000 birds during the 1960s-1980s (Garton et al. 2016). Unfortunately, following a contemporary peak in abundance during the mid-late 1980s, a steep range-wide decline through the mid 1990s dropped to ~25,000 birds by approximately 1995. Populations increased to ~80,000 birds by 2008 but dipped again to ~37,000 birds in 2012 (Garton et al. 2016). A decade later, aerial surveys estimated ~26,591 birds, with >90% of extant lesser prairie-chickens occurring in Kansas (Nasman et al. 2022). Based on the most recent range-wide population survey, the Short-Grass Prairie/CRP Mosaic Ecoregion has become the species stronghold, supporting >70% of extant lesser prairie-chickens, with an estimated 19,847 individuals (Nasman et al. 2022). Populations in the Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions were much smaller with an estimated 4,512 and 1,713 individuals, respectively, and the Sand Shinnery Oak Prairie Ecoregion supported approximately 519 individuals (Nasman et al. 2022). There has not been a range-wide population estimate since 2022.

Lesser prairie-chickens and other prairie grouse require large, contiguous grassland landscapes for population persistence and resilience, which serve as foundational components for research and conservation efforts (Haukos and Zavaleta 2016; Maestas et al. 2022; Boyd et al.

2024). Populations of lesser prairie-chickens in Texas are restricted to landscapes with $\geq 60\%$ native grassland (Crawford and Bolen 1976). In Kansas, lesser prairie-chickens are constrained to areas with $>70\%$ grasslands within a 5-km radius with the probability of use of an area greatest at $\geq 77\%$ native grassland with contiguous patches of grassland (Sullins et al. 2018). Although similar to other grouse species (e.g., greater prairie-chicken), lesser prairie-chickens will use cropland for food resources, grasslands are critical for each life stage of lesser prairie-chickens, providing required cover to meet life history requirements, food resources, protection from predators, and can improve population resilience to intensive drought (Crawford and Bolen 1976; Ross et al. 2016; Sullins et al. 2018).

However, lesser prairie-chicken habitat requirements within grassland landscapes vary among life stages (e.g., breeding, brood-rearing, nonbreeding). For example, ideal lek locations have short or lack vegetation with good visibility at sites of relatively high elevation (Bidwell et al. 2003). Nest-site characteristics consist of selection for greater visual obstruction, horizontal cover, residual grass cover, and litter cover than available (Riley 1978; Riley et al. 1992; Giesen 1994; Pitman et al. 2005; Davis 2009; Hagen et al. 2013; Grisham et al. 2014). Brood-rearing habitat is characterized by sparse and short vegetation to allow for chick movement (Haukos and Zavaleta 2016). Additionally, female lesser prairie-chickens with broods often select areas that have greater food resources and thermoregulatory capacity (e.g., forb-dominated patches; Jamison et al. 2002; Hagen et al. 2005; Bell et al. 2010). To close out the annual life cycle, lesser prairie-chickens require denser grass cover during winter, with grasslands used for roosting and loafing and grain fields for foraging (Hagen et al. 2004; Haukos and Zavaleta 2016).

Many lesser prairie-chicken populations are limited by the lack of available vegetation composition and structure to meet habitat needs during some or all of their life cycle. Grassland

restoration and altering land use practices can serve to produce the necessary vegetation heterogeneity across landscapes to ensure population resilience and colonization. From European settlement through establishment of the U.S. Department of Agriculture Conservation Reserve Program (CRP) in 1985, lesser prairie-chicken habitat consisted of mixed-grass prairie and tall and mixed-grasses within sand sagebrush (*Artemisia filifolia*) and sand-shinnery oak (*Quercus havardii*) prairies in western portions of the species range. These landcover types were primarily associated with sandy soils within the short-grass prairie matrix of the High Plains region of the southwestern Great Plains (Boal and Haukos 2016). Within the Mixed-Grass Prairie Ecoregion, lesser prairie-chickens were historically associated with heterogeneous prairie landscapes characterized by perennial grasses intermixed with sand sagebrush and other shrubs on sandy or loamy soils (Dhillon et al. 1994). The CRP focused on soil conservation by initially planting perennial introduced (New Mexico, Texas, and Oklahoma) and native (Kansas and Colorado) mid- and tall grasses on highly erodible soils in exchange for annual rental payments. However, lesser prairie-chicken populations quickly responded positively to the establishment of CRP throughout the species range. Most dramatically, availability of reliable mid- and tall-grass cover in the Short-Grass Prairie/CRP Mosaic Ecoregion north of the Arkansas River in Kansas facilitated expansion of lesser prairie-chicken occupied range and increased population abundance in previously unoccupied or low population density landscapes (Dahlgren et al. 2016; Sullins et al. 2018).

Lesser prairie-chickens most likely use CRP grasslands when landscapes are ~77% native prairie and where CRP fields are in areas of contiguous patches of native grassland (Sullins et al. 2018). On a different scale, as the percentage of CRP enrolled in a 57-km² area exceeds 20%, the likelihood of lesser prairie-chickens occupying that landscape increases (Hagen et al. 2016). In

the High Plains of Texas, lesser prairie-chickens selected CRP fields with non-native grasses and native grasses with forbs year-round, while row-crop agriculture and native grassland were avoided (Harryman et al. 2019). In the western portion of their occupied range, CRP grasslands disproportionally support lesser prairie-chickens during nesting and roosting periods (Sullins et al. 2018; Berigan et al. 2022). In the Sand Sagebrush Prairie Ecoregion, translocated lesser prairie-chickens selected CRP grasslands at the end of dispersal steps post-release (Berigan et al. 2024). Further, translocated lesser prairie-chickens in Kansas selected for CRP grassland within their home range and nesting (Teige 2021). Lesser prairie-chickens have adapted to CRP during the past four decades to the point that reduction or elimination of CRP will significantly affect lesser prairie-chickens.

In addition to the requirement of large, contiguous grasslands, other landscape features influence occupancy and space use by lesser prairie-chickens. Similar to the requirement of $\geq 60\%$ grassland for persistence of a lesser prairie-chicken population, many of these features, such as tree density and anthropogenic structures, have defined thresholds that are critical points at which relatively small changes in landscape features result in rapid declines in population abundance and occupied area (Hagen et al. 2007; Environmental Protection Agency 2016; Table 2.1).

Historically, lesser prairie-chickens evolved in prairie landscapes with few to no trees. Encroachment of woody vegetation, particularly eastern red cedar (*Juniperus virginiana*), elicits avoidance behaviors by lesser prairie-chickens in Kansas (Lautenbach et al. 2017). Lesser prairie-chickens were 40 times more likely to use habitats with 0 trees/ha when compared to landscapes with 5 trees/ha (Lautenbach et al. 2017). Additionally, lesser prairie-chickens were 19 times more likely to use habitats that were >1 km from the nearest tree compared to habitats

<100 m away from the nearest tree (Lautenbach et al. 2017). Female lesser prairie-chickens selected for habitats with <2 trees/ha and distances >300 m from a tree when placing nests. Thresholds were established as no nests were observed in areas with >2 trees/ha and habitat use ceases completely with 8 trees/ha (Lautenbach et al. 2017).

Lesser prairie-chickens will avoid multiple types of anthropogenic structures, such as transmission lines, distribution power lines, oil wells, gas wells, wind turbines, and cellular towers (Plumb et al. 2019). High densities of anthropogenic structures negatively affect lesser prairie-chickens; thus, they often select areas with minimal structures within a 2-km radius (Sullins et al. 2019). Roads and oil/gas energy development, along with associated noise, are a potential threat to this species (Hagen et al. 2011; Lipp 2016). Movement, nest-site selection, and general habitat use by prairie grouse species, including lesser prairie-chickens, are negatively affected by power lines (e.g., transmission and distribution power lines; Patten et al. 2005; Beck et al. 2006; Hagen et al. 2007; Wolfe et al. 2007; Stevens et al. 2012; Plumb et al. 2019). Lesser prairie-chickens established home ranges and placed nests farther from powerlines than what would be expected at random (Plumb et al. 2019). It was reported that the probability of use of an area decreases at a powerline density of 0.15 km per 12.6 km² (Sullins et al. 2019). Peterson et al. (2020) suggested that the tallest features on the landscape (e.g., towers, windmills, and transmission lines) were avoided at greater distances. Areas with >2 oil or gas wells/12.6 km² have 8 times lower rate of use (Sullins et al. 2019). Additionally, space use declines with greater well density, as female lesser prairie-chickens avoided areas containing 23 wells/250 ha (Plumb 2015). While gravel and paved roads may not be as problematic as other anthropogenic structures, there are still some risks associated with these features. Gravel and paved roads, and noise produced from cars may trigger avoidance behaviors in lesser prairie-chickens, resulting in

potential deterrence from the area (Plumb et al. 2019). Female lesser prairie-chickens established nesting sites farther from paved roads than what would be expected (Hagen et al. 2011). These patterns of habitat use may have cascading effects on reproductive behavior, including lek establishment.

The lekking period is the first and most conspicuous stage of the breeding season. Male lesser prairie-chickens gather at leks in early spring (late Feb – early Mar) to establish territories with females visiting a few weeks later. Males attract females with an exhilarating courtship display consisting of booming, fanning their tails, and rapidly stomping on the lek (Applegate and Riley 1998). Male lesser prairie-chickens often return to the same lek site year after year. Thus, prevention of lek isolation and maintaining connectivity among leks is important for persistence of the local populations (Applegate and Riley 1998; Boal and Haukos 2016). Surveys for monitoring lesser prairie-chicken populations are based on spring (Mar-Apr) lek counts, with inference regarding population status based on the number of detected leks and counts of attending birds. An intrinsic threshold regarding lek attendance, determined using aerial and ground lek survey data, has been recently established. This threshold suggests that lesser prairie-chicken leks with <10 males present at the lek have a much greater probability of extinction within 5 years, while leks above this threshold (≥ 10) have a greater probability of persistence (Whetten et al. *In Review*). This attendance threshold and trends in lek attendance may hint at future population declines that can be attributed to Allee effects, such as those that greatly diminished populations of heath hen and Attwater's prairie-chicken.

Failure to meet habitat requirements (e.g., >60% grassland) and surpassing other thresholds of features surrounding leks will likely result in decreased attendance, lek abandonment, and eventual extinction. Monitoring landscapes surrounding leks relative to

established ecological thresholds can identify populations of lesser prairie-chickens at risk of localized extinction, highlight areas with relatively greater conservation need, and inform conservation efforts of potential risks of future landscape changes (e.g., anthropogenic development). Within the lesser prairie-chicken occupied range, specifically surrounding leks, assessing thresholds can identify areas at heightened risk of population decline or local extinction (Crawford and Bolen 1976; Ross et al. 2016; Lautenbach et al. 2017; Sullins et al. 2018; Plumb et al. 2019). This knowledge will enable more effective prioritization of conservation actions and management strategies.

My goal was to use identified ecological thresholds to evaluate the status of lesser prairie-chicken leks in Kansas and create a comprehensive database to be used by managers for future conservation efforts. Specifically, my objectives were to 1) assess landscape composition surrounding identified leks relative to established ecological thresholds and 2) determine the proportion of leks with attendance counts above and below the survival threshold of 10 birds, and Extinct leks (historical leks with no males in attendance during the 2018-2023 survey period) for each defined lesser prairie-chicken ecoregion in Kansas. I 1) classified each lesser prairie-chicken lek as <10 , ≥ 10 , or Extinct based on average lek attendance from 2018-2023, 2) determined the status of each lek based on ecological thresholds, and 3) determined which ecoregion had the greatest proportion of leks that are approaching or have passed thresholds. I predicted the Short-Grass Prairie/CRP Mosaic Ecoregion would have a greater proportion of leks exceeding the grassland threshold, and fewer leks that have exceeded thresholds pertaining to woody encroachment and anthropogenic structures compared to the Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions.

Study Area

Three defined ecoregions of the lesser prairie-chicken occupied range in Kansas were of focus for this study. The Short-Grass Prairie/CRP Mosaic Ecoregion is a semi-arid climatic zone north of the Arkansas River with a range of 25-51 cm annual precipitation. This ecoregion is dominated by fine, sandy loam soil and primary land use includes CRP grasslands, livestock grazing, and row-crop agriculture (Robinson et al. 2018; Kansas Department of Wildlife and Parks 2022). Grasses present in this ecoregion include big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), hairy grama (*Bouteloua hirsuta*), sideoats grama (*B. curtipendula*), blue grama (*B. gracilis*), and buffalograss (*B. dactyloides*). The forb community is comprised of Illinois bundleflower (*Desmanthus illinoensis*), prairie sunflower (*Helianthus petiolaris*), annual buckwheat (*Eriogonum annuum*), sand milkweed (*Asclepias arenaria*), nine-anther dalea (*Dalea enneandra*), and western ragweed (*Ambrosia psilostachya*; Lauver et al., 1999). The CRP fields were planted with native grass species including big bluestem, little bluestem, sideoats grama, blue grama, buffalograss, switchgrass (*Panicum virgatum*), and golden feather grass (*Sorghastrum nutans*). Starting in the mid-1990s, CRP fields were interseeded with forbs such as white sweet clover (*Melilotus albus*), yellow sweet clover (*M. officinalis*), Maximillian sunflower (*Helianthus maximiliani*), Illinois bundleflower, purple prairie clover (*Dalea purpurea*), and prairie coneflower (*Ratibida columnifera*; Fields 2006). Woody species found in this ecoregion include bur oak (*Quercus macrocarpa*), green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), eastern cottonwood (*Populus deltoides*), sugar maple (*Acer saccharum*), river birch (*Betula nigra*), and hackberry (*Celtis occidentalis*; Kansas Department of Wildlife and Parks 2022). Salt cedar (*Tamarix* spp.) is a non-native

species and eastern red cedar (*Juniperus virginiana*) is native; both of these invasive woody species are rapidly encroaching in this ecoregion.

The Mixed-Grass Prairie Ecoregion has a dry, sub-humid to semi-arid climate with a range of 51-76 cm of annual precipitation (Kansas Department of Wildlife and Parks 2022). Soil in this ecoregion is loamy. Primary land uses are livestock grazing, oil/gas extraction, and row-crop agriculture (Robinson et al. 2018). Grasses include big bluestem, little bluestem, blue grama, hairy grama, sideoats grama, western wheatgrass (*Pascopyrum smithii*), buffalograss, switchgrass, golden feather grass, sand lovegrass (*Eragrostis trichodes*), tall dropseed (*Sporobolus compositus*), and alkali sacaton (*Sporobolus airoides*). Forbs in this ecoregion include purple coneflower (*Echinacea purpurea*), leadplant (*Amorpha canescens*), dotted blazing star (*Liatris punctata*), heath aster (*Symphyotrichum ericoides*), hairy sunflower (*Helianthus hirsutus*), round leaf bladderpod (*Lesquerella ovalifolia*), western ragweed, lamb's quarters (*Chenopodium album*), Russian thistle (*Salsola tragus*), annual sunflower (*Helianthus annuus*), kochia (*Bassia scoparia*), and Patagonian plantain (*Plantago patagonica*). Native woody species include southern hackberry (*Celtis laevigata*), western snowberry (*Symphoricarpos occidentalis*), eastern cottonwood (*Populus deltoides*), eastern red cedar, honey mesquite (*Prosopis glandulosa*), and green ash (*Fraxinus pennsylvanica*; Robinson et al. 2018). Invasive woody species include salt cedar, with native species such as eastern red cedar also exhibiting rapid encroachment (Kansas Department of Wildlife and Parks n.d.).

The Sand Sagebrush Prairie Ecoregion is a semi-arid, drought-prone region with a range of 41-53 cm of annual precipitation. This ecoregion has sandy soil with dunes found throughout, associated with river drainages (e.g., Cimarron, Arkansas). Grassland with irrigated row-crop agriculture, livestock grazing, and oil/gas extraction are the predominant land uses for this

ecoregion. Sand dropseed (*Sporobolus cryptandrus*), sideoats grama, hairy grama, blue grama, big bluestem, little bluestem, sand bluestem (*Andropogon hallii*), buffalograss, prairie sandreed (*Calamovilfa longifolia*), and alkali sacaton are commonly occurring grasses. The forb community includes annual buckwheat, dotted blazing star, western ragweed, prairie sunflower, annual sunflower, Russian thistle, camphorweed (*Heterotheca subaxillaris*), Indian blanket flower (*Gaillardia pulchella*), tansy aster (*Machaeranthera tanacetifolia*), buffalo bur (*Solanum rostratum*), buffalo gourd (*Cucurbita foetidissima*), wax goldenweed (*Grindelia papposa*), prickly lettuce (*Lactuca serriola*), and maretail (*Conzya canadensis*). Woody and shrubby vegetation includes cottonwood, elm (*Ulmus* spp.), eastern red cedar, salt cedar, and sand sagebrush (*Artemisia filifolia*; Vhay 2022).

Methods

Lek Survey Dataset

A multi-decadal dataset (1960-2023) of lesser prairie-chicken lek surveys was used for this research, however, analyses in this study were restricted to surveys conducted from 2018-2023 to identify lek locations and classify leks based on counts of attending birds. In Kansas, ground surveys were implemented and served as an index to lesser prairie-chicken population trends in the early 1960s. This dataset spanned from 1963-2023 and included established annual ground surveys and opportunistic reporting of identified leks. Originating with single transects in six counties, efforts increased to 17 transects in 15 counties by 2014. Ideally, surveys were conducted twice each season between March 20 and April 20, starting between 0500 and 0700. When conducting a survey, observers drove a 16-km transect, stopping every 1.6 km to listen for three minutes to detect leks. Once the route was completed, the observer would return to identified leks, flush the birds, and count any lesser prairie-chickens (Ross et al. 2016). A lek

observation was labeled opportunistic when it was located >1.6 km from an established survey route. Similar data were collected for these leks as those found along established survey routes. Additional opportunistic leks were submitted to an online database by conservation managers, biologists, researchers, and landowners (Pitman 2014).

This dataset was reformatted to organize data by individual lek within each ecoregion with the male lesser prairie-chicken count per survey year, rather than all lek observations without unique identifiers. Additionally, I restricted data to 2018-2023 for analyses as this 5-year time frame reflected the most recently available data, represented contemporary landscape characteristics, included a range of environmental (i.e., precipitation) conditions, and results will be more informative for conservation efforts compared to using the entire dataset.

Lek Attendance Groups

Lesser prairie-chicken leks were categorized as <10 birds, ≥ 10 birds, or Extinct based on average lek attendance during 2018-2023. A lek was considered Extinct if there were zero males observed at a previously identified lek during annual survey efforts across the time frame. I started with a total of 343 individual leks in my analyses. I checked for duplicates or observations with missing data (e.g., coordinates). Eight leks were removed from the data set; five due to not being consistently surveyed across the time period. I removed one lek from the data set because it had identical coordinates as another lek, keeping the lek with the highest male count. I removed an opportunistic lek from the data set because it had the same coordinates as a lek found via survey. The last lek I removed was an Extinct lek within 500 m of another Extinct lek. These changes resulted in a final total of 335 leks for analyses.

I calculated the average male attendance from 2018-2023 for each lek observation, rounding as necessary. Some leks were inconsistently surveyed during this time frame, but

because it was not confirmed that zero males were present during each survey attempt, there was still a possibility of presence. For example, a lek might have zero males in attendance for three of the five years and “N/A” for the remaining two years. Despite not being surveyed, this lek was treated as a consistently surveyed lek rather than an Extinct lek, to account for the possibility of males being present. In the dataset, the male count was entered as “N/A”; these leks were still used in my analyses. For each lek attendance category, I included the survey route (if applicable), county, and ecoregion for each lek. I overlaid lesser prairie-chicken survey routes with lek locations to identify the survey route associated with each lek. I determined which county and ecoregion for each lek using Kansas counties and lesser prairie-chicken occupied range ecoregion maps (Lesser Prairie Chicken Interstate Working Group 2022; Kansas Department of Labor 2025).

Establishment of Lek Locations

In ArcGIS Pro 3.2, I created X, Y points using the XY Table to Point tool for each lek attendance category (<10, ≥10, and Extinct). I reprojected these spatial layers to change the coordinate system to “NAD 1983 UTM Zone 14N”. Using a specific UTM zone can limit distortion and improve accuracy, as latitude and longitude coordinates are not ideal for measuring distances and area due to the Earth’s shape. Map projections using UTM coordinates minimizes distortion within each zone (e.g., Zone 14), making the distance and area calculations within my study area more accurate (Geography Realm 2020).

I defined boundaries of Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions and used the Select by Location map tool to identify the number of known leks per attendance group per ecoregion (Lesser Prairie Chicken Interstate Working Group 2022). Additionally, this tool allowed me to highlight all leks within each ecoregion and

provided a count in an attribute table. Following previous lesser prairie-chicken research that suggests a 5-km scale of selection, I generated a 5-km buffer around each lek (Sullins et al. 2019). Land cover type did not change for the few 5-km buffers of leks in the Sand Sagebrush Prairie and Mixed-Grass Prairie ecoregions that crossed into Colorado or Oklahoma. I calculated the total area (ha) of each landcover variable within all 5-km buffers and the average area per 5-km buffer for each lek attendance category using the SUM and AVERAGE functions; values of 0 were included in all calculations.

Estimation of Landcover Variables

Grassland

Kansas land cover data were retrieved from the Ecological Mapping Systems of Kansas (Diamond et al. 2021). This layer contains 49 land cover classes for Kansas including short-grass prairie, mixed-grass prairie, and sand sagebrush prairie. To estimate the proportion of native grassland cover types within a 5-km radius buffer surrounding each lek, I joined the Ecological Mapping Systems of Kansas grassland layer to the lek buffers in ArcGIS PRO 3.2. I then quantified the area of each grassland cover type within each buffer. The area of each cover type per buffer was displayed in the attribute table; the sum of each landcover class was calculated using the SUM function in Excel. I combined the following cover types for the native grassland category: mixed-grass prairie, mixed-grass prairie breaks grassland, sand sagebrush prairie, sandhills prairie, shortgrass prairie, chalkflat mixed-grass prairie, and western lowland grassland.

Data on existing Conservation Reserve Program fields from 2021 were provided by the United States Department of Agriculture Farm Service Agency. The 2021 data represents the mid-point of the study's time frame (2018-2023). This variable was treated as a binomial

variable (present or absent); Conservation Practice was not recorded. The mean, standard error, and percentage of CRP for each lek was derived for each lek category in each ecoregion.

To prevent over-estimation of the native grassland variable, I converted the CRP spatial layer into a raster, merged the grassland layer with the CRP layer, and erased native grassland where it overlapped with CRP grassland. I then added the CRP variable to the native grassland variable for an estimate of total grassland. I derived the mean, standard error, and percentage for each grassland variable (native grassland, CRP, total grassland) for each lek category in each ecoregion.

Cropland

Cropland was included in the Ecological Mapping Systems of Kansas land cover layer, so I estimated this variable in the same manner as the grassland variable. I then calculated the mean, standard error, and percentage of cropland per 5-km radius buffer for each lek category in each ecoregion using the corresponding functions in Excel.

Trees

I obtained 2021 Kansas tree data from EarthDefine (<https://www.earthdefine.com/treemap/>). This spatial layer was presented as a binary raster (1 = tree, 0 = no tree) with 5-m resolution. I developed an index to estimate the number of individual trees within 5-km of each lek. I randomly selected 10 leks and generated 500 random points in each 5-km buffer. I generated 1-ha buffers around each random point, and randomly selected 10 points, each with varying proportions of trees. I then estimated what proportion of a tree was covered by each 25-m² pixel in the spatial layer (e.g., 0.25, 0.50, 0.75, 1.0). To determine the approximate number of trees per pixel, I counted the total number of pixels covering 0.25% of a tree and multiplied that by 25 (ex: 60 pixels x 0.25). I repeated this for the remaining categories

of coverage (0.50%, 0.75%, and 1%). I then divided the total number of tree coverage by the total number of pixels to get a value of 0.49 trees per pixel when trees were indicated in a pixel.

To estimate trees/ha, I first converted the EarthDefine tree raster into polygons and clipped the tree polygons to each 5-km buffer. I then used Zonal Statistics to retrieve the number of individual tree pixels per buffer. The value of 0.49 trees per pixel was multiplied by the total number of pixels in each 5-km buffer, resulting in an estimated count of trees per buffer. The number of trees per 5-km buffer was then divided by the area in hectares of the 5-km buffer to get trees/ha.

Anthropogenic Structures

I quantified each anthropogenic structure type within 5 km of all recorded lesser prairie-chicken leks. Thresholds for oil/gas wells, vertical structures (cellular towers and wind turbines), transmission lines, and roads were adapted from Sullins et al. (2019). Thresholds were multiplied by the ratio of buffer areas ($78.5 \text{ km}^2/12.6 \text{ km}^2 = 6.23$) to account for the larger spatial scale. Resulting thresholds were ≥ 13 oil/gas wells, ≥ 13 vertical structures, >0.94 km of transmission lines, and >0.94 km of roads (gravel/paved) within a 5-km buffer. Anthropogenic structure spatial layers were obtained from several sources. Data for Kansas oil and gas wells, cellular towers, and paved/gravel roads were gathered from the Kansas Data Access and Support Center. Locations of individual wind turbines in Kansas were from the U.S. Geological Survey Wind Turbine Database; transmission line locations were obtained from the U.S. Department of Homeland Security open data site via ArcGIS.com. To retrieve the count of oil/gas wells per buffer, I clipped the oil/gas well spatial layer to the lek spatial layer and viewed the attribute table. Oil and gas wells on the landscape were not differentiated, and I did not remove plugged, dry, or abandoned wells as these may have been active at some point from 2018-2023. I repeated

these steps for individual wind turbines and cell phone towers. For transmission lines, I first clipped the spatial layer to the spatial layer with the lek locations. I then visually confirmed if a transmission line crossed through the buffer. I determined the total length of transmission lines per buffer by joining the attribute table with the lengths of individual transmission lines to the lek spatial layer. I repeated these steps to estimate the length of paved/gravel roads in the buffer.

Determination of Threshold Status

For each lek, I used the estimated land cover variables and ecological thresholds to determine if leks were near or have passed each threshold. For grassland (native and total) and cropland, I used the area estimated from the Ecological Mapping Systems of Kansas layer. For trees and anthropogenic structures, I estimated the number per hectare by dividing the total count for each lek by the area of the buffer (7,854 ha). I then assigned a threshold status for each variable (Above Threshold or Below Threshold; Table 3.1).

Statistical Analyses

Statistical analyses were conducted in Program R to identify relationships and test for differences among lek attendance groups (<10, ≥10, or Extinct) for the count of leks above or below ecological thresholds (e.g., grassland, trees, anthropogenic structures). Pearson's chi-squared tests of independence were used to determine whether threshold status differed among attendance groups. Results are presented with 95% confidence intervals, and statistical significance was defined as $\alpha = 0.05$.

Results

Of the 335 total leks, 114 were in the Short-Grass Prairie/CRP Mosaic Ecoregion, 106 in the Mixed-Grass Prairie Ecoregion, and 115 in the Sand Sagebrush Prairie Ecoregion. The Short-Grass Prairie/CRP Mosaic Ecoregion had the greatest proportion of surveyed leks above the

attendance threshold of ≥ 10 males (39.47%) and lowest proportion of Extinct leks (26.32%; Table 3.2). Conversely, the Mixed-Grass Prairie Ecoregion had the lowest proportion of surveyed leks above the ≥ 10 bird attendance threshold (5.66%) and greatest proportion of Extinct leks (64.15%; Table 3.3). Greater than 80% of surveyed leks in the Sand Sagebrush Prairie Ecoregion were either below the attendance threshold of 10 males (42.61%) or Extinct (46.96%; Table 3.4).

Across the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions, 160 leks (47.76%) exceeded 60% native grassland, 263 leks (78.51%) exceeded 60% total grassland, 48 leks (14.33%) exceeded the threshold of 40% cropland, and 60 leks (17.91%) exceeded 2 trees/ha (Figures 3.3, 3.4). Aside from grassland, the greatest number of leks exceeded the threshold for trees, specifically in the Short-Grass Prairie/CRP Mosaic and Mixed-Grass Prairie ecoregions (Figure 3.4). In total, 4 leks (1.19%) were above thresholds for native and total grassland, cropland, and trees: 2 in the Short-Grass Prairie/CRP Mosaic Ecoregion and 2 in the Mixed-Grass Prairie Ecoregion.

In the Short-Grass Prairie/CRP Mosaic Ecoregion, lek attendance groups (<10 , ≥ 10 , and Extinct) did not vary in the number of leks above or below the threshold for native grassland ($\chi^2(2) = 3.01$, $P = 0.22$), total grassland ($\chi^2(2) = 5.07$, $P = 0.08$), cropland ($\chi^2(2) = 1.93$, $P = 0.38$), trees/ha ($\chi^2(2) = 0.78$, $P = 0.68$), oil/gas wells ($\chi^2(2) = 5.93$, $P = 0.05$), vertical structures ($\chi^2(2) = 2.52$, $P = 0.28$), and transmission lines ($\chi^2(2) = 0.80$, $P = 0.67$). Comparisons were unable to be made for roads, as all leks in this ecoregion exceeded the threshold of 0.94 km within 5 km (Table 3.5). Of the leks with <10 birds, 46.15% were above the threshold for grassland ($\geq 60\%$). Combining CRP grassland with native grassland increased this to 84.62% of leks with sufficient grassland. Among leks with ≥ 10 birds, 28.89% had at least 60% grassland,

and this increased to 77.78% with the addition of CRP grassland. Finally, 43.33% of Extinct leks were above the threshold for grassland. Including CRP grassland increased this to 96.67% of leks with $\geq 60\%$ grassland. Extinct leks had the greatest number below the threshold of 40% cropland (96.67%), followed by leks with <10 birds (87.18%) and ≥ 10 birds (77.78%). The <10 attendance group had the greatest number of leks with >2 trees/ha (28.21%), followed by Extinct leks (23.33%) and leks with ≥ 10 birds (20%).

In the Mixed-Grass Prairie Ecoregion, lek attendance groups did not vary in the number of leks above or below the threshold for native grassland ($\chi^2(2) = 1.30, P = 0.52$), total grassland ($\chi^2(2) = 0.26, P = 0.88$), cropland ($\chi^2(2) = 1.42, P = 0.49$), trees/ha ($\chi^2(2) = 4.15, P = 0.13$), and vertical structures ($\chi^2(2) = 16.83, P < 0.001$). Comparisons were unable to be made for roads, as all leks in this ecoregion exceeded the threshold of 0.94 km within 5 km. Among leks with <10 birds, 43.75% were above the 60% threshold for grassland. When CRP grassland was added, this increased to 62.50% of leks exceeding the threshold; 66.67% of leks with ≥ 10 birds were above the grassland threshold, which remained unchanged with the addition of CRP grassland. Lastly, 42.65% of Extinct leks were above the threshold for grassland. This increased to 67.65% once CRP grassland was included. Extinct leks had the greatest proportion below the 40% threshold for cropland (80.88%), followed by leks with <10 birds (71.88%) and ≥ 10 birds (66.67%). All leks with ≥ 10 birds had fewer than 2 trees/ha, whereas 41.94% of leks with <10 birds and 29.41% of Extinct leks had more than 2 trees/ha. Lek attendance groups varied in the number of leks above or below the threshold for oil/gas wells ($\chi^2(2) = 7.52, P = 0.02$), with all Extinct leks ($n = 68$) exceeding the threshold of ≥ 13 oil/gas wells within 5 km (Table 3.6). Lastly, lek attendance groups varied in the number of leks above or below the threshold for transmission lines ($\chi^2(2) = 10.07, P = 0.01$), with a greater number of leks below the threshold (Table 3.6).

In the Sand Sagebrush Prairie Ecoregion, lek attendance groups varied in number of leks above or below the threshold for native grassland ($\chi^2(2) = 29.55, P < 0.001$); specifically, between Extinct leks and leks with <10 birds. 85.19% of Extinct leks had $>60\%$ native grassland, whereas only 32.65% of leks with <10 birds exceeded this threshold. Lek attendance groups varied in number of leks above or below the threshold for total grassland ($\chi^2(2) = 20.56, P < 0.001$); a greater number of Extinct leks had $\geq 60\%$ total grassland compared to leks with <10 and ≥ 10 birds. The addition of CRP grassland increased the number of Extinct leks with at least 60% grassland from 85.19% to 100%. Lastly, lek attendance groups varied in the number of leks above or below the threshold for cropland ($\chi^2(2) = 12.31, P = 0.002$). Extinct leks differed from leks with <10 birds and ≥ 10 birds; 100% of Extinct leks had less than 40% cropland, whereas 81.63% of leks with <10 birds and 75% of leks with ≥ 10 birds had less than 40% cropland. Comparisons were unable to be made for trees, as all leks in this ecoregion were below both thresholds. Lek attendance groups varied in the number of leks above or below the threshold for oil/gas wells ($\chi^2(2) = 9.54, P = 0.01$) and transmission lines ($\chi^2(2) = 17.06, P < 0.001$). A greater number of leks exceeded 13 oil/gas wells within 5 km, whereas more leks were below the threshold of 0.94 km of transmission lines within 5 km (Table 3.7). All leks in this ecoregion were below the threshold for vertical structures (cellular towers and wind turbines), but all leks exceeded the threshold for roads (Table. 3.7).

Discussion

Overall, lek attendance groups (<10 , ≥ 10 , Extinct) were similar in the number of leks above and below identified ecological thresholds within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions. However, different land cover characteristics influencing threshold status were observed among ecoregions. A greater

proportion of leks in the Short-Grass Prairie/CRP Mosaic and Mixed-Grass Prairie ecoregions exceeded the threshold of 2 trees/ha and were below the threshold for native grassland when compared to leks in the Sand Sagebrush Prairie Ecoregion. Conversely, the opposite pattern was observed in the Sand Sagebrush Prairie Ecoregion, as no leks exceeded 2 trees/ha and the least proportion of leks were below the threshold for native grassland.

Despite these ecoregional differences, presence of CRP grassland was highly influential; once combined with native grassland, 78.51% of leks exceeded 60% grassland, representing a 30.75% increase in leks surpassing this threshold. For example, in the Short-Grass Prairie/CRP Mosaic Ecoregion, the proportion of leks with ≥ 10 birds with 60% grassland within 5 km tripled with the addition of CRP grassland. In the Sand Sagebrush Prairie Ecoregion, a greater proportion of Extinct leks had at least 60% native grassland, and once CRP was incorporated, 100% of leks ($n = 68$) exceeded the grassland threshold. These results emphasize the importance of CRP grassland on the landscape and are consistent with previous research demonstrating that CRP grassland supports lesser prairie-chickens during intensive drought, nesting, brood-rearing, roosting, and dispersal movements (Ross et al. 2016; Dahlgren et al. 2016; Hagen et al. 2016; Sullins et al. 2018; Teige 2021; Berigan et al. 2022, 2024). For leks below the attendance threshold of 10 birds, a starting point for management could consist of increasing CRP grassland on the landscape within 5 km of leks, potentially providing critical resources for lesser prairie-chickens.

I hypothesized that the Short-Grass Prairie/CRP Mosaic Ecoregion would have a greater proportion of leks exceeding the threshold for total grassland ($\geq 60\%$) compared to the Mixed-Grass Prairie and Sand Sagebrush Prairie ecoregions. The Short-Grass Prairie/CRP Mosaic Ecoregion may be a stronghold for lesser prairie-chicken populations, but historically, the Sand

Sagebrush Prairie and Mixed-Grass Prairie ecoregions supported the greatest density of birds (Garton et al. 2016; Nasman et al. 2022). In the Mixed-Grass Prairie Ecoregion, increased woody encroachment has resulted in loss of native grassland. Furthermore, grasslands have been reduced in the Sand Sagebrush Prairie Ecoregion due to conversion for agricultural purposes. However, my results did not fully support my hypothesis. A greater proportion of leks in the Short-Grass Prairie/CRP Mosaic Ecoregion had $\geq 60\%$ total grassland when compared to the Mixed-Grass Prairie Ecoregion, but all Extinct leks ($n = 12$) in the Sand Sagebrush Prairie Ecoregion had $\geq 60\%$ total grassland. While it appears that there is sufficient grassland on the landscape, vegetation composition and structure may not be supporting lesser prairie-chicken populations in this ecoregion, as lekking, nesting, brood-rearing, and wintering stages have unique vegetation requirements (Riley 1978; Riley et al. 1992; Giesen 1994; Jamison et al. 2002; Bidwell et al. 2003; Hagen et al. 2005; Pitman et al. 2005; Davis 2009; Bell et al. 2010; Hagen et al. 2013; Grisham et al. 2014; Haukos and Zavaleta 2016).

I also hypothesized that the Short-Grass Prairie/CRP Mosaic Ecoregion would have the lowest proportion of leks exceeding the thresholds of 2 trees/ha due to larger populations in this ecoregion and known avoidance of trees by lesser prairie-chickens (Lautenbach et al. 2017). While my results did not support this, because all leks in the Sand Sagebrush Prairie Ecoregion ($n = 115$) were below the threshold for trees, leks with ≥ 10 birds in the Short-Grass Prairie/CRP Mosaic Ecoregion had the lowest proportion exceeding 2 trees/ha, whereas leks with < 10 birds had the greatest proportion exceeding the threshold. Further, leks above the attendance threshold in this ecoregion were farther away from trees when compared to leks below the threshold and Extinct leks (Chapter II). In the Mixed-Grass Prairie Ecoregion, all leks with ≥ 10 birds were below the threshold for trees. This emphasizes the importance of limited trees within the lesser

prairie-chicken occupied range, particularly within 5 km of leks in the Mixed-Grass Prairie Ecoregion.

Lastly, I predicted that leks in the Short-Grass Prairie/CRP Mosaic Ecoregion would have the lowest number of leks exceeding thresholds for anthropogenic structures. My results did not support this prediction, as there are high densities of anthropogenic structures within 5 km of lesser prairie-chicken leks in this ecoregion. Specifically, 97.37% of leks in the Short-Grass Prairie/CRP Mosaic Ecoregion contained ≥ 13 oil/gas wells within 5 km. This result was similar within the Mixed-Grass Prairie (97.17% of leks), whereas leks in the Sand Sagebrush Prairie Ecoregion had fewer leks exceeding this threshold (76.52%). Consolidation of anthropogenic structures, and removal of above-ground pieces of oil/gas wells should be considered in management strategies, specifically within 5 km of lesser prairie-chicken leks.

Within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, I used knowledge of ecological thresholds to quantify land cover variables within 5 km of lesser prairie-chicken leks from 2018-2023 (Chapter II). Using that information, I assigned a threshold status (Above or Below) for each lek and determined the proportion of leks above or below thresholds in each ecoregion (Appendix 3.A; 3.B). Identifying the status of lesser prairie-chicken leks observed in recent years, relative to established ecological thresholds, can further inform conservation and management efforts. The Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions exhibited varying proportions of leks above and below ecological thresholds. Thus, management approaches tailored to each ecoregion with regard to thresholds affecting the most leks, may yield more beneficial results. While differences were limited within ecoregions, it is important to consider landscape characteristics of all leks, as changing conditions can negatively affect leks

above the attendance threshold of 10 birds. Specifically, in the Short-Grass Prairie/CRP Mosaic Ecoregion, the threshold for trees was exceeded more than thresholds for cropland and anthropogenic structures. Implementing management strategies that reduce tree cover may shift leks that currently exceed this threshold into favorable conditions. Additionally, management strategies should consider leks with <10 birds, due to these leks being occupied from 2018-2023. To prevent future extinction of these leks, the surrounding landscape can be managed with the overall goal of increasing attendance of lesser prairie-chickens. Overall, these results can provide an overview of the status of lesser prairie-chicken leks and aid in deciding what conservation actions need to be taken to improve persistence of lesser prairie-chickens in Kansas.

Literature Cited

- Applegate, R. D., and T. Z. Riley. 1998. Lesser prairie-chicken management. *Rangelands* 20:13–15.
- Beck, J. L. 2006. Summary of oil and natural gas development impacts on prairie grouse. Unpublished Report, Colorado Division of Wildlife, Grand Junction, Colorado, USA.
- Bell, L. A., S. D. Fuhlendorf, M. A. Patten, D. H. Wolfe, and S. K. Sherrod. 2010. Lesser prairie-chicken hen and brood habitat use on sand shinnery oak. *Rangeland Ecology & Management* 63:478–486.
- Berigan, L. A., C. S. H. Aulicky, E. C. Teige, D. S. Sullins, D. A. Haukos, K. A. Fricke, J. H. Reitz, L. G. Rossi, K. A. Shultz, and A. M. Ricketts. 2022. Availability of lesser prairie-chicken nesting habitat impairs restoration success. *Wildlife Society Bulletin* 46:e1379.
- Berigan, L. A., C. S. H. Aulicky, E. C. Teige, D. S. Sullins, K. A. Fricke, J. H. Reitz, L. G. Rossi, K. A. Shultz, M. B. Rice, E. Tanner, S. D. Fuhlendorf, and D. A. Haukos. 2024. Lesser prairie-chicken dispersal after translocation: implications for restoration and population connectivity. *Ecology and Evolution* 14:e10871.
- Bidwell, T. G., S. Fuhlendorf, B. Gillen, S. Harmon, R. Horton, R. Manes, R. Rodgers, S. Sherrod, and D. Wolfe. 2003. Ecology and management of the greater prairie-chicken in Oklahoma. Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources. Oklahoma State University, Stillwater, USA.

- Boal, C. W., and D. A. Haukos. 2016. The lesser prairie-chicken: a brief introduction to the grouse of the Southern Great Plains. Pages 1–11 in D. A. Haukos and C. W. Boal (editors), *Ecology and conservation of lesser prairie-chickens*. Studies in Avian Biology (no. 48), CRC Press, Boca Raton, Florida, USA.
- Boyd, C. S., M. K. Creutzburg, A. V. Kumar, J. T. Smith, K. E. Doherty, B. A. Meador, J. B. Bradford, M. Cahill, S. M. Copeland, C. A. Duquette, L. Garner, M. C. Holdrege, B. Sparklin, and T. B. Cross. 2024. A strategic and science-based framework for management of invasive annual grasses in the sagebrush biome. *Rangeland Ecology & Management* 97:67–72.
- Crawford, J. A., and E. G. Bolen. 1976. Effects of land use on lesser prairie-chickens in Texas. *Journal of Wildlife Management* 40:96–104.
- Dahlgren, D. K., R. D. Rodgers, R. D. Elmore, and M. R. Bain. 2016. Grasslands of western Kansas, north of the Arkansas River. Pages 259–279 in D. A. Haukos and C. W. Boal, editors. *Ecology and conservation of lesser prairie-chickens*. Studies in Avian Biology No. 48. CRC Press, Boca Raton, Florida, USA.
- Davis, D. M. 2009. Nesting ecology and preproductive success of lesser prairie-chickens in shinnery oak-dominated rangelands. *Wilson Journal of Ornithology* 121:322–327.
- Dhillon, S. S., M. A. McGinley, C. F. Friese, and J.C. Zak. 1994. Construction of sand shinnery oak communities of the Llano Estacado: animal disturbances, plant community structure, and restoration. *Restoration Ecology* 2:51–60.
- Diamond, D. D., L. F. Elliott, G. Steinauer, K. Kindscher, P. Hanberry, D. True, and M. Sunde. 2021. *Ecological Systems of Kansas and Nebraska: Final Report*. Submitted to Kansas Department of Wildlife, Parks and Tourism, and Nebraska Game and Parks Commission.
- Environmental Protection Agency. 2016. *Climate impacts on ecosystems*. EPA.
- Fields, T.L., G. C. White, W. C. Gilgert, and R. D. Rodgers. 2006. Nest and brood survival of lesser prairie-chickens in west central Kansas. *Journal of Wildlife Management* 70:931–938.
- Garton, E. O., C. A. Hagen, G. M. Beauprez, S. C. Kyle, J. C. Pitman, D. D. Schoeling, and W. E. Van Pelt. 2016. Population dynamics of lesser prairie-chickens. Pages 49–76 in D. A. Haukos and C. W. Boal, editors. *Ecology and conservation of lesser prairie-chickens*. Studies in Avian Biology No. 48. CRC Press, Boca Raton, Florida, USA.
- Geography Realm. 2020. Universal Transverse Mercator (UTM). *Geography Realm*. Accessed 2025 Jul 22. <https://www.geographyrealm.com/universal-transverse-mercator/>.

- Giesen, K. M. 1994. Movements and nesting habitat of lesser prairie-chicken hens in Colorado. *Southwestern Naturalist* 39:96–98.
- Grisham, B. A., P. K. Borsdorf, C. W. Boal, and K. K. Boydston. 2014. Nesting ecology and nest survival of lesser prairie-chickens on the Southern High Plains of Texas. *Journal of Wildlife Management* 78:857–866.
- Gross, A. O. 1928. The heath hen. *Memoirs of the Boston Society of Natural History* 6(4):491–588.
- Hagen, C. A., B. E. Jamison, K. M. Giesen, and T. Z. Riley. 2004. Guidelines for managing lesser prairie-chicken populations and their habitats. *Wildlife Society Bulletin* 32:69–82.
- Hagen, C. A., G. C. Salter, J. C. Pitman, R. J. Robel, and R. D. Applegate. 2005. Lesser prairie-chicken brood habitat in sand sagebrush: invertebrate biomass and vegetation. *Wildlife Society Bulletin* 33:1080–1091.
- Hagen, C. A., J. C. Pitman, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2007. Age specific survival and probable causes of mortality in female lesser prairie-chickens. *Journal of Wildlife Management* 71:518–525.
- Hagen, C. A., J. C. Pitman, T. M. Loughin, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2011. Impacts of anthropogenic features on habitat use by lesser prairie-chickens. Pages 63–75 in B. K. Sandercock, K. Martin, and G. Segelbacher (editors). *Ecology, conservation, and management of grouse. Studies in Avian Biology* (39), University of California Press, Berkeley, USA.
- Hagen, C. A., B. A. Grisham, C. W. Boal, and D. A. Haukos. 2013. A meta-analysis of lesser prairie-chicken nesting and brood rearing habitats: implications for habitat management. *Wildlife Society Bulletin* 37:750–758.
- Hagen, C. A., D. C. Pavlacky, K. A. Adachi, F. E. Hornsby, T. J. Rintz, and L. L. McDonald. 2016. Multiscale occupancy modeling provides insight into range-wide conservation need of lesser prairie-chicken (*Tympanuchus pallidicinctus*). *Condor* 118:597–612.
- Harryman, S. W., B. A. Grisham, C. W. Boal, S. S. Kahl, R. L. Martin, and C. A. Hagen. 2019. Multiscale habitat selection of lesser prairie-chickens in a row-crop and Conservation Reserve Program land matrix. *Journal of Fish and Wildlife Management* 10:126–136.
- Haukos, D. A., and J. C. Zavaleta. 2016. Habitat. Pages 99–132 in D.A. Haukos, and C.W. Boal (editors). *Ecology and conservation of lesser prairie-chickens. Studies in Avian Biology* (no. 48) CRC Press, Boca Raton, Florida, USA.

- Jamison, B. E., R. J. Robel, J. S. Pontius, and R. D. Applegate. 2002. Invertebrate biomass: associations with lesser prairie-chicken habitat use and sand sagebrush density in southwestern Kansas. *Wildlife Society Bulletin* 30:517–526.
- Jamison, B. E., R. J. Robel, J. S. Pontius, and R. D. Applegate. 2002. Invertebrate biomass: associations with lesser prairie-chicken habitat use and sand sagebrush density in southwestern Kansas. *Wildlife Society Bulletin* 30:517–526.
- Kansas Department of Labor. 2025. Kansas Counties Feature Layer. ArcGIS Online. <https://www.arcgis.com/home/item.html?id=b912469d52204af98b4a6e475253762a>
- Kamm, M. 2015. The life and death of the heath hen. *Bird Observer* 43(1):5–14.
- Kansas Department of Wildlife & Parks. 2022. Kansas State Wildlife Action Plan (SWAP). Chapters 4 and 5. Kansas Department of Wildlife & Parks, Pratt, KS, USA. <https://ksoutdoors.com/Services/Kansas-SWAP>. Accessed 1 June 2025.
- Kansas Department of Wildlife and Parks. N.d. Saltcedar. <https://ksoutdoors.gov/Fishing/Aquatic-Invasive-Species/Aquatic-Invasive-Species-List/Saltcedar>. Accessed 27 January 2026.
- Lautenbach, J. M., R. T. Plumb, S. G. Robinson, C. A. Hagen, D. A. Haukos, and J. C. Pitman. 2017. Lesser prairie-chicken avoidance of trees in a grassland landscape. *Rangeland Ecology & Management* 70:78–86.
- Lauver, C. L., K. Kindscher, F. L. Don, and R. Schneider. 1999. A classification of the natural vegetation of Kansas. *Southwestern Naturalist* 44:421–443.
- Lesser Prairie-Chicken Interstate Working Group (LPCIWG). 2022. Lesser prairie-chicken estimated occupied range 2022 Update. LCPIWG, Western Association of Fish and Wildlife Agencies, Boise, USA.
- Lipp, T. W. 2016. Geospatial analysis of how oil and gas energy development influences lesser prairie-chicken spatial ecology in Kansas. Thesis, Bowling Green State University, Bowling Green, Ohio, USA.
- Maestas, J. D., M. Porter, M. Cahill, and D. Twidwell. 2022. Defend the core: Maintaining intact rangelands by reducing vulnerability to invasive annual grasses. *Rangelands* 44:181–186.
- McDonald, L., G. Beauprez, G. Gardner, J. Griswold, C. Hagen, D. Klute, S. Kyle, J. Pitman, T. Rintz, and B. Van Pelt. 2014. Range-wide population size of the lesser prairie-chicken: 2012 and 2013. *Wildlife Society Bulletin* 38:536–546.

- Nasman, K., T. Rintz, G. DiDonato, and F. Kuzler. 2022. 2012 to 2022 Range-wide population size of the lesser prairie-chicken. Western EcoSystems Technology, Inc., Cheyenne, Wyoming, USA.
- Patten, M.A., Wolfe, D.H., Shochat, E., and S.K. Sherrod. 2005. Habitat fragmentation, rapid evolution and population persistence. *Evolutionary Ecology Research* 7:1–15.
- Peterson, J. M., J. E. Earl, S. D. Fuhlendorf, R. D. Elmore, D. A. Haukos, A. M. Tanner, and S. A. Carlson. 2020. Estimating response distances of lesser prairie-chickens to anthropogenic features during long-distance movements. *Ecosphere* 11(9): e03202.
- Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2005. Location and success of lesser prairie-chicken nests in relation to vegetation and human disturbance. *Journal of Wildlife Management* 69:1259–1269.
- Pitman, J. C. 2014. Prairie chicken lek survey: performance report, statewide wildlife research and surveys. Kansas Department of Wildlife, Parks, and Tourism. Pittman-Robertson Federal Aid in Wildlife Restoration. Grant W39- R-20, Emporia, USA.
- Plumb, R.T. 2015. Lesser prairie-chicken movement, space use, survival, and response to anthropogenic structures in Kansas and Colorado. Thesis, Kansas State University, Manhattan, USA.
- Plumb, R. T., J. M. Lautenbach, S. G. Robinson, D. A. Haukos, V. L. Winder, C. A. Hagen, D. S. Sullins, J. C. Pitman, and D. K. Dahlgren. 2019. Lesser prairie-chicken space use in relation to anthropogenic structures. *Journal of Wildlife Management* 83:216–230.
- Riley, T. Z. 1978. Nesting and brood-rearing habitat of lesser prairie-chickens in southeastern New Mexico. M.S. thesis, New Mexico State University, Las Cruces, New Mexico, USA.
- Riley, T. Z., C. A. Davis, M. Ortiz, and M. J. Wisdom. 1992. Vegetative characteristics of successful and unsuccessful nests of lesser prairie-chickens. *Journal of Wildlife Management* 56(2):383–387.
- Robinson, S. G., D. A., Haukos, R. T. Plumb, J. D. Kraft, D. S. Sullins, J. M. Lautenbach, J. D. Lautenbach, B. K. Sandercock, C. A. Hagen, A. Bartuszevige, and M. A. Rice. 2018. Effects of landscape characteristics on annual survival of lesser prairie-chickens. *American Midland Naturalist* 180:66–86.
- Rodgers, R. D. 2016. A history of lesser prairie-chickens. Pages 15–38 in D. A. Haukos and C. W. Boal (editors), *Ecology and conservation of lesser prairie-chickens. Studies in Avian Biology* (no. 48), CRC Press, Boca Raton, Florida, USA.

- Ross, B. E., D. A. Haukos, C. A. Hagen, and J. C. Pitman. 2016. Landscape composition creates a threshold influencing lesser prairie-chicken population resilience to extreme drought. *Global Ecology and Conservation* 6:179–188.
- Spencer, D., D. A. Haukos, C. A. Hagen, M. Daniels, and D. Goodin. 2017. Conservation reserve program mitigates grassland loss in the lesser prairie-chicken range of Kansas. *Global Ecology and Conservation* 9:21–38.
- Stevens, B.S., Connelly, J.W. and K. P. Reese. 2012. Multi-scale assessment of greater sage-grouse fence collision as a function of site and broad scale factors. *Journal of Wildlife Management*, 76:1370– 1380.
- Sullins, D. S., J. D. Kraft, D. A. Haukos, S. G. Robinson, J. H. Reitz, R. T. Plumb, J. M. Lautenbach, J. D. Lautenbach, B. K. Sandercock, and C. A. Hagen. 2018. Demographic consequences of conservation reserve program grasslands for lesser prairie-chickens. *Journal of Wildlife Management* 82:1617–1632.
- Sullins, D. S., D. A. Haukos, J. M. Lautenbach, J. D. Lautenbach, S. G. Robinson, M. B. Rice, B. K. Sandercock, J. D. Kraft, R. T. Plumb, J. H. Reitz, J. M. S. Hutchinson, and C. A. Hagen. 2019. Strategic conservation for lesser prairie-chickens among landscapes of varying anthropogenic influence. *Biological Conservation* 238:108213.
- Svedarsky, W. D., R. L. Westemeier, R. J. Robel, S. Gough, and J. E. Toepfer. 2000. Status and management of the greater prairie-chicken *Tympanuchus cupido pinnatus* in North America. *Wildlife Biology* 6:277–284.
- Teige, E. C. 2021. Assessment of lesser prairie-chicken translocation through survival, space use, and resource selection. Thesis, Kansas State University, Manhattan, USA.
- Vhay, M.P. 2022. Retrospective assessment of lesser prairie-chicken habitat in the sand sagebrush prairie ecoregion. Thesis, Kansas State University, Manhattan, USA.
- Wolfe, D. H., M. A. Patten, E. Shochat, C. L. Pruett, and S. K. Sherrod. 2007. Causes and patterns of mortality in lesser prairie-chickens (*Tympanuchus pallidicinctus*) and implications for management. *Wildlife Biology* 13:95–104.

Tables

Table 3.1. Identified landscape thresholds associated with lesser prairie-chicken (LEPC) persistence within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA.

Variable	Threshold	References
Grassland	Restricted to areas with $\geq 60\%$ native grassland	Crawford and Bolen 1976
	$\geq 77\%$ native grassland and contiguous patches of native grassland at 5-km radius scale (7,854 ha)	Sullins et al. 2018
CRP	As CRP in a 57-km ² (5,626 ha) area exceeds 20%, the likelihood of LEPC occupying that landscape increases	Hagen et al. 2016
Cropland	Below 1:10 ratio cropland:grassland <40% cropland for persistence	Ross et al. 2016
Trees	$\geq 2/\text{ha}$ - avoid nesting $\geq 8/\text{ha}$ - complete avoidance	Lautenbach et al. 2017
Anthropogenic Structures	Display avoidance at 2 vertical structures Decreased probability of use with 2 structures/12.6 km ² (County/paved roads, oil/gas wells, cellular towers, wind turbines, transmission lines)	Plumb et al. 2019 Sullins et al. 2019
Lek Attendance	Leks with <10 birds (males) present at the lek have a high probability of extinction within 5 years, while leks above this threshold (≥ 10) will persist	Whetten et al. <i>In Review</i>

Table 3.2. Total number (%) of lesser prairie-chicken leks above or below established landscape thresholds (lek attendance, native grassland, total grassland, cropland, trees/ha, anthropogenic structures) in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA. Lek attendance was determined using average male attendance during 2018-2023.

Threshold	Status	
	Above	Below
Lek Attendance^a	45 (39.50%)	69 (60.50%)
Native Grassland^b	44 (38.60%)	70 (61.40%)
Total Grassland^c	97 (85.09%)	17 (14.91%)
Cropland^d	12 (10.53%)	102 (89.47%)
Trees/ha^e	27 (23.68%)	87 (76.32%)
Anthropogenic^f Structures/ha	0 (0%)	114 (100%)

^a Leks with ≥ 10 birds in attendance have a greater likelihood of persistence

^b 60% native grassland

^c Native grassland + CRP grassland

^d $< 40\%$ for persistence

^e ≥ 2 trees/ha- avoid nesting

^f ≤ 2 Anthropogenic structures/ha

Table 3.3. Total number (%) of lesser prairie-chicken leks above or below established landscape thresholds (lek attendance, native grassland, total grassland, cropland, trees/ha, anthropogenic structures) in the Mixed-Grass Prairie Ecoregion in Kansas, USA. Lek attendance was determined using average male attendance during 2018-2023.

Threshold	Status	
	Above	Below
Lek Attendance^a	6 (5.7%)	100 (94.3%)
Native Grassland^b	59 (55.7%)	47 (44.3%)
Total Grassland^c	70 (66.0%)	36 (34.0%)
Cropland^d	24 (22.6%)	82 (77.4%)
Trees/ha^e	33 (31.1%)	73 (68.9%)
Anthropogenic^f Structures/ha	0 (0%)	106 (100%)

^a Leks with ≥ 10 birds in attendance have a greater likelihood of persistence

^b 60% native grassland

^c Native grassland + CRP grassland

^d $< 40\%$ for persistence

^e ≥ 2 trees/ha- avoid nesting

^f ≤ 2 Anthropogenic structures/ha

Table 3.4. Total number (%) of lesser prairie-chicken leks above or below established landscape thresholds (lek attendance, native grassland, total grassland, cropland, trees/ha, anthropogenic structures) in the Sand Sagebrush Prairie Ecoregion in Kansas, USA. Lek attendance was determined using average male attendance during 2018-2023.

Threshold	Status	
	Above	Below
Lek Attendance^a	12 (10.4%)	103 (89.6%)
Native Grassland^b	69 (60.0%)	46 (40.0%)
Total Grassland^c	96 (83.5%)	19 (16.5%)
Cropland^d	12 (10.4%)	103 (89.6%)
Trees/ha^e	0 (0%)	115 (100%)
Anthropogenic^f Structures/ha	0 (0%)	115 (100%)

^a Leks with ≥ 10 birds in attendance have a greater likelihood of persistence

^b 60% native grassland

^c Native grassland + CRP grassland

^d $< 40\%$ for persistence

^e ≥ 2 trees/ha- avoid nesting

^f ≤ 2 Anthropogenic structures/ha

Table 3.5. Total number (%) of lesser prairie-chicken leks above or below established landscape thresholds for anthropogenic structures per 5-km radius in the Short-Grass Prairie/CRP Mosaic Ecoregion in Kansas, USA. Lek attendance was determined using average male attendance during 2018-2023.

Threshold	Status	
	Above	Below
Oil/Gas Wells^a	111 (97.37%)	3 (2.63%)
Vertical Structures^b	4 (3.51%)	110 (96.49%)
Transmission Lines^c	24 (21.05%)	90 (78.95%)
Roads^d	114 (100%)	0 (0%)

^a ≥ 13 oil/gas wells

^b ≥ 13 combined cellular towers and wind turbines

^c 0.94 km of transmission lines

^d 0.94 km of roads (gravel/paved)

Table 3.6. Total number (%) of lesser prairie-chicken leks above or below established landscape thresholds for anthropogenic structures per 5-km radius in the Mixed-Grass Prairie Ecoregion in Kansas, USA. Lek attendance was determined using average male attendance during 2018-2023.

Threshold	Status	
	Above	Below
Oil/Gas Wells^a	103 (97.17%)	3 (2.83%)
Vertical Structures^b	1 (0.94%)	105 (99.06%)
Transmission Lines^c	22 (20.75%)	84 (79.25%)
Roads^d	106 (100%)	0 (0%)

^a ≥ 13 oil/gas wells

^b ≥ 13 combined cellular towers and wind turbines

^c 0.94 km of transmission lines

^d 0.94 km of roads (gravel/paved)

Table 3.7. Total number (%) of lesser prairie-chicken leks above or below established landscape thresholds for anthropogenic structures per 5-km radius in the Sand Sagebrush Prairie Ecoregion in Kansas, USA. Lek attendance was determined using average male attendance during 2018-2023.

Threshold	Status	
	Above	Below
Oil/Gas Wells^a	88 (76.52%)	27 (23.48%)
Vertical Structures^b	0 (0%)	115 (100%)
Transmission Lines^c	33 (28.70%)	82 (71.30%)
Roads^d	115 (100%)	0 (0%)

^a ≥ 13 oil/gas wells

^b ≥ 13 combined cellular towers and wind turbines

^c 0.94 km of transmission lines

^d 0.94 km of roads (gravel/paved)

Figures

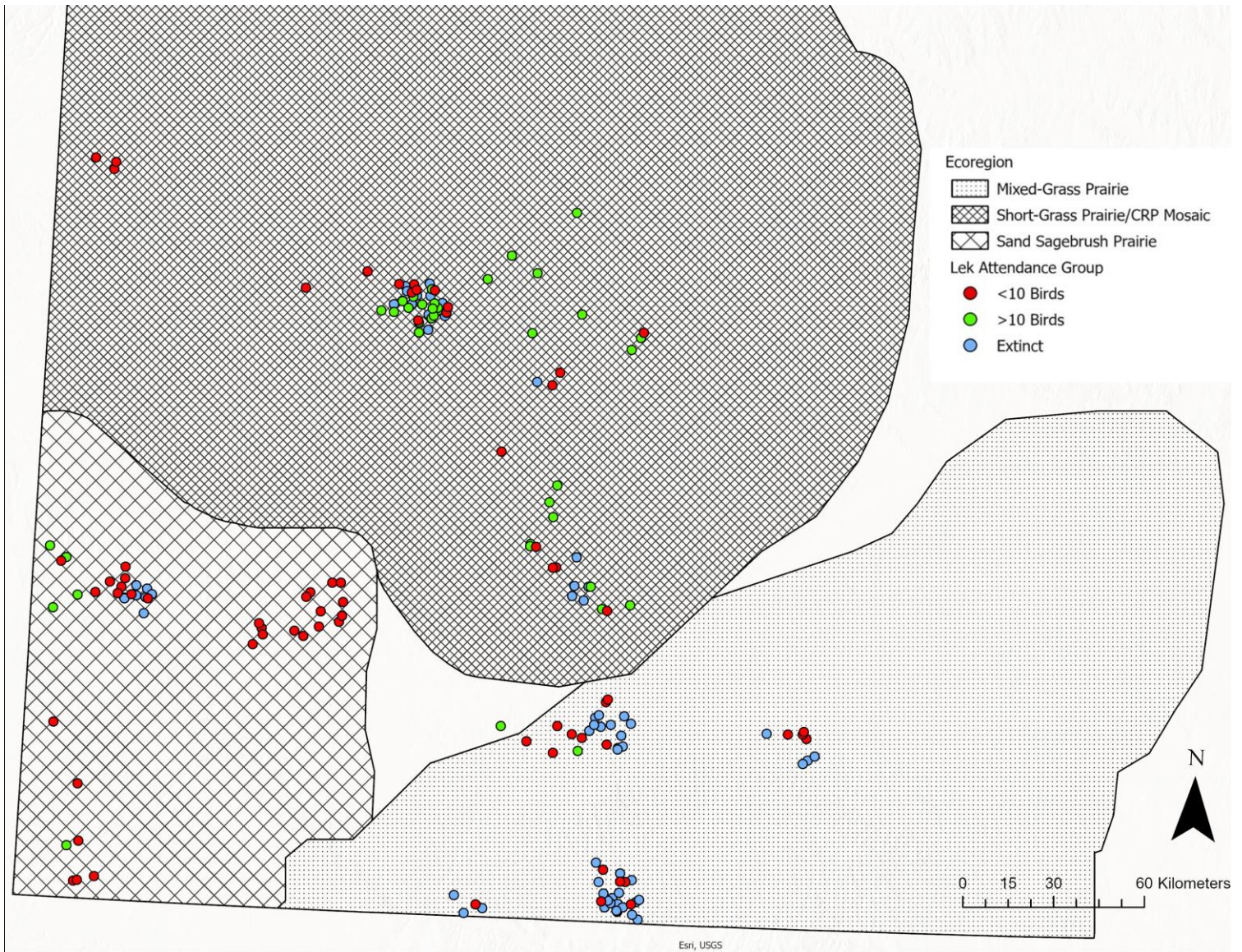


Figure 3.1. Lesser prairie-chicken leks observed in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023 that were below the established threshold of $\geq 60\%$ grassland.

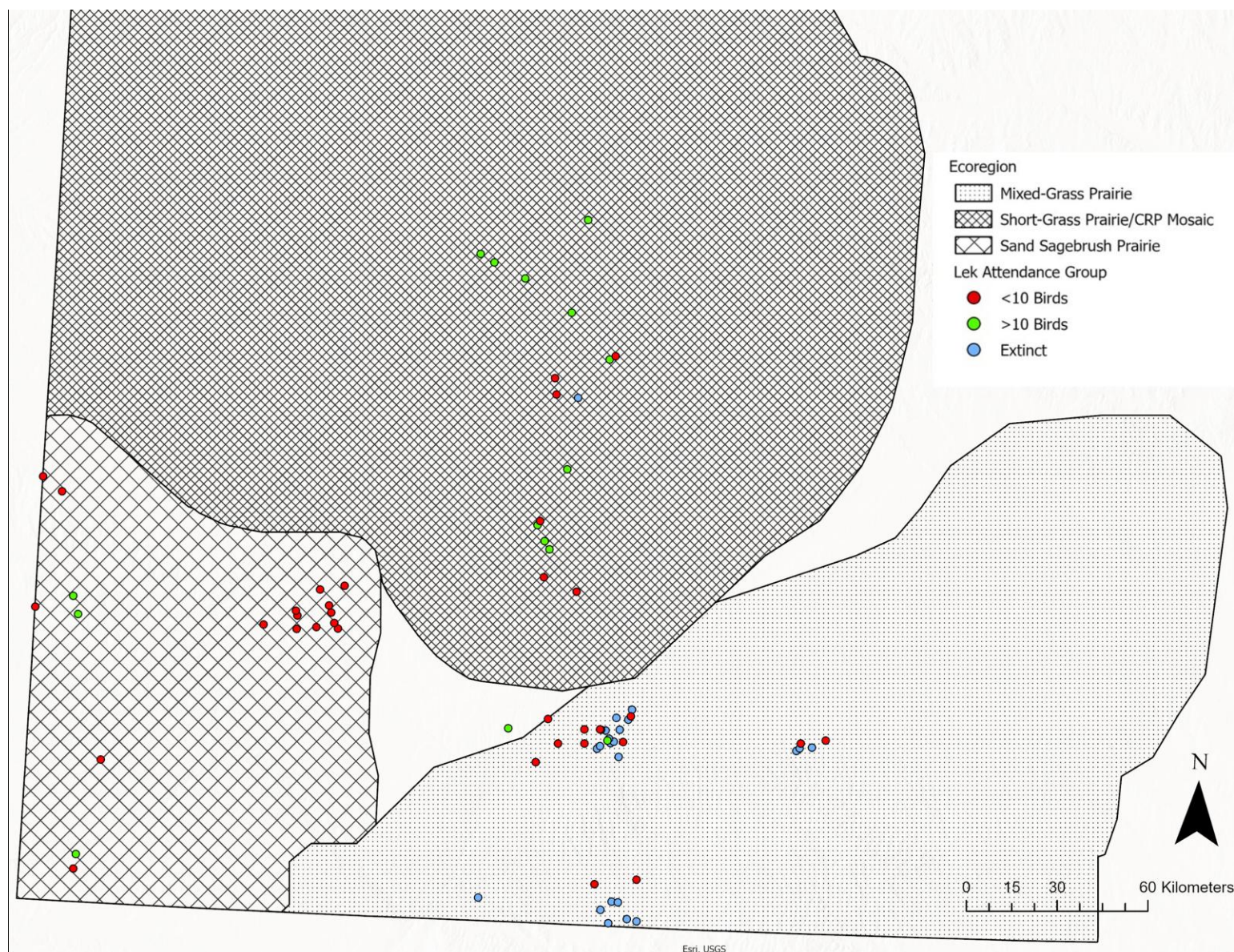


Figure 3.2. Lesser prairie-chicken leks observed in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023 that were below the established threshold of $\geq 60\%$ grassland when CRP grassland was included in land cover estimates.

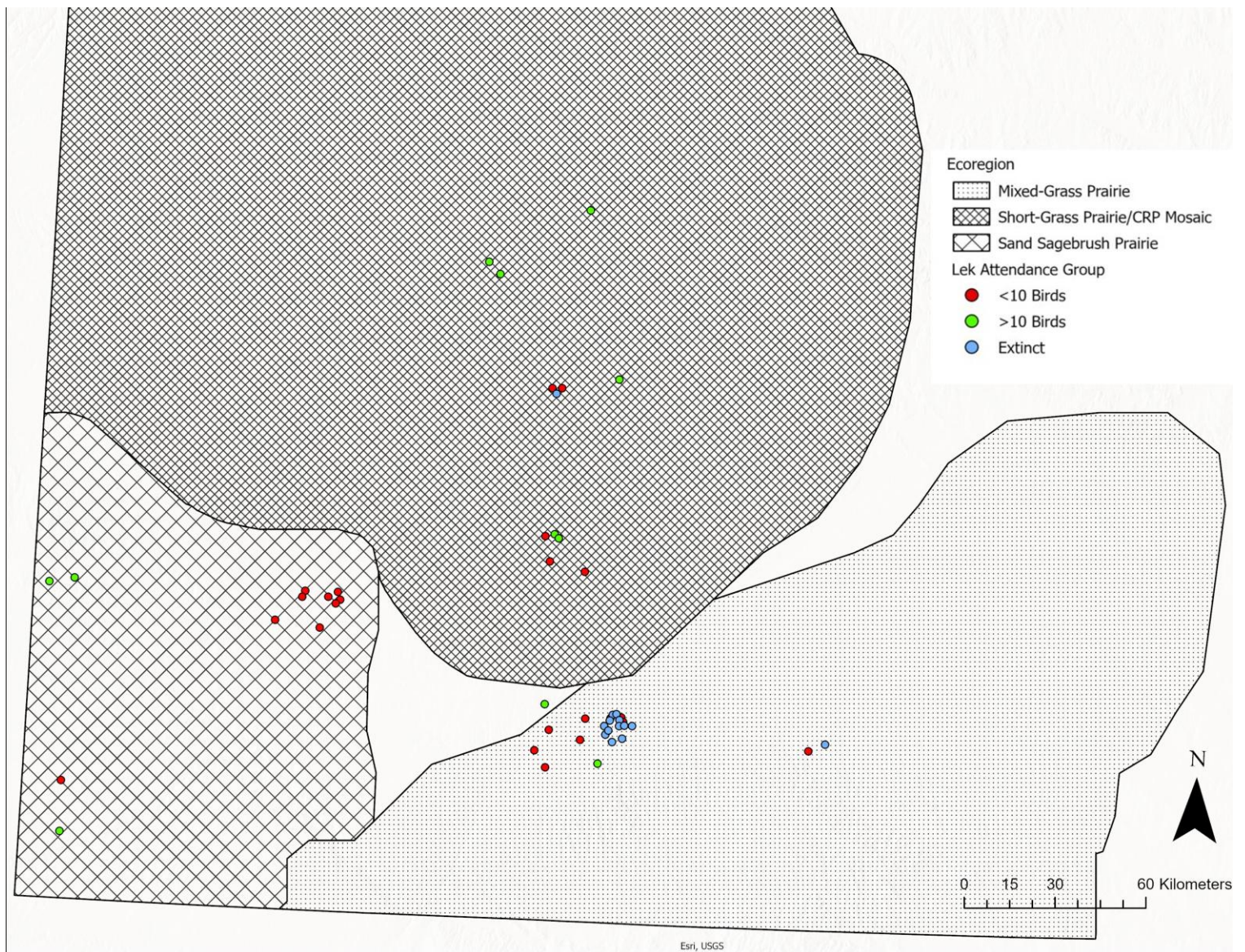


Figure 3.3. Lesser prairie-chicken leks observed in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023 that exceeded the established threshold of <40% cropland.

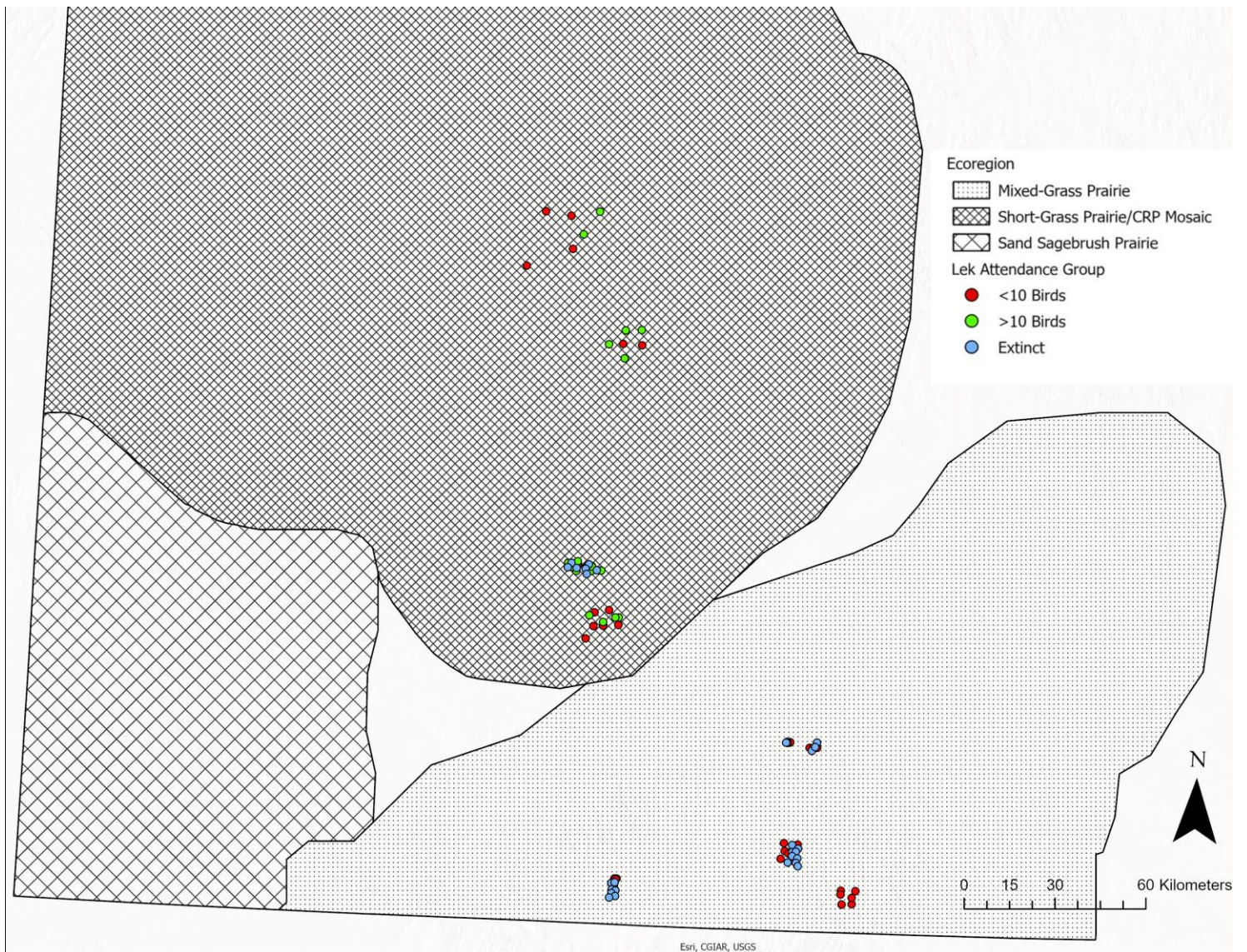


Figure 3.4. Lesser prairie-chicken leks observed in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023 that exceeded the established threshold of ≤ 2 trees/ha.

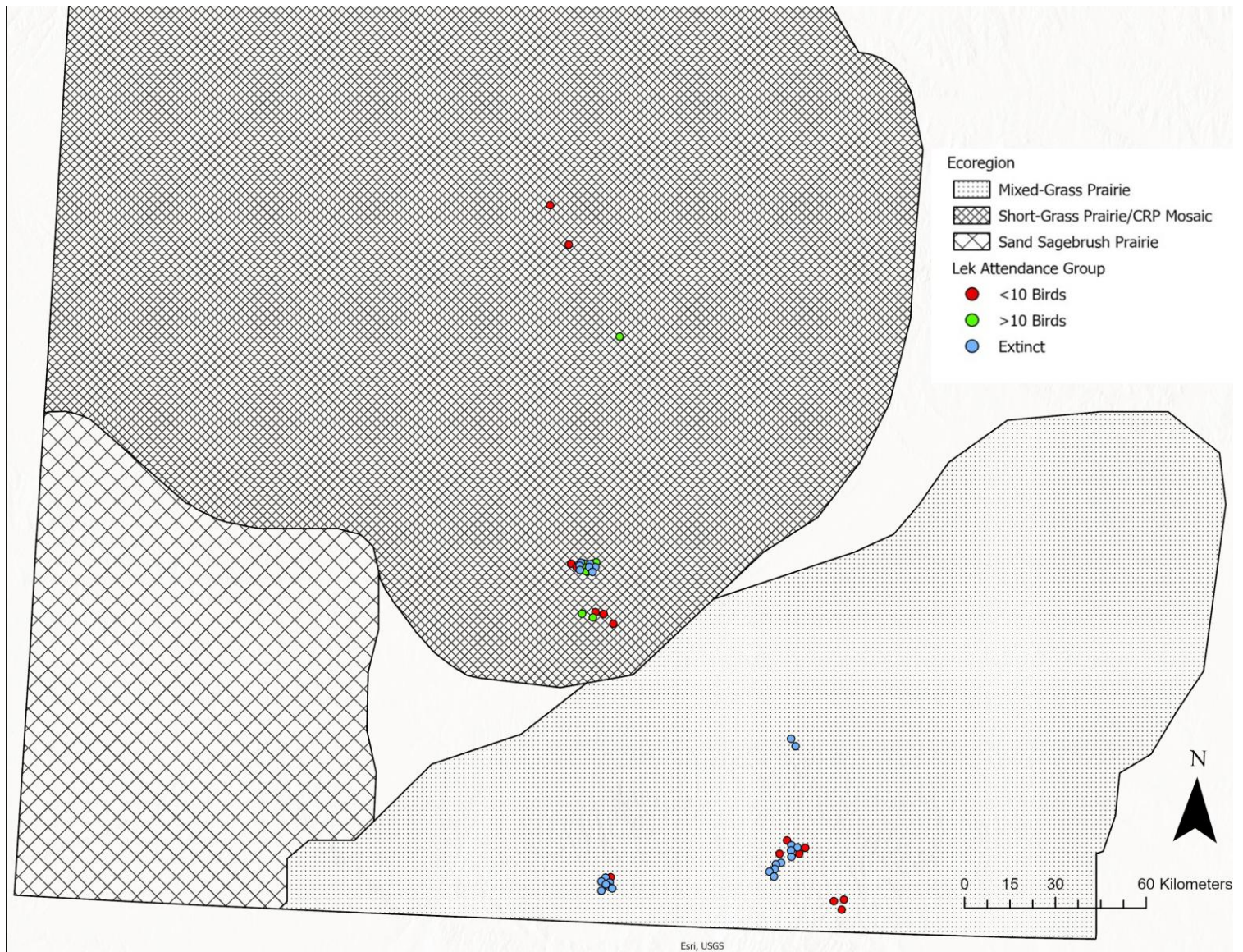


Figure 3.5. Lesser prairie-chicken leks observed in the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, during 2018-2023 that were below the established threshold of $\geq 60\%$ grassland and exceeded the threshold of ≤ 2 trees/ha.

Appendix A - Chapter 3 Supplemental Data

Appendix Table A.1. Land cover variables were measured within 5 km of lesser prairie-chicken leks within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, from 2018-2023. A threshold status (Above/Below) was assigned to each lek for average lek attendance, proportion of native grassland, total grassland, cropland, trees/ha, and anthropogenic structures/ha.

			Native Grassland		Total Grassland		Cropland		Trees/ha	Anthropogenic Structures		
Lek ID	Ecoregion	Lek Attendance Group	%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
1	SGPR/CRP	<10	43%	Below Threshold	24%	67%	Above Threshold	31%	Below Threshold	1.38	Below threshold	Below threshold
2	SGPR/CRP	<10	39%	Below Threshold	38%	77%	Above Threshold	21%	Below Threshold	0.33	Below threshold	Below threshold
3	SGPR/CRP	<10	41%	Below Threshold	26%	68%	Above Threshold	30%	Below Threshold	1.29	Below threshold	Below threshold
4	SGPR/CRP	<10	45%	Below Threshold	38%	83%	Above Threshold	13%	Below Threshold	0.13	Below threshold	Below threshold
5	SGPR/CRP	<10	46%	Below Threshold	35%	81%	Above Threshold	15%	Below Threshold	0.10	Below threshold	Below threshold
6	SGPR/CRP	<10	44%	Below Threshold	33%	77%	Above Threshold	19%	Below Threshold	0.21	Below threshold	Below threshold
7	SGPR/CRP	<10	40%	Below Threshold	37%	77%	Above Threshold	20%	Below Threshold	0.31	Below threshold	Below threshold
8	SGPR/CRP	<10	46%	Below Threshold	31%	77%	Above Threshold	19%	Below Threshold	0.46	Below threshold	Below threshold
9	SGPR/CRP	<10	65%	Above Threshold	13%	79%	Above Threshold	18%	Below Threshold	3.03	Above threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland			Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status		Density	Threshold Status	Threshold Status
10	SGPR/CRP	<10	69%	Above Threshold	10%	79%	Above Threshold	17%	Below Threshold		2.90	Above threshold	Below threshold
11	SGPR/CRP	<10	64%	Above Threshold	15%	79%	Above Threshold	18%	Below Threshold		2.35	Above threshold	Below threshold
12	SGPR/CRP	<10	61%	Above Threshold	15%	75%	Above Threshold	21%	Below Threshold		2.77	Above threshold	Below threshold
13	SGPR/CRP	<10	40%	Below Threshold	12%	52%	Below Threshold	45%	Above Threshold		0.41	Below threshold	Below threshold
14	SGPR/CRP	<10	62%	Above Threshold	13%	75%	Above Threshold	19%	Below Threshold		3.94	Above threshold	Below threshold
15	SGPR/CRP	<10	54%	Below Threshold	1%	55%	Below Threshold	43%	Above Threshold		0.85	Below threshold	Below threshold
16	SGPR/CRP	<10	63%	Above Threshold	2%	64%	Above Threshold	33%	Below Threshold		0.63	Below threshold	Below threshold
17	SGPR/CRP	<10	53%	Below Threshold	1%	54%	Below Threshold	44%	Above Threshold		0.82	Below threshold	Below threshold
18	SGPR/CRP	<10	82%	Above Threshold	5%	87%	Above Threshold	11%	Below Threshold		0.81	Below threshold	Below threshold
19	SGPR/CRP	<10	75%	Above Threshold	12%	87%	Above Threshold	10%	Below Threshold		1.68	Below threshold	Below threshold
20	SGPR/CRP	<10	63%	Above Threshold	2%	65%	Above Threshold	33%	Below Threshold		0.80	Below threshold	Below threshold
21	SGPR/CRP	<10	67%	Above Threshold	4%	71%	Above Threshold	27%	Below Threshold		1.08	Below threshold	Below threshold
22	SGPR/CRP	<10	60%	Above Threshold	9%	69%	Above Threshold	29%	Below Threshold		0.42	Below threshold	Below threshold
23	SGPR/CRP	<10	64%	Above Threshold	5%	68%	Above Threshold	30%	Below Threshold		0.79	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
24	SGPR/CRP	<10	57%	Below Threshold	10%	67%	Above Threshold	31%	Below Threshold	0.20	Below threshold	Below threshold
25	SGPR/CRP	<10	51%	Below Threshold	15%	66%	Above Threshold	32%	Below Threshold	3.16	Above threshold	Below threshold
26	SGPR/CRP	<10	60%	Above Threshold	8%	68%	Above Threshold	30%	Below Threshold	0.15	Below threshold	Below threshold
27	SGPR/CRP	<10	37%	Below Threshold	27%	64%	Above Threshold	33%	Below Threshold	0.23	Below threshold	Below threshold
28	SGPR/CRP	<10	47%	Below Threshold	15%	62%	Above Threshold	36%	Below Threshold	0.55	Below threshold	Below threshold
29	SGPR/CRP	<10	52%	Below Threshold	19%	72%	Above Threshold	26%	Below Threshold	0.76	Below threshold	Below threshold
30	SGPR/CRP	<10	55%	Below Threshold	4%	58%	Below Threshold	39%	Below Threshold	2.59	Above threshold	Below threshold
31	SGPR/CRP	<10	70%	Above Threshold	5%	75%	Above Threshold	23%	Below Threshold	2.84	Above threshold	Below threshold
32	SGPR/CRP	<10	39%	Below Threshold	28%	66%	Above Threshold	31%	Below Threshold	0.22	Below threshold	Below threshold
33	SGPR/CRP	<10	37%	Below Threshold	27%	64%	Above Threshold	33%	Below Threshold	0.21	Below threshold	Below threshold
34	SGPR/CRP	<10	47%	Below Threshold	6%	52%	Below Threshold	45%	Above Threshold	0.99	Below threshold	Below threshold
35	SGPR/CRP	<10	64%	Above Threshold	2%	66%	Above Threshold	30%	Below Threshold	2.15	Above threshold	Below threshold
36	SGPR/CRP	<10	66%	Above Threshold	2%	68%	Above Threshold	28%	Below Threshold	1.94	Below threshold	Below threshold
37	SGPR/CRP	<10	61%	Above Threshold	3%	64%	Above Threshold	32%	Below Threshold	3.97	Above threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
38	SGPR/CRP	<10	52%	Below Threshold	3%	55%	Below Threshold	40%	Above Threshold	0.36	Below threshold	Below threshold
39	SGPR/CRP	<10	63%	Above Threshold	9%	72%	Above Threshold	26%	Below Threshold	3.31	Above threshold	Below threshold
40	SGPR/CRP	≥10	44%	Below Threshold	33%	77%	Above Threshold	18%	Below Threshold	0.48	Below threshold	Below threshold
41	SGPR/CRP	≥10	45%	Below Threshold	30%	75%	Above Threshold	22%	Below Threshold	0.44	Below threshold	Below threshold
42	SGPR/CRP	≥10	38%	Below Threshold	43%	81%	Above Threshold	15%	Below Threshold	0.15	Below threshold	Below threshold
43	SGPR/CRP	≥10	42%	Below Threshold	26%	68%	Above Threshold	30%	Below Threshold	1.31	Below threshold	Below threshold
44	SGPR/CRP	≥10	42%	Below Threshold	29%	71%	Above Threshold	26%	Below Threshold	1.10	Below threshold	Below threshold
45	SGPR/CRP	≥10	45%	Below Threshold	29%	74%	Above Threshold	22%	Below Threshold	0.48	Below threshold	Below threshold
46	SGPR/CRP	≥10	43%	Below Threshold	26%	68%	Above Threshold	30%	Below Threshold	1.21	Below threshold	Below threshold
47	SGPR/CRP	≥10	59%	Below Threshold	17%	75%	Above Threshold	23%	Below Threshold	0.74	Below threshold	Below threshold
48	SGPR/CRP	≥10	66%	Above Threshold	12%	77%	Above Threshold	19%	Below Threshold	2.51	Above threshold	Below threshold
49	SGPR/CRP	≥10	61%	Above Threshold	15%	75%	Above Threshold	21%	Below Threshold	2.48	Above threshold	Below threshold
50	SGPR/CRP	≥10	65%	Above Threshold	8%	73%	Above Threshold	21%	Below Threshold	2.15	Above threshold	Below threshold
51	SGPR/CRP	≥10	62%	Above Threshold	13%	75%	Above Threshold	19%	Below Threshold	3.92	Above threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
52	SGPR/CRP	≥10	79%	Above Threshold	8%	87%	Above Threshold	11%	Below Threshold	1.26	Below threshold	Below threshold
53	SGPR/CRP	≥10	61%	Above Threshold	1%	62%	Above Threshold	36%	Below Threshold	0.80	Below threshold	Below threshold
54	SGPR/CRP	≥10	72%	Above Threshold	15%	87%	Above Threshold	10%	Below Threshold	1.98	Below threshold	Below threshold
55	SGPR/CRP	≥10	73%	Above Threshold	8%	82%	Above Threshold	15%	Below Threshold	1.47	Below threshold	Below threshold
56	SGPR/CRP	≥10	67%	Above Threshold	4%	71%	Above Threshold	27%	Below Threshold	1.06	Below threshold	Below threshold
57	SGPR/CRP	≥10	62%	Above Threshold	7%	69%	Above Threshold	29%	Below Threshold	1.01	Below threshold	Below threshold
58	SGPR/CRP	≥10	43%	Below Threshold	16%	59%	Above Threshold	39%	Below Threshold	0.88	Below threshold	Below threshold
59	SGPR/CRP	≥10	42%	Below Threshold	17%	58%	Below Threshold	39%	Below Threshold	0.88	Below threshold	Below threshold
60	SGPR/CRP	≥10	60%	Above Threshold	5%	65%	Above Threshold	33%	Below Threshold	0.32	Below threshold	Below threshold
61	SGPR/CRP	≥10	63%	Above Threshold	12%	75%	Above Threshold	22%	Below Threshold	0.23	Below threshold	Below threshold
62	SGPR/CRP	≥10	42%	Below Threshold	5%	47%	Below Threshold	50%	Above Threshold	0.53	Below threshold	Below threshold
63	SGPR/CRP	≥10	53%	Below Threshold	6%	59%	Below Threshold	39%	Below Threshold	1.94	Below threshold	Below threshold
64	SGPR/CRP	≥10	38%	Below Threshold	39%	77%	Above Threshold	18%	Below Threshold	0.15	Below threshold	Below threshold
65	SGPR/CRP	≥10	43%	Below Threshold	36%	79%	Above Threshold	17%	Below Threshold	0.10	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
66	SGPR/CRP	≥10	45%	Below Threshold	36%	81%	Above Threshold	15%	Below Threshold	0.09	Below threshold	Below threshold
67	SGPR/CRP	≥10	40%	Below Threshold	42%	82%	Above Threshold	15%	Below Threshold	0.10	Below threshold	Below threshold
68	SGPR/CRP	≥10	51%	Below Threshold	5%	56%	Below Threshold	38%	Below Threshold	1.41	Below threshold	Below threshold
69	SGPR/CRP	≥10	42%	Below Threshold	35%	76%	Above Threshold	20%	Below Threshold	0.10	Below threshold	Below threshold
70	SGPR/CRP	≥10	59%	Below Threshold	12%	72%	Above Threshold	16%	Below Threshold	1.20	Below threshold	Below threshold
71	SGPR/CRP	≥10	60%	Above Threshold	5%	66%	Above Threshold	28%	Below Threshold	0.87	Below threshold	Below threshold
72	SGPR/CRP	≥10	47%	Below Threshold	6%	53%	Below Threshold	45%	Above Threshold	1.35	Below threshold	Below threshold
73	SGPR/CRP	≥10	48%	Below Threshold	6%	54%	Below Threshold	44%	Above Threshold	1.26	Below threshold	Below threshold
74	SGPR/CRP	≥10	53%	Below Threshold	4%	57%	Below Threshold	36%	Below Threshold	1.59	Below threshold	Below threshold
75	SGPR/CRP	≥10	56%	Below Threshold	1%	57%	Below Threshold	41%	Above Threshold	2.85	Above threshold	Below threshold
76	SGPR/CRP	≥10	56%	Below Threshold	4%	59%	Above Threshold	31%	Below Threshold	5.36	Above threshold	Below threshold
77	SGPR/CRP	≥10	48%	Below Threshold	18%	67%	Above Threshold	32%	Below Threshold	2.31	Above threshold	Below threshold
78	SGPR/CRP	≥10	44%	Below Threshold	5%	49%	Below Threshold	48%	Above Threshold	0.50	Below threshold	Below threshold
79	SGPR/CRP	≥10	34%	Below Threshold	32%	66%	Above Threshold	31%	Below Threshold	0.30	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland		Total Grassland		Cropland		Trees/ha		Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
80	SGPR/CRP	≥10	38%	Below Threshold	43%	81%	Above Threshold	16%	Below Threshold	0.15	Below threshold	Below threshold
81	SGPR/CRP	≥10	50%	Below Threshold	30%	80%	Above Threshold	16%	Below Threshold	0.04	Below threshold	Below threshold
82	SGPR/CRP	≥10	53%	Below Threshold	29%	82%	Above Threshold	13%	Below Threshold	0.19	Below threshold	Below threshold
83	SGPR/CRP	≥10	50%	Below Threshold	5%	55%	Below Threshold	41%	Above Threshold	4.20	Above threshold	Below threshold
84	SGPR/CRP	≥10	54%	Below Threshold	16%	70%	Above Threshold	28%	Below Threshold	2.55	Above threshold	Below threshold
85	SGPR/CRP	Extinct	44%	Below Threshold	33%	77%	Above Threshold	18%	Below Threshold	0.46	Below threshold	Below threshold
86	SGPR/CRP	Extinct	39%	Below Threshold	40%	80%	Above Threshold	17%	Below Threshold	0.09	Below threshold	Below threshold
87	SGPR/CRP	Extinct	38%	Below Threshold	32%	69%	Above Threshold	29%	Below Threshold	0.89	Below threshold	Below threshold
88	SGPR/CRP	Extinct	39%	Below Threshold	33%	72%	Above Threshold	26%	Below Threshold	0.50	Below threshold	Below threshold
89	SGPR/CRP	Extinct	40%	Below Threshold	41%	81%	Above Threshold	16%	Below Threshold	0.10	Below threshold	Below threshold
90	SGPR/CRP	Extinct	44%	Below Threshold	26%	70%	Above Threshold	28%	Below Threshold	1.04	Below threshold	Below threshold
91	SGPR/CRP	Extinct	45%	Below Threshold	27%	72%	Above Threshold	26%	Below Threshold	0.63	Below threshold	Below threshold
92	SGPR/CRP	Extinct	38%	Below Threshold	39%	76%	Above Threshold	21%	Below Threshold	0.03	Below threshold	Below threshold
93	SGPR/CRP	Extinct	43%	Below Threshold	24%	67%	Above Threshold	31%	Below Threshold	1.38	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
94	SGPR/CRP	Extinct	39%	Below Threshold	39%	78%	Above Threshold	19%	Below Threshold	0.05	Below threshold	Below threshold
95	SGPR/CRP	Extinct	47%	Below Threshold	29%	76%	Above Threshold	20%	Below Threshold	0.33	Below threshold	Below threshold
96	SGPR/CRP	Extinct	62%	Above Threshold	15%	76%	Above Threshold	20%	Below Threshold	3.02	Above threshold	Below threshold
97	SGPR/CRP	Extinct	58%	Below Threshold	11%	69%	Above Threshold	28%	Below Threshold	1.04	Below threshold	Below threshold
98	SGPR/CRP	Extinct	69%	Above Threshold	10%	79%	Above Threshold	17%	Below Threshold	2.90	Above threshold	Below threshold
99	SGPR/CRP	Extinct	69%	Above Threshold	9%	78%	Above Threshold	17%	Below Threshold	2.76	Above threshold	Below threshold
100	SGPR/CRP	Extinct	47%	Below Threshold	15%	62%	Above Threshold	35%	Below Threshold	0.46	Below threshold	Below threshold
101	SGPR/CRP	Extinct	64%	Above Threshold	10%	74%	Above Threshold	22%	Below Threshold	2.08	Above threshold	Below threshold
102	SGPR/CRP	Extinct	62%	Above Threshold	13%	75%	Above Threshold	19%	Below Threshold	4.53	Above threshold	Below threshold
103	SGPR/CRP	Extinct	61%	Above Threshold	15%	76%	Above Threshold	21%	Below Threshold	2.28	Above threshold	Below threshold
104	SGPR/CRP	Extinct	45%	Below Threshold	17%	62%	Above Threshold	36%	Below Threshold	0.57	Below threshold	Below threshold
105	SGPR/CRP	Extinct	52%	Below Threshold	14%	66%	Above Threshold	32%	Below Threshold	0.83	Below threshold	Below threshold
106	SGPR/CRP	Extinct	63%	Above Threshold	14%	77%	Above Threshold	19%	Below Threshold	2.69	Above threshold	Below threshold
107	SGPR/CRP	Extinct	46%	Below Threshold	14%	60%	Above Threshold	37%	Below Threshold	0.61	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
108	SGPR/CRP	Extinct	61%	Above Threshold	9%	70%	Above Threshold	26%	Below Threshold	1.54	Below threshold	Below threshold
109	SGPR/CRP	Extinct	83%	Above Threshold	5%	88%	Above Threshold	10%	Below Threshold	0.45	Below threshold	Below threshold
110	SGPR/CRP	Extinct	79%	Above Threshold	8%	87%	Above Threshold	11%	Below Threshold	0.94	Below threshold	Below threshold
111	SGPR/CRP	Extinct	73%	Above Threshold	13%	87%	Above Threshold	11%	Below Threshold	1.69	Below threshold	Below threshold
112	SGPR/CRP	Extinct	64%	Above Threshold	3%	66%	Above Threshold	32%	Below Threshold	0.62	Below threshold	Below threshold
113	SGPR/CRP	Extinct	77%	Above Threshold	9%	87%	Above Threshold	11%	Below Threshold	1.37	Below threshold	Below threshold
114	SGPR/CRP	Extinct	51%	Below Threshold	0%	51%	Below Threshold	47%	Above Threshold	0.91	Below threshold	Below threshold
115	MGPR	<10	74%	Above Threshold	0%	74%	Above Threshold	3%	Below Threshold	2.32	Above threshold	Below threshold
116	MGPR	<10	73%	Above Threshold	0%	73%	Above Threshold	0%	Below Threshold	2.07	Above threshold	Below threshold
117	MGPR	<10	65%	Above Threshold	0%	65%	Above Threshold	3%	Below Threshold	3.11	Above threshold	Below threshold
118	MGPR	<10	60%	Above Threshold	4%	64%	Above Threshold	11%	Below Threshold	1.48	Below threshold	Below threshold
119	MGPR	<10	59%	Below Threshold	5%	64%	Above Threshold	13%	Below Threshold	1.73	Below threshold	Below threshold
120	MGPR	<10	55%	Below Threshold	13%	68%	Above Threshold	23%	Below Threshold	1.96	Below threshold	Below threshold
121	MGPR	<10	61%	Above Threshold	4%	65%	Above Threshold	11%	Below Threshold	1.72	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
122	MGPR	<10	88%	Above Threshold	1%	89%	Above Threshold	7%	Below Threshold	3.15	Above threshold	Below threshold
123	MGPR	<10	42%	Below Threshold	12%	53%	Below Threshold	44%	Above Threshold	1.16	Below threshold	Below threshold
124	MGPR	<10	43%	Below Threshold	12%	55%	Below Threshold	43%	Above Threshold	1.39	Below threshold	Below threshold
125	MGPR	<10	41%	Below Threshold	13%	54%	Below Threshold	43%	Above Threshold	0.97	Below threshold	Below threshold
126	MGPR	<10	45%	Below Threshold	7%	52%	Below Threshold	45%	Above Threshold	2.33	Above threshold	Below threshold
127	MGPR	<10	59%	Below Threshold	10%	69%	Above Threshold	24%	Below Threshold	3.70	Above threshold	Below threshold
128	MGPR	<10	58%	Below Threshold	10%	68%	Above Threshold	24%	Below Threshold	3.70	Above threshold	Below threshold
129	MGPR	<10	50%	Below Threshold	7%	57%	Below Threshold	39%	Below Threshold	2.91	Above threshold	Below threshold
130	MGPR	<10	71%	Above Threshold	19%	90%	Above Threshold	7%	Below Threshold	1.11	Below threshold	Below threshold
131	MGPR	<10	74%	Above Threshold	17%	91%	Above Threshold	5%	Below Threshold	1.14	Below threshold	Below threshold
132	MGPR	<10	54%	Below Threshold	14%	67%	Above Threshold	5%	Below Threshold	0.77	Below threshold	Below threshold
133	MGPR	<10	91%	Above Threshold	0%	91%	Above Threshold	4%	Below Threshold	3.98	Above threshold	Below threshold
134	MGPR	<10	47%	Below Threshold	13%	59%	Below Threshold	38%	Below Threshold	2.00	Above threshold	Below threshold
135	MGPR	<10	47%	Below Threshold	13%	59%	Below Threshold	38%	Below Threshold	2.00	Above threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
136	MGPR	<10	50%	Below Threshold	13%	62%	Above Threshold	33%	Below Threshold	2.04	Above threshold	Below threshold
137	MGPR	<10	90%	Above Threshold	0%	90%	Above Threshold	7%	Below Threshold	4.25	Above threshold	Below threshold
138	MGPR	<10	72%	Above Threshold	2%	74%	Above Threshold	2%	Below Threshold	0.64	Below threshold	Below threshold
139	MGPR	<10	67%	Above Threshold	11%	78%	Above Threshold	12%	Below Threshold	1.54	Below threshold	Below threshold
140	MGPR	<10	82%	Above Threshold	6%	88%	Above Threshold	10%	Below Threshold	0.39	Below threshold	Below threshold
141	MGPR	<10	64%	Above Threshold	13%	77%	Above Threshold	22%	Below Threshold	1.68	Below threshold	Below threshold
142	MGPR	<10	27%	Below Threshold	11%	38%	Below Threshold	55%	Above Threshold	0.49	Below threshold	Below threshold
143	MGPR	<10	10%	Below Threshold	0%	10%	Below Threshold	87%	Above Threshold	0.26	Below threshold	Below threshold
144	MGPR	<10	35%	Below Threshold	11%	46%	Below Threshold	52%	Above Threshold	0.24	Below threshold	Below threshold
145	MGPR	<10	19%	Below Threshold	7%	26%	Below Threshold	69%	Above Threshold	0.95	Below threshold	Below threshold
146	MGPR	<10	27%	Below Threshold	4%	31%	Below Threshold	65%	Above Threshold	0.26	Below threshold	Below threshold
147	MGPR	≥10	82%	Above Threshold	7%	89%	Above Threshold	9%	Below Threshold	0.25	Below threshold	Below threshold
148	MGPR	≥10	83%	Above Threshold	6%	89%	Above Threshold	10%	Below Threshold	0.37	Below threshold	Below threshold
149	MGPR	≥10	65%	Above Threshold	13%	78%	Above Threshold	19%	Below Threshold	1.17	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
150	MGPR	≥10	65%	Above Threshold	5%	70%	Above Threshold	22%	Below Threshold	1.13	Below threshold	Below threshold
151	MGPR	≥10	27%	Below Threshold	8%	36%	Below Threshold	62%	Above Threshold	0.21	Below threshold	Below threshold
152	MGPR	≥10	29%	Below Threshold	12%	41%	Below Threshold	59%	Above Threshold	0.19	Below threshold	Below threshold
153	MGPR	Extinct	66%	Above Threshold	1%	67%	Above Threshold	7%	Below Threshold	1.29	Below threshold	Below threshold
154	MGPR	Extinct	55%	Below Threshold	2%	57%	Below Threshold	5%	Below Threshold	0.79	Below threshold	Below threshold
155	MGPR	Extinct	66%	Above Threshold	0%	66%	Above Threshold	4%	Below Threshold	1.03	Below threshold	Below threshold
156	MGPR	Extinct	47%	Below Threshold	13%	60%	Above Threshold	38%	Below Threshold	2.02	Above threshold	Below threshold
157	MGPR	Extinct	59%	Below Threshold	1%	60%	Above Threshold	5%	Below Threshold	0.94	Below threshold	Below threshold
158	MGPR	Extinct	58%	Below Threshold	9%	67%	Above Threshold	16%	Below Threshold	1.93	Below threshold	Below threshold
159	MGPR	Extinct	59%	Below Threshold	3%	62%	Above Threshold	12%	Below Threshold	1.26	Below threshold	Below threshold
160	MGPR	Extinct	45%	Below Threshold	0%	45%	Below Threshold	4%	Below Threshold	0.24	Below threshold	Below threshold
161	MGPR	Extinct	64%	Above Threshold	0%	64%	Above Threshold	4%	Below Threshold	0.79	Below threshold	Below threshold
162	MGPR	Extinct	49%	Below Threshold	2%	52%	Below Threshold	5%	Below Threshold	0.54	Below threshold	Below threshold
163	MGPR	Extinct	57%	Below Threshold	13%	70%	Above Threshold	18%	Below Threshold	2.14	Above threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
164	MGPR	Extinct	54%	Below Threshold	13%	67%	Above Threshold	24%	Below Threshold	1.95	Below threshold	Below threshold
165	MGPR	Extinct	58%	Below Threshold	5%	63%	Above Threshold	14%	Below Threshold	1.72	Below threshold	Below threshold
166	MGPR	Extinct	56%	Below Threshold	12%	68%	Above Threshold	22%	Below Threshold	1.98	Below threshold	Below threshold
167	MGPR	Extinct	51%	Below Threshold	15%	66%	Above Threshold	30%	Below Threshold	2.27	Above threshold	Below threshold
168	MGPR	Extinct	59%	Below Threshold	12%	71%	Above Threshold	9%	Below Threshold	2.54	Above threshold	Below threshold
169	MGPR	Extinct	59%	Below Threshold	5%	64%	Above Threshold	14%	Below Threshold	1.85	Below threshold	Below threshold
170	MGPR	Extinct	63%	Above Threshold	6%	69%	Above Threshold	7%	Below Threshold	2.01	Above threshold	Below threshold
171	MGPR	Extinct	67%	Above Threshold	2%	69%	Above Threshold	5%	Below Threshold	1.60	Below threshold	Below threshold
172	MGPR	Extinct	57%	Below Threshold	0%	57%	Below Threshold	4%	Below Threshold	0.41	Below threshold	Below threshold
173	MGPR	Extinct	71%	Above Threshold	1%	72%	Above Threshold	3%	Below Threshold	1.56	Below threshold	Below threshold
174	MGPR	Extinct	61%	Above Threshold	2%	63%	Above Threshold	4%	Below Threshold	1.05	Below threshold	Below threshold
175	MGPR	Extinct	57%	Below Threshold	14%	72%	Above Threshold	11%	Below Threshold	2.26	Above threshold	Below threshold
176	MGPR	Extinct	50%	Below Threshold	0%	51%	Below Threshold	4%	Below Threshold	0.27	Below threshold	Below threshold
177	MGPR	Extinct	50%	Below Threshold	0%	50%	Below Threshold	4%	Below Threshold	0.33	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
178	MGPR	Extinct	51%	Below Threshold	13%	64%	Above Threshold	31%	Below Threshold	2.10	Above threshold	Below threshold
179	MGPR	Extinct	57%	Below Threshold	11%	67%	Above Threshold	21%	Below Threshold	1.94	Below threshold	Below threshold
180	MGPR	Extinct	62%	Above Threshold	3%	65%	Above Threshold	9%	Below Threshold	1.51	Below threshold	Below threshold
181	MGPR	Extinct	82%	Above Threshold	2%	84%	Above Threshold	12%	Below Threshold	2.71	Above threshold	Below threshold
182	MGPR	Extinct	90%	Above Threshold	0%	90%	Above Threshold	2%	Below Threshold	3.73	Above threshold	Below threshold
183	MGPR	Extinct	89%	Above Threshold	0%	90%	Above Threshold	5%	Below Threshold	3.64	Above threshold	Below threshold
184	MGPR	Extinct	95%	Above Threshold	0%	95%	Above Threshold	1%	Below Threshold	4.55	Above threshold	Below threshold
185	MGPR	Extinct	87%	Above Threshold	1%	87%	Above Threshold	8%	Below Threshold	3.51	Above threshold	Below threshold
186	MGPR	Extinct	91%	Above Threshold	0%	91%	Above Threshold	2%	Below Threshold	3.46	Above threshold	Below threshold
187	MGPR	Extinct	89%	Above Threshold	0%	89%	Above Threshold	2%	Below Threshold	3.71	Above threshold	Below threshold
188	MGPR	Extinct	92%	Above Threshold	0%	92%	Above Threshold	3%	Below Threshold	3.99	Above threshold	Below threshold
189	MGPR	Extinct	85%	Above Threshold	0%	85%	Above Threshold	7%	Below Threshold	2.55	Above threshold	Below threshold
190	MGPR	Extinct	41%	Below Threshold	11%	53%	Below Threshold	44%	Above Threshold	0.84	Below threshold	Below threshold
191	MGPR	Extinct	39%	Below Threshold	11%	50%	Below Threshold	47%	Above Threshold	0.83	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
192	MGPR	Extinct	30%	Below Threshold	9%	39%	Below Threshold	57%	Above Threshold	0.58	Below threshold	Below threshold
193	MGPR	Extinct	35%	Below Threshold	10%	45%	Below Threshold	51%	Above Threshold	0.63	Below threshold	Below threshold
194	MGPR	Extinct	38%	Below Threshold	10%	47%	Below Threshold	49%	Above Threshold	0.85	Below threshold	Below threshold
195	MGPR	Extinct	33%	Below Threshold	8%	42%	Below Threshold	55%	Above Threshold	0.69	Below threshold	Below threshold
196	MGPR	Extinct	28%	Below Threshold	9%	37%	Below Threshold	59%	Above Threshold	0.54	Below threshold	Below threshold
197	MGPR	Extinct	39%	Below Threshold	11%	51%	Below Threshold	46%	Above Threshold	0.84	Below threshold	Below threshold
198	MGPR	Extinct	40%	Below Threshold	12%	52%	Below Threshold	45%	Above Threshold	0.77	Below threshold	Below threshold
199	MGPR	Extinct	42%	Below Threshold	11%	54%	Below Threshold	43%	Above Threshold	1.02	Below threshold	Below threshold
200	MGPR	Extinct	43%	Below Threshold	12%	55%	Below Threshold	42%	Above Threshold	1.20	Below threshold	Below threshold
201	MGPR	Extinct	38%	Below Threshold	10%	49%	Below Threshold	48%	Above Threshold	0.76	Below threshold	Below threshold
202	MGPR	Extinct	46%	Below Threshold	6%	52%	Below Threshold	44%	Above Threshold	2.79	Above threshold	Below threshold
203	MGPR	Extinct	52%	Below Threshold	6%	58%	Below Threshold	37%	Below Threshold	3.50	Above threshold	Below threshold
204	MGPR	Extinct	59%	Below Threshold	7%	66%	Above Threshold	28%	Below Threshold	4.62	Above threshold	Below threshold
205	MGPR	Extinct	61%	Above Threshold	11%	72%	Above Threshold	20%	Below Threshold	4.10	Above threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
206	MGPR	Extinct	45%	Below Threshold	11%	56%	Below Threshold	38%	Below Threshold	1.98	Below threshold	Below threshold
207	MGPR	Extinct	62%	Above Threshold	16%	79%	Above Threshold	6%	Below Threshold	1.04	Below threshold	Below threshold
208	MGPR	Extinct	71%	Above Threshold	3%	74%	Above Threshold	20%	Below Threshold	0.66	Below threshold	Below threshold
209	MGPR	Extinct	64%	Above Threshold	21%	85%	Above Threshold	6%	Below Threshold	0.59	Below threshold	Below threshold
210	MGPR	Extinct	71%	Above Threshold	17%	88%	Above Threshold	9%	Below Threshold	1.27	Below threshold	Below threshold
211	MGPR	Extinct	48%	Below Threshold	10%	58%	Below Threshold	4%	Below Threshold	0.61	Below threshold	Below threshold
212	MGPR	Extinct	74%	Above Threshold	16%	91%	Above Threshold	6%	Below Threshold	1.18	Below threshold	Below threshold
213	MGPR	Extinct	66%	Above Threshold	18%	84%	Above Threshold	6%	Below Threshold	0.89	Below threshold	Below threshold
214	MGPR	Extinct	73%	Above Threshold	17%	90%	Above Threshold	6%	Below Threshold	1.11	Below threshold	Below threshold
215	MGPR	Extinct	72%	Above Threshold	5%	77%	Above Threshold	6%	Below Threshold	0.92	Below threshold	Below threshold
216	MGPR	Extinct	68%	Above Threshold	3%	70%	Above Threshold	17%	Below Threshold	0.71	Below threshold	Below threshold
217	MGPR	Extinct	56%	Below Threshold	11%	67%	Above Threshold	5%	Below Threshold	0.94	Below threshold	Below threshold
218	MGPR	Extinct	64%	Above Threshold	2%	66%	Above Threshold	16%	Below Threshold	0.70	Below threshold	Below threshold
219	MGPR	Extinct	71%	Above Threshold	8%	79%	Above Threshold	5%	Below Threshold	1.00	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
220	MGPR	Extinct	59%	Below Threshold	6%	65%	Above Threshold	2%	Below Threshold	0.98	Below threshold	Below threshold
221	SSPR	<10	54%	Below Threshold	0%	54%	Below Threshold	39%	Below Threshold	0.01	Below threshold	Below threshold
222	SSPR	<10	73%	Above Threshold	0%	73%	Above Threshold	23%	Below Threshold	0.01	Below threshold	Below threshold
223	SSPR	<10	54%	Below Threshold	0%	54%	Below Threshold	39%	Below Threshold	0.01	Below threshold	Below threshold
224	SSPR	<10	69%	Above Threshold	0%	70%	Above Threshold	26%	Below Threshold	0.01	Below threshold	Below threshold
225	SSPR	<10	70%	Above Threshold	0%	70%	Above Threshold	26%	Below Threshold	0.01	Below threshold	Below threshold
226	SSPR	<10	62%	Above Threshold	0%	62%	Above Threshold	34%	Below Threshold	0.01	Below threshold	Below threshold
227	SSPR	<10	65%	Above Threshold	0%	65%	Above Threshold	31%	Below Threshold	0.01	Below threshold	Below threshold
228	SSPR	<10	61%	Above Threshold	0%	61%	Above Threshold	34%	Below Threshold	0.01	Below threshold	Below threshold
229	SSPR	<10	52%	Below Threshold	0%	52%	Below Threshold	41%	Above Threshold	0.02	Below threshold	Below threshold
230	SSPR	<10	61%	Above Threshold	0%	61%	Above Threshold	34%	Below Threshold	0.01	Below threshold	Below threshold
231	SSPR	<10	67%	Above Threshold	0%	67%	Above Threshold	29%	Below Threshold	0.01	Below threshold	Below threshold
232	SSPR	<10	70%	Above Threshold	0%	70%	Above Threshold	24%	Below Threshold	0.01	Below threshold	Below threshold
233	SSPR	<10	72%	Above Threshold	0%	72%	Above Threshold	24%	Below Threshold	0.01	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
234	SSPR	<10	66%	Above Threshold	0%	67%	Above Threshold	29%	Below Threshold	0.01	Below threshold	Below threshold
235	SSPR	<10	48%	Below Threshold	0%	48%	Below Threshold	44%	Above Threshold	0.01	Below threshold	Below threshold
236	SSPR	<10	53%	Below Threshold	24%	76%	Above Threshold	17%	Below Threshold	0.50	Below threshold	Below threshold
237	SSPR	<10	74%	Above Threshold	15%	90%	Above Threshold	8%	Below Threshold	0.03	Below threshold	Below threshold
238	SSPR	<10	57%	Below Threshold	21%	78%	Above Threshold	15%	Below Threshold	0.29	Below threshold	Below threshold
239	SSPR	<10	77%	Above Threshold	10%	87%	Above Threshold	2%	Below Threshold	0.37	Below threshold	Below threshold
240	SSPR	<10	57%	Below Threshold	24%	81%	Above Threshold	14%	Below Threshold	0.28	Below threshold	Below threshold
241	SSPR	<10	54%	Below Threshold	21%	75%	Above Threshold	18%	Below Threshold	0.34	Below threshold	Below threshold
242	SSPR	<10	49%	Below Threshold	24%	74%	Above Threshold	19%	Below Threshold	0.79	Below threshold	Below threshold
243	SSPR	<10	20%	Below Threshold	43%	62%	Above Threshold	32%	Below Threshold	0.01	Below threshold	Below threshold
244	SSPR	<10	25%	Below Threshold	28%	53%	Below Threshold	41%	Above Threshold	0.00	Below threshold	Below threshold
245	SSPR	<10	18%	Below Threshold	49%	67%	Above Threshold	28%	Below Threshold	0.01	Below threshold	Below threshold
246	SSPR	<10	14%	Below Threshold	71%	85%	Above Threshold	11%	Below Threshold	0.01	Below threshold	Below threshold
247	SSPR	<10	25%	Below Threshold	45%	70%	Above Threshold	25%	Below Threshold	0.01	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
248	SSPR	<10	47%	Below Threshold	0%	47%	Below Threshold	43%	Above Threshold	0.60	Below threshold	Below threshold
249	SSPR	<10	45%	Below Threshold	0%	45%	Below Threshold	47%	Above Threshold	0.22	Below threshold	Below threshold
250	SSPR	<10	43%	Below Threshold	0%	43%	Below Threshold	50%	Above Threshold	0.17	Below threshold	Below threshold
251	SSPR	<10	54%	Below Threshold	0%	54%	Below Threshold	39%	Below Threshold	0.62	Below threshold	Below threshold
252	SSPR	<10	44%	Below Threshold	0%	44%	Below Threshold	50%	Above Threshold	0.18	Below threshold	Below threshold
253	SSPR	<10	41%	Below Threshold	4%	45%	Below Threshold	44%	Above Threshold	0.03	Below threshold	Below threshold
254	SSPR	<10	38%	Below Threshold	24%	62%	Above Threshold	36%	Below Threshold	0.09	Below threshold	Below threshold
255	SSPR	<10	29%	Below Threshold	29%	58%	Below Threshold	38%	Below Threshold	0.05	Below threshold	Below threshold
256	SSPR	<10	58%	Below Threshold	20%	78%	Above Threshold	21%	Below Threshold	0.05	Below threshold	Below threshold
257	SSPR	<10	63%	Above Threshold	13%	77%	Above Threshold	19%	Below Threshold	0.23	Below threshold	Below threshold
258	SSPR	<10	9%	Below Threshold	24%	32%	Below Threshold	67%	Above Threshold	0.01	Below threshold	Below threshold
259	SSPR	<10	53%	Below Threshold	18%	70%	Above Threshold	28%	Below Threshold	0.84	Below threshold	Below threshold
260	SSPR	<10	56%	Below Threshold	11%	67%	Above Threshold	31%	Below Threshold	0.01	Below threshold	Below threshold
261	SSPR	<10	21%	Below Threshold	48%	70%	Above Threshold	30%	Below Threshold	0.02	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
262	SSPR	<10	72%	Above Threshold	16%	88%	Above Threshold	7%	Below Threshold	0.08	Below threshold	Below threshold
263	SSPR	<10	43%	Below Threshold	37%	80%	Above Threshold	14%	Below Threshold	0.93	Below threshold	Below threshold
264	SSPR	<10	37%	Below Threshold	40%	77%	Above Threshold	17%	Below Threshold	1.16	Below threshold	Below threshold
265	SSPR	<10	38%	Below Threshold	39%	76%	Above Threshold	18%	Below Threshold	1.14	Below threshold	Below threshold
266	SSPR	<10	9%	Below Threshold	18%	26%	Below Threshold	33%	Below Threshold	0.13	Below threshold	Below threshold
267	SSPR	<10	20%	Below Threshold	33%	53%	Below Threshold	29%	Below Threshold	0.03	Below threshold	Below threshold
268	SSPR	<10	17%	Below Threshold	29%	46%	Below Threshold	34%	Below Threshold	0.04	Below threshold	Below threshold
269	SSPR	<10	74%	Above Threshold	6%	80%	Above Threshold	19%	Below Threshold	0.01	Below threshold	Below threshold
270	SSPR	≥10	64%	Above Threshold	20%	85%	Above Threshold	12%	Below Threshold	0.08	Below threshold	Below threshold
271	SSPR	≥10	74%	Above Threshold	15%	89%	Above Threshold	7%	Below Threshold	0.04	Below threshold	Below threshold
272	SSPR	≥10	81%	Above Threshold	2%	83%	Above Threshold	7%	Below Threshold	1.04	Below threshold	Below threshold
273	SSPR	≥10	74%	Above Threshold	7%	81%	Above Threshold	18%	Below Threshold	0.00	Below threshold	Below threshold
274	SSPR	≥10	72%	Above Threshold	15%	88%	Above Threshold	7%	Below Threshold	0.02	Below threshold	Below threshold
275	SSPR	≥10	31%	Below Threshold	25%	56%	Below Threshold	42%	Above Threshold	0.04	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
276	SSPR	≥10	51%	Below Threshold	17%	67%	Above Threshold	19%	Below Threshold	0.58	Below threshold	Below threshold
277	SSPR	≥10	48%	Below Threshold	16%	64%	Above Threshold	18%	Below Threshold	1.11	Below threshold	Below threshold
278	SSPR	≥10	12%	Below Threshold	37%	50%	Below Threshold	46%	Above Threshold	0.13	Below threshold	Below threshold
279	SSPR	≥10	71%	Above Threshold	17%	87%	Above Threshold	7%	Below Threshold	0.08	Below threshold	Below threshold
280	SSPR	≥10	13%	Below Threshold	40%	53%	Below Threshold	46%	Above Threshold	0.02	Below threshold	Below threshold
281	SSPR	≥10	64%	Above Threshold	23%	87%	Above Threshold	12%	Below Threshold	0.02	Below threshold	Below threshold
282	SSPR	Extinct	56%	Below Threshold	26%	82%	Above Threshold	16%	Below Threshold	0.08	Below threshold	Below threshold
283	SSPR	Extinct	47%	Below Threshold	20%	67%	Above Threshold	24%	Below Threshold	0.50	Below threshold	Below threshold
284	SSPR	Extinct	75%	Above Threshold	7%	82%	Above Threshold	6%	Below Threshold	0.44	Below threshold	Below threshold
285	SSPR	Extinct	70%	Above Threshold	19%	89%	Above Threshold	10%	Below Threshold	0.03	Below threshold	Below threshold
286	SSPR	Extinct	61%	Above Threshold	23%	84%	Above Threshold	13%	Below Threshold	0.07	Below threshold	Below threshold
287	SSPR	Extinct	75%	Above Threshold	15%	90%	Above Threshold	7%	Below Threshold	0.03	Below threshold	Below threshold
288	SSPR	Extinct	70%	Above Threshold	20%	91%	Above Threshold	9%	Below Threshold	0.02	Below threshold	Below threshold
289	SSPR	Extinct	45%	Below Threshold	23%	68%	Above Threshold	23%	Below Threshold	0.81	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
290	SSPR	Extinct	76%	Above Threshold	9%	85%	Above Threshold	5%	Below Threshold	0.21	Below threshold	Below threshold
291	SSPR	Extinct	69%	Above Threshold	19%	88%	Above Threshold	12%	Below Threshold	0.03	Below threshold	Below threshold
292	SSPR	Extinct	74%	Above Threshold	6%	80%	Above Threshold	7%	Below Threshold	0.31	Below threshold	Below threshold
293	SSPR	Extinct	74%	Above Threshold	15%	90%	Above Threshold	7%	Below Threshold	0.03	Below threshold	Below threshold
294	SSPR	Extinct	74%	Above Threshold	6%	80%	Above Threshold	7%	Below Threshold	0.32	Below threshold	Below threshold
295	SSPR	Extinct	77%	Above Threshold	10%	87%	Above Threshold	2%	Below Threshold	0.35	Below threshold	Below threshold
296	SSPR	Extinct	61%	Above Threshold	24%	84%	Above Threshold	13%	Below Threshold	0.08	Below threshold	Below threshold
297	SSPR	Extinct	70%	Above Threshold	20%	90%	Above Threshold	9%	Below Threshold	0.02	Below threshold	Below threshold
298	SSPR	Extinct	73%	Above Threshold	17%	91%	Above Threshold	7%	Below Threshold	0.03	Below threshold	Below threshold
299	SSPR	Extinct	71%	Above Threshold	5%	76%	Above Threshold	8%	Below Threshold	0.65	Below threshold	Below threshold
300	SSPR	Extinct	59%	Below Threshold	24%	83%	Above Threshold	13%	Below Threshold	0.17	Below threshold	Below threshold
301	SSPR	Extinct	75%	Above Threshold	16%	91%	Above Threshold	6%	Below Threshold	0.05	Below threshold	Below threshold
302	SSPR	Extinct	74%	Above Threshold	5%	80%	Above Threshold	7%	Below Threshold	0.34	Below threshold	Below threshold
303	SSPR	Extinct	77%	Above Threshold	10%	87%	Above Threshold	2%	Below Threshold	0.41	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
304	SSPR	Extinct	74%	Above Threshold	15%	89%	Above Threshold	7%	Below Threshold	0.04	Below threshold	Below threshold
305	SSPR	Extinct	74%	Above Threshold	8%	82%	Above Threshold	6%	Below Threshold	0.21	Below threshold	Below threshold
306	SSPR	Extinct	57%	Below Threshold	26%	82%	Above Threshold	14%	Below Threshold	0.23	Below threshold	Below threshold
307	SSPR	Extinct	52%	Below Threshold	25%	77%	Above Threshold	17%	Below Threshold	0.76	Below threshold	Below threshold
308	SSPR	Extinct	76%	Above Threshold	13%	88%	Above Threshold	6%	Below Threshold	0.04	Below threshold	Below threshold
309	SSPR	Extinct	73%	Above Threshold	17%	90%	Above Threshold	9%	Below Threshold	0.03	Below threshold	Below threshold
310	SSPR	Extinct	74%	Above Threshold	16%	90%	Above Threshold	8%	Below Threshold	0.03	Below threshold	Below threshold
311	SSPR	Extinct	52%	Below Threshold	27%	79%	Above Threshold	20%	Below Threshold	0.21	Below threshold	Below threshold
312	SSPR	Extinct	51%	Below Threshold	20%	71%	Above Threshold	21%	Below Threshold	0.41	Below threshold	Below threshold
313	SSPR	Extinct	85%	Above Threshold	4%	88%	Above Threshold	11%	Below Threshold	1.49	Below threshold	Below threshold
314	SSPR	Extinct	76%	Above Threshold	8%	84%	Above Threshold	14%	Below Threshold	0.55	Below threshold	Below threshold
315	SSPR	Extinct	85%	Above Threshold	5%	91%	Above Threshold	8%	Below Threshold	0.79	Below threshold	Below threshold
316	SSPR	Extinct	73%	Above Threshold	6%	79%	Above Threshold	20%	Below Threshold	1.47	Below threshold	Below threshold
317	SSPR	Extinct	70%	Above Threshold	7%	77%	Above Threshold	22%	Below Threshold	1.32	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland			Total Grassland		Cropland		Trees/ha	Anthropogenic Structures	
			%	Threshold Status	CRP Grassland	%	Threshold Status	%	Threshold Status	Density	Threshold Status	Threshold Status
318	SSPR	Extinct	70%	Above Threshold	12%	82%	Above Threshold	17%	Below Threshold	0.91	Below threshold	Below threshold
319	SSPR	Extinct	84%	Above Threshold	6%	90%	Above Threshold	9%	Below Threshold	0.54	Below threshold	Below threshold
320	SSPR	Extinct	63%	Above Threshold	10%	73%	Above Threshold	25%	Below Threshold	1.12	Below threshold	Below threshold
321	SSPR	Extinct	82%	Above Threshold	7%	89%	Above Threshold	10%	Below Threshold	0.56	Below threshold	Below threshold
322	SSPR	Extinct	90%	Above Threshold	3%	93%	Above Threshold	6%	Below Threshold	0.98	Below threshold	Below threshold
323	SSPR	Extinct	80%	Above Threshold	7%	87%	Above Threshold	12%	Below Threshold	0.76	Below threshold	Below threshold
324	SSPR	Extinct	87%	Above Threshold	5%	92%	Above Threshold	7%	Below Threshold	0.88	Below threshold	Below threshold
325	SSPR	Extinct	61%	Above Threshold	10%	71%	Above Threshold	27%	Below Threshold	1.20	Below threshold	Below threshold
326	SSPR	Extinct	67%	Above Threshold	17%	84%	Above Threshold	14%	Below Threshold	0.73	Below threshold	Below threshold
327	SSPR	Extinct	81%	Above Threshold	6%	88%	Above Threshold	11%	Below Threshold	1.34	Below threshold	Below threshold
328	SSPR	Extinct	78%	Above Threshold	9%	86%	Above Threshold	12%	Below Threshold	1.43	Below threshold	Below threshold
329	SSPR	Extinct	83%	Above Threshold	6%	89%	Above Threshold	10%	Below Threshold	1.11	Below threshold	Below threshold
330	SSPR	Extinct	76%	Above Threshold	6%	81%	Above Threshold	18%	Below Threshold	1.50	Below threshold	Below threshold
331	SSPR	Extinct	76%	Above Threshold	8%	85%	Above Threshold	14%	Below Threshold	0.76	Below threshold	Below threshold

Lek ID	Ecoregion	Lek Attendance Group	Native Grassland		CRP Grassland	Total Grassland		Cropland		Trees/ha Density	Anthropogenic Structures	
			%	Threshold Status		%	Threshold Status	%	Threshold Status		Threshold Status	Threshold Status
332	SSPR	Extinct	66%	Above Threshold	8%	74%	Above Threshold	24%	Below Threshold	1.27	Below threshold	Below threshold
333	SSPR	Extinct	86%	Above Threshold	5%	90%	Above Threshold	9%	Below Threshold	1.00	Below threshold	Below threshold
334	SSPR	Extinct	65%	Above Threshold	9%	73%	Above Threshold	25%	Below Threshold	1.26	Below threshold	Below threshold
335	SSPR	Extinct	74%	Above Threshold	9%	83%	Above Threshold	16%	Below Threshold	0.92	Below threshold	Below threshold

Appendix B - Chapter 3 Supplemental Data

Appendix B.1. Anthropogenic Structures were measured within 5 km of lesser prairie-chicken leks within the Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, and Sand Sagebrush Prairie ecoregions in Kansas, USA, from 2018-2023. A threshold status (Above/Below) was assigned to each lek for average lek attendance, proportion of native grassland, total grassland, cropland, trees/ha, and anthropogenic structures/ha.

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
1	SGPR/CRP	<10	99	Above Threshold	0	Below Threshold	0	Below Threshold	46.77	Above Threshold
2	SGPR/CRP	<10	178	Above Threshold	0	Below Threshold	0	Below Threshold	53.94	Above Threshold
3	SGPR/CRP	<10	106	Above Threshold	0	Below Threshold	0	Below Threshold	38.93	Above Threshold
4	SGPR/CRP	<10	168	Above Threshold	0	Below Threshold	0	Below Threshold	52.91	Above Threshold
5	SGPR/CRP	<10	184	Above Threshold	0	Below Threshold	0	Below Threshold	56.23	Above Threshold
6	SGPR/CRP	<10	188	Above Threshold	0	Below Threshold	0	Below Threshold	57.91	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
7	SGPR/CRP	<10	177	Above Threshold	0	Below Threshold	0	Below Threshold	55.68	Above Threshold
8	SGPR/CRP	<10	209	Above Threshold	0	Below Threshold	0	Below Threshold	55.91	Above Threshold
9	SGPR/CRP	<10	105	Above Threshold	1	Below Threshold	0	Below Threshold	83.25	Above Threshold
10	SGPR/CRP	<10	80	Above Threshold	1	Below Threshold	0	Below Threshold	82.70	Above Threshold
11	SGPR/CRP	<10	152	Above Threshold	0	Below Threshold	0	Below Threshold	80.68	Above Threshold
12	SGPR/CRP	<10	154	Above Threshold	1	Below Threshold	0	Below Threshold	85.43	Above Threshold
13	SGPR/CRP	<10	76	Above Threshold	0	Below Threshold	0	Below Threshold	78.00	Above Threshold
14	SGPR/CRP	<10	133	Above Threshold	2	Below Threshold	1.01	Above Threshold	124.35	Above Threshold
15	SGPR/CRP	<10	381	Above Threshold	0	Below Threshold	0	Below Threshold	84.30	Above Threshold
16	SGPR/CRP	<10	354	Above Threshold	0	Below Threshold	0.01	Below Threshold	74.69	Above Threshold
17	SGPR/CRP	<10	370	Above Threshold	0	Below Threshold	0	Below Threshold	80.68	Above Threshold
18	SGPR/CRP	<10	336	Above Threshold	0	Below Threshold	9.91	Above Threshold	60.48	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
19	SGPR/CRP	<10	319	Above Threshold	0	Below Threshold	8.96	Above Threshold	58.17	Above Threshold
20	SGPR/CRP	<10	356	Above Threshold	0	Below Threshold	0	Below Threshold	76.07	Above Threshold
21	SGPR/CRP	<10	46	Above Threshold	0	Below Threshold	0	Below Threshold	54.33	Above Threshold
22	SGPR/CRP	<10	20	Above Threshold	0	Below Threshold	0	Below Threshold	36.31	Above Threshold
23	SGPR/CRP	<10	50	Above Threshold	1	Below Threshold	0	Below Threshold	52.38	Above Threshold
24	SGPR/CRP	<10	24	Above Threshold	0	Below Threshold	0	Below Threshold	35.31	Above Threshold
25	SGPR/CRP	<10	57	Above Threshold	13	Above Threshold	0	Below Threshold	86.06	Above Threshold
26	SGPR/CRP	<10	28	Above Threshold	0	Below Threshold	6.33	Above Threshold	52.29	Above Threshold
27	SGPR/CRP	<10	4	Below Threshold	0	Below Threshold	10.98	Above Threshold	92.26	Above Threshold
28	SGPR/CRP	<10	36	Above Threshold	0	Below Threshold	0	Below Threshold	93.84	Above Threshold
29	SGPR/CRP	<10	150	Above Threshold	0	Below Threshold	0	Below Threshold	53.64	Above Threshold
30	SGPR/CRP	<10	101	Above Threshold	0	Below Threshold	12.85	Above Threshold	88.85	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
31	SGPR/CRP	<10	31	Above Threshold	0	Below Threshold	9.82	Above Threshold	85.47	Above Threshold
32	SGPR/CRP	<10	4	Below Threshold	0	Below Threshold	11.04	Above Threshold	95.17	Above Threshold
33	SGPR/CRP	<10	5	Below Threshold	0	Below Threshold	10.79	Above Threshold	89.01	Above Threshold
34	SGPR/CRP	<10	56	Above Threshold	1	Below Threshold	0	Below Threshold	66.91	Above Threshold
35	SGPR/CRP	<10	36	Above Threshold	1	Below Threshold	0	Below Threshold	99.71	Above Threshold
36	SGPR/CRP	<10	32	Above Threshold	0	Below Threshold	0	Below Threshold	98.03	Above Threshold
37	SGPR/CRP	<10	200	Above Threshold	1	Below Threshold	0	Below Threshold	74.85	Above Threshold
38	SGPR/CRP	<10	18	Above Threshold	3	Below Threshold	0	Below Threshold	81.75	Above Threshold
39	SGPR/CRP	<10	30	Above Threshold	1	Below Threshold	9.88	Above Threshold	87.21	Above Threshold
40	SGPR/CRP	$\geq$ 10	208	Above Threshold	0	Below Threshold	0	Below Threshold	53.14	Above Threshold
41	SGPR/CRP	$\geq$ 10	194	Above Threshold	0	Below Threshold	0	Below Threshold	53.06	Above Threshold
42	SGPR/CRP	$\geq$ 10	155	Above Threshold	0	Below Threshold	0	Below Threshold	56.70	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
43	SGPR/CRP	≥ 10	112	Above Threshold	0	Below Threshold	0	Below Threshold	40.05	Above Threshold
44	SGPR/CRP	≥ 10	97	Above Threshold	0	Below Threshold	0	Below Threshold	34.04	Above Threshold
45	SGPR/CRP	≥ 10	216	Above Threshold	0	Below Threshold	0	Below Threshold	56.48	Above Threshold
46	SGPR/CRP	≥ 10	117	Above Threshold	0	Below Threshold	0	Below Threshold	41.05	Above Threshold
47	SGPR/CRP	≥ 10	124	Above Threshold	0	Below Threshold	0	Below Threshold	67.64	Above Threshold
48	SGPR/CRP	≥ 10	92	Above Threshold	0	Below Threshold	0	Below Threshold	72.64	Above Threshold
49	SGPR/CRP	≥ 10	163	Above Threshold	1	Below Threshold	0	Below Threshold	84.85	Above Threshold
50	SGPR/CRP	≥ 10	57	Above Threshold	0	Below Threshold	0	Below Threshold	82.43	Above Threshold
51	SGPR/CRP	≥ 10	134	Above Threshold	2	Below Threshold	1.00	Above Threshold	123.95	Above Threshold
52	SGPR/CRP	≥ 10	332	Above Threshold	0	Below Threshold	9.69	Above Threshold	57.18	Above Threshold
53	SGPR/CRP	≥ 10	379	Above Threshold	0	Below Threshold	0	Below Threshold	80.31	Above Threshold
54	SGPR/CRP	≥ 10	305	Above Threshold	1	Below Threshold	8.20	Above Threshold	58.58	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
55	SGPR/CRP	≥ 10	19	Above Threshold	0	Below Threshold	0	Below Threshold	42.34	Above Threshold
56	SGPR/CRP	≥ 10	47	Above Threshold	0	Below Threshold	0	Below Threshold	54.32	Above Threshold
57	SGPR/CRP	≥ 10	21	Above Threshold	0	Below Threshold	0	Below Threshold	35.31	Above Threshold
58	SGPR/CRP	≥ 10	164	Above Threshold	0	Below Threshold	0	Below Threshold	56.64	Above Threshold
59	SGPR/CRP	≥ 10	151	Above Threshold	0	Below Threshold	0	Below Threshold	67.29	Above Threshold
60	SGPR/CRP	≥ 10	33	Above Threshold	0	Below Threshold	0	Below Threshold	49.85	Above Threshold
61	SGPR/CRP	≥ 10	19	Above Threshold	0	Below Threshold	5.04	Above Threshold	40.26	Above Threshold
62	SGPR/CRP	≥ 10	95	Above Threshold	0	Below Threshold	0	Below Threshold	72.81	Above Threshold
63	SGPR/CRP	≥ 10	35	Above Threshold	0	Below Threshold	0	Below Threshold	65.74	Above Threshold
64	SGPR/CRP	≥ 10	32	Above Threshold	0	Below Threshold	0	Below Threshold	47.04	Above Threshold
65	SGPR/CRP	≥ 10	46	Above Threshold	0	Below Threshold	0	Below Threshold	50.67	Above Threshold
66	SGPR/CRP	≥ 10	59	Above Threshold	0	Below Threshold	0	Below Threshold	50.80	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
67	SGPR/CRP	≥ 10	95	Above Threshold	0	Below Threshold	0	Below Threshold	51.11	Above Threshold
68	SGPR/CRP	≥ 10	54	Above Threshold	2	Below Threshold	0	Below Threshold	93.76	Above Threshold
69	SGPR/CRP	≥ 10	52	Above Threshold	0	Below Threshold	0	Below Threshold	53.00	Above Threshold
70	SGPR/CRP	≥ 10	259	Above Threshold	0	Below Threshold	9.48	Above Threshold	88.48	Above Threshold
71	SGPR/CRP	≥ 10	27	Above Threshold	0	Below Threshold	0	Below Threshold	58.07	Above Threshold
72	SGPR/CRP	≥ 10	23	Above Threshold	0	Below Threshold	0	Below Threshold	85.86	Above Threshold
73	SGPR/CRP	≥ 10	19	Above Threshold	0	Below Threshold	0	Below Threshold	81.14	Above Threshold
74	SGPR/CRP	≥ 10	27	Above Threshold	0	Below Threshold	0	Below Threshold	60.27	Above Threshold
75	SGPR/CRP	≥ 10	145	Above Threshold	22	Above Threshold	0	Below Threshold	106.92	Above Threshold
76	SGPR/CRP	≥ 10	89	Above Threshold	2	Below Threshold	7.37	Above Threshold	46.60	Above Threshold
77	SGPR/CRP	≥ 10	42	Above Threshold	22	Above Threshold	8.38	Above Threshold	76.20	Above Threshold
78	SGPR/CRP	≥ 10	77	Above Threshold	0	Below Threshold	0	Below Threshold	67.15	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
79	SGPR/CRP	≥ 10	123	Above Threshold	0	Below Threshold	0	Below Threshold	63.51	Above Threshold
80	SGPR/CRP	≥ 10	154	Above Threshold	0	Below Threshold	0	Below Threshold	56.75	Above Threshold
81	SGPR/CRP	≥ 10	57	Above Threshold	0	Below Threshold	0	Below Threshold	43.95	Above Threshold
82	SGPR/CRP	≥ 10	46	Above Threshold	0	Below Threshold	0	Below Threshold	48.69	Above Threshold
83	SGPR/CRP	≥ 10	239	Above Threshold	0	Below Threshold	0	Below Threshold	61.55	Above Threshold
84	SGPR/CRP	≥ 10	38	Above Threshold	14	Above Threshold	6.67	Above Threshold	69.93	Above Threshold
85	SGPR/CRP	Extinct	208	Above Threshold	0	Below Threshold	0	Below Threshold	52.17	Above Threshold
86	SGPR/CRP	Extinct	145	Above Threshold	0	Below Threshold	0	Below Threshold	55.01	Above Threshold
87	SGPR/CRP	Extinct	131	Above Threshold	0	Below Threshold	0	Below Threshold	39.24	Above Threshold
88	SGPR/CRP	Extinct	133	Above Threshold	0	Below Threshold	0	Below Threshold	41.75	Above Threshold
89	SGPR/CRP	Extinct	144	Above Threshold	0	Below Threshold	0	Below Threshold	55.50	Above Threshold
90	SGPR/CRP	Extinct	172	Above Threshold	0	Below Threshold	0	Below Threshold	49.30	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
91	SGPR/CRP	Extinct	192	Above Threshold	0	Below Threshold	0	Below Threshold	52.42	Above Threshold
92	SGPR/CRP	Extinct	161	Above Threshold	0	Below Threshold	0	Below Threshold	55.58	Above Threshold
93	SGPR/CRP	Extinct	98	Above Threshold	0	Below Threshold	0	Below Threshold	46.92	Above Threshold
94	SGPR/CRP	Extinct	152	Above Threshold	0	Below Threshold	0	Below Threshold	54.27	Above Threshold
95	SGPR/CRP	Extinct	220	Above Threshold	0	Below Threshold	0	Below Threshold	57.44	Above Threshold
96	SGPR/CRP	Extinct	142	Above Threshold	1	Below Threshold	0	Below Threshold	86.74	Above Threshold
97	SGPR/CRP	Extinct	78	Above Threshold	0	Below Threshold	0	Below Threshold	68.78	Above Threshold
98	SGPR/CRP	Extinct	85	Above Threshold	1	Below Threshold	0	Below Threshold	82.58	Above Threshold
99	SGPR/CRP	Extinct	68	Above Threshold	0	Below Threshold	0	Below Threshold	83.63	Above Threshold
100	SGPR/CRP	Extinct	107	Above Threshold	0	Below Threshold	0	Below Threshold	72.63	Above Threshold
101	SGPR/CRP	Extinct	81	Above Threshold	0	Below Threshold	0	Below Threshold	74.42	Above Threshold
102	SGPR/CRP	Extinct	134	Above Threshold	2	Below Threshold	1.77	Above Threshold	130.45	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
103	SGPR/CRP	Extinct	157	Above Threshold	0	Below Threshold	0	Below Threshold	83.94	Above Threshold
104	SGPR/CRP	Extinct	112	Above Threshold	0	Below Threshold	0	Below Threshold	73.44	Above Threshold
105	SGPR/CRP	Extinct	144	Above Threshold	0	Below Threshold	0	Below Threshold	78.18	Above Threshold
106	SGPR/CRP	Extinct	143	Above Threshold	0	Below Threshold	0	Below Threshold	83.00	Above Threshold
107	SGPR/CRP	Extinct	117	Above Threshold	0	Below Threshold	0	Below Threshold	80.69	Above Threshold
108	SGPR/CRP	Extinct	67	Above Threshold	0	Below Threshold	0	Below Threshold	74.09	Above Threshold
109	SGPR/CRP	Extinct	363	Above Threshold	0	Below Threshold	7.96	Above Threshold	57.85	Above Threshold
110	SGPR/CRP	Extinct	341	Above Threshold	0	Below Threshold	9.89	Above Threshold	58.37	Above Threshold
111	SGPR/CRP	Extinct	317	Above Threshold	0	Below Threshold	6.79	Above Threshold	53.08	Above Threshold
112	SGPR/CRP	Extinct	336	Above Threshold	0	Below Threshold	2.62	Above Threshold	72.44	Above Threshold
113	SGPR/CRP	Extinct	332	Above Threshold	0	Below Threshold	3.70	Above Threshold	55.74	Above Threshold
114	SGPR/CRP	Extinct	354	Above Threshold	0	Below Threshold	0	Below Threshold	80.06	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
115	MGPR	<10	131	Above Threshold	1	Below Threshold	0	Below Threshold	35.03	Above Threshold
116	MGPR	<10	172	Above Threshold	1	Below Threshold	0	Below Threshold	39.40	Above Threshold
117	MGPR	<10	171	Above Threshold	0	Below Threshold	0	Below Threshold	33.50	Above Threshold
118	MGPR	<10	37	Above Threshold	0	Below Threshold	0	Below Threshold	61.63	Above Threshold
119	MGPR	<10	41	Above Threshold	0	Below Threshold	0	Below Threshold	61.89	Above Threshold
120	MGPR	<10	49	Above Threshold	0	Below Threshold	0	Below Threshold	65.92	Above Threshold
121	MGPR	<10	40	Above Threshold	0	Below Threshold	0	Below Threshold	64.43	Above Threshold
122	MGPR	<10	65	Above Threshold	0	Below Threshold	0	Below Threshold	68.32	Above Threshold
123	MGPR	<10	145	Above Threshold	0	Below Threshold	3.95	Above Threshold	82.60	Above Threshold
124	MGPR	<10	144	Above Threshold	0	Below Threshold	0	Below Threshold	83.56	Above Threshold
125	MGPR	<10	143	Above Threshold	0	Below Threshold	11.01	Above Threshold	77.49	Above Threshold
126	MGPR	<10	73	Above Threshold	0	Below Threshold	0	Below Threshold	114.26	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
127	MGPR	<10	56	Above Threshold	0	Below Threshold	19.06	Above Threshold	67.25	Above Threshold
128	MGPR	<10	54	Above Threshold	0	Below Threshold	18.33	Above Threshold	67.64	Above Threshold
129	MGPR	<10	79	Above Threshold	0	Below Threshold	0	Below Threshold	110.17	Above Threshold
130	MGPR	<10	84	Above Threshold	0	Below Threshold	0	Below Threshold	59.01	Above Threshold
131	MGPR	<10	86	Above Threshold	0	Below Threshold	0	Below Threshold	55.58	Above Threshold
132	MGPR	<10	47	Above Threshold	1	Below Threshold	0	Below Threshold	46.58	Above Threshold
133	MGPR	<10	77	Above Threshold	0	Below Threshold	0	Below Threshold	72.66	Above Threshold
134	MGPR	<10	41	Above Threshold	0	Below Threshold	3.15	Above Threshold	100.41	Above Threshold
135	MGPR	<10	40	Above Threshold	0	Below Threshold	3.31	Above Threshold	100.62	Above Threshold
136	MGPR	<10	55	Above Threshold	0	Below Threshold	0	Below Threshold	87.13	Above Threshold
137	MGPR	<10	61	Above Threshold	0	Below Threshold	8.17	Above Threshold	65.52	Above Threshold
138	MGPR	<10	45	Above Threshold	0	Below Threshold	0	Below Threshold	63.68	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
139	MGPR	<10	70	Above Threshold	0	Below Threshold	0	Below Threshold	60.18	Above Threshold
140	MGPR	<10	71	Above Threshold	0	Below Threshold	0	Below Threshold	76.88	Above Threshold
141	MGPR	<10	43	Above Threshold	0	Below Threshold	11.99	Above Threshold	76.33	Above Threshold
142	MGPR	<10	95	Above Threshold	0	Below Threshold	0	Below Threshold	126.55	Above Threshold
143	MGPR	<10	9	Below Threshold	10	Below Threshold	6.27	Above Threshold	69.62	Above Threshold
144	MGPR	<10	29	Above Threshold	2	Below Threshold	17.25	Above Threshold	78.19	Above Threshold
145	MGPR	<10	21	Above Threshold	1	Below Threshold	0	Below Threshold	107.85	Above Threshold
146	MGPR	<10	7	Below Threshold	1	Below Threshold	5.03	Above Threshold	67.25	Above Threshold
147	MGPR	$\geq$ 10	90	Above Threshold	1	Below Threshold	0	Below Threshold	86.28	Above Threshold
148	MGPR	$\geq$ 10	61	Above Threshold	0	Below Threshold	0	Below Threshold	70.74	Above Threshold
149	MGPR	$\geq$ 10	39	Above Threshold	0	Below Threshold	12.83	Above Threshold	79.16	Above Threshold
150	MGPR	$\geq$ 10	80	Above Threshold	0	Below Threshold	0	Below Threshold	83.18	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
151	MGPR	≥ 10	32	Above Threshold	24	Above Threshold	13.84	Above Threshold	98.24	Above Threshold
152	MGPR	≥ 10	5	Below Threshold	8	Below Threshold	3.16	Above Threshold	73.37	Above Threshold
153	MGPR	Extinct	37	Above Threshold	0	Below Threshold	0	Below Threshold	63.78	Above Threshold
154	MGPR	Extinct	28	Above Threshold	0	Below Threshold	0	Below Threshold	62.58	Above Threshold
155	MGPR	Extinct	39	Above Threshold	0	Below Threshold	0	Below Threshold	65.89	Above Threshold
156	MGPR	Extinct	43	Above Threshold	0	Below Threshold	0.70	Below Threshold	99.83	Above Threshold
157	MGPR	Extinct	31	Above Threshold	0	Below Threshold	0	Below Threshold	63.91	Above Threshold
158	MGPR	Extinct	43	Above Threshold	0	Below Threshold	0	Below Threshold	63.01	Above Threshold
159	MGPR	Extinct	41	Above Threshold	0	Below Threshold	0	Below Threshold	60.64	Above Threshold
160	MGPR	Extinct	24	Above Threshold	0	Below Threshold	0	Below Threshold	48.56	Above Threshold
161	MGPR	Extinct	32	Above Threshold	0	Below Threshold	0	Below Threshold	61.24	Above Threshold
162	MGPR	Extinct	26	Above Threshold	0	Below Threshold	0	Below Threshold	56.21	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
163	MGPR	Extinct	38	Above Threshold	0	Below Threshold	0	Below Threshold	75.88	Above Threshold
164	MGPR	Extinct	54	Above Threshold	0	Below Threshold	0	Below Threshold	63.13	Above Threshold
165	MGPR	Extinct	39	Above Threshold	0	Below Threshold	0	Below Threshold	62.23	Above Threshold
166	MGPR	Extinct	45	Above Threshold	0	Below Threshold	0	Below Threshold	66.82	Above Threshold
167	MGPR	Extinct	51	Above Threshold	0	Below Threshold	0	Below Threshold	90.85	Above Threshold
168	MGPR	Extinct	39	Above Threshold	0	Below Threshold	0	Below Threshold	69.36	Above Threshold
169	MGPR	Extinct	40	Above Threshold	0	Below Threshold	0	Below Threshold	60.76	Above Threshold
170	MGPR	Extinct	35	Above Threshold	0	Below Threshold	0	Below Threshold	67.96	Above Threshold
171	MGPR	Extinct	42	Above Threshold	0	Below Threshold	0	Below Threshold	62.67	Above Threshold
172	MGPR	Extinct	42	Above Threshold	0	Below Threshold	0	Below Threshold	53.91	Above Threshold
173	MGPR	Extinct	40	Above Threshold	0	Below Threshold	0	Below Threshold	65.37	Above Threshold
174	MGPR	Extinct	34	Above Threshold	0	Below Threshold	0	Below Threshold	67.69	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
175	MGPR	Extinct	41	Above Threshold	0	Below Threshold	0	Below Threshold	70.01	Above Threshold
176	MGPR	Extinct	26	Above Threshold	0	Below Threshold	0	Below Threshold	49.82	Above Threshold
177	MGPR	Extinct	25	Above Threshold	0	Below Threshold	0	Below Threshold	52.96	Above Threshold
178	MGPR	Extinct	53	Above Threshold	0	Below Threshold	0	Below Threshold	86.76	Above Threshold
179	MGPR	Extinct	48	Above Threshold	0	Below Threshold	0	Below Threshold	65.42	Above Threshold
180	MGPR	Extinct	34	Above Threshold	0	Below Threshold	0	Below Threshold	59.66	Above Threshold
181	MGPR	Extinct	69	Above Threshold	0	Below Threshold	6.17	Above Threshold	76.44	Above Threshold
182	MGPR	Extinct	80	Above Threshold	0	Below Threshold	0	Below Threshold	66.25	Above Threshold
183	MGPR	Extinct	67	Above Threshold	0	Below Threshold	0	Below Threshold	69.17	Above Threshold
184	MGPR	Extinct	96	Above Threshold	0	Below Threshold	0	Below Threshold	74.46	Above Threshold
185	MGPR	Extinct	63	Above Threshold	0	Below Threshold	1.59	Above Threshold	74.38	Above Threshold
186	MGPR	Extinct	97	Above Threshold	0	Below Threshold	0	Below Threshold	56.29	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
187	MGPR	Extinct	85	Above Threshold	0	Below Threshold	0	Below Threshold	55.38	Above Threshold
188	MGPR	Extinct	72	Above Threshold	0	Below Threshold	0	Below Threshold	70.16	Above Threshold
189	MGPR	Extinct	100	Above Threshold	0	Below Threshold	0	Below Threshold	61.76	Above Threshold
190	MGPR	Extinct	148	Above Threshold	0	Below Threshold	1.55	Above Threshold	79.34	Above Threshold
191	MGPR	Extinct	146	Above Threshold	0	Below Threshold	0	Below Threshold	84.95	Above Threshold
192	MGPR	Extinct	154	Above Threshold	0	Below Threshold	7.74	Above Threshold	100.49	Above Threshold
193	MGPR	Extinct	147	Above Threshold	0	Below Threshold	4.43	Above Threshold	92.71	Above Threshold
194	MGPR	Extinct	157	Above Threshold	0	Below Threshold	0	Below Threshold	91.85	Above Threshold
195	MGPR	Extinct	164	Above Threshold	0	Below Threshold	0	Below Threshold	91.36	Above Threshold
196	MGPR	Extinct	162	Above Threshold	0	Below Threshold	3.58	Above Threshold	101.49	Above Threshold
197	MGPR	Extinct	147	Above Threshold	0	Below Threshold	0	Below Threshold	81.13	Above Threshold
198	MGPR	Extinct	140	Above Threshold	0	Below Threshold	6.77	Above Threshold	83.27	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
199	MGPR	Extinct	144	Above Threshold	0	Below Threshold	0	Below Threshold	79.62	Above Threshold
200	MGPR	Extinct	147	Above Threshold	0	Below Threshold	0	Below Threshold	82.92	Above Threshold
201	MGPR	Extinct	149	Above Threshold	0	Below Threshold	0	Below Threshold	88.60	Above Threshold
202	MGPR	Extinct	54	Above Threshold	0	Below Threshold	0	Below Threshold	94.33	Above Threshold
203	MGPR	Extinct	56	Above Threshold	0	Below Threshold	0	Below Threshold	91.01	Above Threshold
204	MGPR	Extinct	84	Above Threshold	0	Below Threshold	0	Below Threshold	99.24	Above Threshold
205	MGPR	Extinct	62	Above Threshold	0	Below Threshold	22.58	Above Threshold	67.03	Above Threshold
206	MGPR	Extinct	59	Above Threshold	0	Below Threshold	0	Below Threshold	85.41	Above Threshold
207	MGPR	Extinct	52	Above Threshold	0	Below Threshold	0	Below Threshold	52.86	Above Threshold
208	MGPR	Extinct	103	Above Threshold	0	Below Threshold	0	Below Threshold	68.95	Above Threshold
209	MGPR	Extinct	75	Above Threshold	0	Below Threshold	0	Below Threshold	56.81	Above Threshold
210	MGPR	Extinct	88	Above Threshold	0	Below Threshold	0	Below Threshold	63.86	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
211	MGPR	Extinct	35	Above Threshold	0	Below Threshold	0	Below Threshold	36.97	Above Threshold
212	MGPR	Extinct	71	Above Threshold	0	Below Threshold	0	Below Threshold	60.26	Above Threshold
213	MGPR	Extinct	62	Above Threshold	0	Below Threshold	0	Below Threshold	53.57	Above Threshold
214	MGPR	Extinct	71	Above Threshold	0	Below Threshold	0	Below Threshold	58.24	Above Threshold
215	MGPR	Extinct	62	Above Threshold	0	Below Threshold	0	Below Threshold	60.05	Above Threshold
216	MGPR	Extinct	100	Above Threshold	0	Below Threshold	0	Below Threshold	66.02	Above Threshold
217	MGPR	Extinct	41	Above Threshold	0	Below Threshold	0	Below Threshold	47.01	Above Threshold
218	MGPR	Extinct	104	Above Threshold	0	Below Threshold	0	Below Threshold	67.45	Above Threshold
219	MGPR	Extinct	52	Above Threshold	0	Below Threshold	0	Below Threshold	59.37	Above Threshold
220	MGPR	Extinct	43	Above Threshold	0	Below Threshold	0	Below Threshold	48.11	Above Threshold
221	SSPR	<10	137	Above Threshold	1	Below Threshold	49.67	Above Threshold	53.01	Above Threshold
222	SSPR	<10	155	Above Threshold	1	Below Threshold	18.83	Above Threshold	40.37	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
223	SSPR	<10	133	Above Threshold	1	Below Threshold	49.12	Above Threshold	53.63	Above Threshold
224	SSPR	<10	153	Above Threshold	1	Below Threshold	23.59	Above Threshold	44.21	Above Threshold
225	SSPR	<10	138	Above Threshold	0	Below Threshold	20.04	Above Threshold	41.80	Above Threshold
226	SSPR	<10	152	Above Threshold	0	Below Threshold	38.67	Above Threshold	45.76	Above Threshold
227	SSPR	<10	155	Above Threshold	0	Below Threshold	32.28	Above Threshold	43.19	Above Threshold
228	SSPR	<10	147	Above Threshold	0	Below Threshold	41.81	Above Threshold	45.58	Above Threshold
229	SSPR	<10	142	Above Threshold	1	Below Threshold	49.19	Above Threshold	56.04	Above Threshold
230	SSPR	<10	138	Above Threshold	0	Below Threshold	43.00	Above Threshold	45.18	Above Threshold
231	SSPR	<10	138	Above Threshold	0	Below Threshold	27.23	Above Threshold	43.34	Above Threshold
232	SSPR	<10	157	Above Threshold	1	Below Threshold	19.57	Above Threshold	39.71	Above Threshold
233	SSPR	<10	143	Above Threshold	0	Below Threshold	19.00	Above Threshold	41.15	Above Threshold
234	SSPR	<10	147	Above Threshold	1	Below Threshold	27.40	Above Threshold	42.14	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
235	SSPR	<10	136	Above Threshold	1	Below Threshold	53.42	Above Threshold	57.81	Above Threshold
236	SSPR	<10	5	Below Threshold	0	Below Threshold	0	Below Threshold	45.56	Above Threshold
237	SSPR	<10	43	Above Threshold	0	Below Threshold	0	Below Threshold	22.49	Above Threshold
238	SSPR	<10	5	Below Threshold	0	Below Threshold	0	Below Threshold	42.80	Above Threshold
239	SSPR	<10	60	Above Threshold	0	Below Threshold	0	Below Threshold	36.91	Above Threshold
240	SSPR	<10	5	Below Threshold	0	Below Threshold	0	Below Threshold	30.22	Above Threshold
241	SSPR	<10	5	Below Threshold	0	Below Threshold	0	Below Threshold	48.43	Above Threshold
242	SSPR	<10	7	Below Threshold	0	Below Threshold	0	Below Threshold	51.12	Above Threshold
243	SSPR	<10	180	Above Threshold	1	Below Threshold	4.45	Above Threshold	68.62	Above Threshold
244	SSPR	<10	186	Above Threshold	0	Below Threshold	8.38	Above Threshold	64.37	Above Threshold
245	SSPR	<10	193	Above Threshold	0	Below Threshold	0.44	Below Threshold	68.42	Above Threshold
246	SSPR	<10	163	Above Threshold	1	Below Threshold	0	Below Threshold	71.12	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
247	SSPR	<10	200	Above Threshold	0	Below Threshold	0	Below Threshold	64.21	Above Threshold
248	SSPR	<10	188	Above Threshold	0	Below Threshold	50.30	Above Threshold	112.08	Above Threshold
249	SSPR	<10	183	Above Threshold	0	Below Threshold	49.62	Above Threshold	97.16	Above Threshold
250	SSPR	<10	179	Above Threshold	0	Below Threshold	45.07	Above Threshold	81.13	Above Threshold
251	SSPR	<10	172	Above Threshold	0	Below Threshold	38.71	Above Threshold	101.79	Above Threshold
252	SSPR	<10	179	Above Threshold	0	Below Threshold	45.27	Above Threshold	83.56	Above Threshold
253	SSPR	<10	162	Above Threshold	0	Below Threshold	15.50	Above Threshold	46.09	Above Threshold
254	SSPR	<10	331	Above Threshold	0	Below Threshold	0	Below Threshold	104.87	Above Threshold
255	SSPR	<10	365	Above Threshold	0	Below Threshold	0	Below Threshold	116.54	Above Threshold
256	SSPR	<10	245	Above Threshold	2	Below Threshold	0	Below Threshold	90.42	Above Threshold
257	SSPR	<10	9	Below Threshold	2	Below Threshold	0	Below Threshold	53.45	Above Threshold
258	SSPR	<10	120	Above Threshold	0	Below Threshold	5.64	Above Threshold	114.93	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
259	SSPR	<10	194	Above Threshold	0	Below Threshold	0	Below Threshold	80.13	Above Threshold
260	SSPR	<10	9	Below Threshold	0	Below Threshold	0	Below Threshold	49.33	Above Threshold
261	SSPR	<10	23	Above Threshold	0	Below Threshold	0	Below Threshold	75.48	Above Threshold
262	SSPR	<10	53	Above Threshold	0	Below Threshold	0	Below Threshold	30.26	Above Threshold
263	SSPR	<10	44	Above Threshold	0	Below Threshold	6.49	Above Threshold	41.78	Above Threshold
264	SSPR	<10	34	Above Threshold	0	Below Threshold	0	Below Threshold	32.09	Above Threshold
265	SSPR	<10	32	Above Threshold	0	Below Threshold	0	Below Threshold	30.35	Above Threshold
266	SSPR	<10	6	Below Threshold	0	Below Threshold	0	Below Threshold	46.13	Above Threshold
267	SSPR	<10	6	Below Threshold	1	Below Threshold	7.10	Above Threshold	55.40	Above Threshold
268	SSPR	<10	6	Below Threshold	3	Below Threshold	7.41	Above Threshold	55.63	Above Threshold
269	SSPR	<10	9	Below Threshold	3	Below Threshold	0	Below Threshold	32.05	Above Threshold
270	SSPR	≥10	7	Below Threshold	0	Below Threshold	0	Below Threshold	32.80	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
271	SSPR	≥ 10	22	Above Threshold	0	Below Threshold	0	Below Threshold	27.93	Above Threshold
272	SSPR	≥ 10	8	Below Threshold	0	Below Threshold	0	Below Threshold	31.42	Above Threshold
273	SSPR	≥ 10	10	Below Threshold	0	Below Threshold	0	Below Threshold	31.56	Above Threshold
274	SSPR	≥ 10	11	Below Threshold	1	Below Threshold	0	Below Threshold	15.57	Above Threshold
275	SSPR	≥ 10	247	Above Threshold	0	Below Threshold	0	Below Threshold	71.55	Above Threshold
276	SSPR	≥ 10	11	Below Threshold	0	Below Threshold	0	Below Threshold	59.63	Above Threshold
277	SSPR	≥ 10	8	Below Threshold	0	Below Threshold	0	Below Threshold	73.40	Above Threshold
278	SSPR	≥ 10	32	Above Threshold	2	Below Threshold	0	Below Threshold	54.84	Above Threshold
279	SSPR	≥ 10	63	Above Threshold	0	Below Threshold	8.03	Above Threshold	33.49	Above Threshold
280	SSPR	≥ 10	21	Above Threshold	3	Below Threshold	0	Below Threshold	67.52	Above Threshold
281	SSPR	≥ 10	10	Below Threshold	1	Below Threshold	0	Below Threshold	17.19	Above Threshold
282	SSPR	Extinct	12	Below Threshold	0	Below Threshold	0	Below Threshold	30.93	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
283	SSPR	Extinct	6	Below Threshold	0	Below Threshold	0	Below Threshold	61.81	Above Threshold
284	SSPR	Extinct	44	Above Threshold	0	Below Threshold	0	Below Threshold	43.98	Above Threshold
285	SSPR	Extinct	32	Above Threshold	0	Below Threshold	0	Below Threshold	19.40	Above Threshold
286	SSPR	Extinct	11	Below Threshold	0	Below Threshold	0	Below Threshold	29.17	Above Threshold
287	SSPR	Extinct	56	Above Threshold	0	Below Threshold	0	Below Threshold	26.78	Above Threshold
288	SSPR	Extinct	66	Above Threshold	0	Below Threshold	0	Below Threshold	28.06	Above Threshold
289	SSPR	Extinct	11	Below Threshold	0	Below Threshold	0	Below Threshold	62.83	Above Threshold
290	SSPR	Extinct	34	Above Threshold	0	Below Threshold	0	Below Threshold	30.78	Above Threshold
291	SSPR	Extinct	47	Above Threshold	0	Below Threshold	0	Below Threshold	22.53	Above Threshold
292	SSPR	Extinct	25	Above Threshold	0	Below Threshold	0	Below Threshold	42.16	Above Threshold
293	SSPR	Extinct	40	Above Threshold	0	Below Threshold	0	Below Threshold	22.01	Above Threshold
294	SSPR	Extinct	24	Above Threshold	0	Below Threshold	0	Below Threshold	43.49	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
295	SSPR	Extinct	56	Above Threshold	0	Below Threshold	0	Below Threshold	35.75	Above Threshold
296	SSPR	Extinct	7	Below Threshold	0	Below Threshold	0	Below Threshold	28.84	Above Threshold
297	SSPR	Extinct	65	Above Threshold	0	Below Threshold	0	Below Threshold	28.04	Above Threshold
298	SSPR	Extinct	28	Above Threshold	0	Below Threshold	0	Below Threshold	19.15	Above Threshold
299	SSPR	Extinct	57	Above Threshold	1	Below Threshold	0	Below Threshold	77.42	Above Threshold
300	SSPR	Extinct	8	Below Threshold	0	Below Threshold	0	Below Threshold	27.22	Above Threshold
301	SSPR	Extinct	64	Above Threshold	0	Below Threshold	0	Below Threshold	28.48	Above Threshold
302	SSPR	Extinct	27	Above Threshold	0	Below Threshold	0	Below Threshold	46.25	Above Threshold
303	SSPR	Extinct	51	Above Threshold	0	Below Threshold	0	Below Threshold	37.80	Above Threshold
304	SSPR	Extinct	24	Above Threshold	0	Below Threshold	0	Below Threshold	24.79	Above Threshold
305	SSPR	Extinct	25	Above Threshold	0	Below Threshold	0	Below Threshold	31.65	Above Threshold
306	SSPR	Extinct	11	Below Threshold	0	Below Threshold	0	Below Threshold	28.69	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
307	SSPR	Extinct	11	Below Threshold	0	Below Threshold	0	Below Threshold	35.16	Above Threshold
308	SSPR	Extinct	30	Above Threshold	0	Below Threshold	0	Below Threshold	24.79	Above Threshold
309	SSPR	Extinct	42	Above Threshold	0	Below Threshold	0	Below Threshold	22.58	Above Threshold
310	SSPR	Extinct	39	Above Threshold	0	Below Threshold	0	Below Threshold	22.07	Above Threshold
311	SSPR	Extinct	13	Above Threshold	0	Below Threshold	0	Below Threshold	30.47	Above Threshold
312	SSPR	Extinct	6	Below Threshold	0	Below Threshold	0	Below Threshold	54.23	Above Threshold
313	SSPR	Extinct	169	Above Threshold	0	Below Threshold	0	Below Threshold	69.93	Above Threshold
314	SSPR	Extinct	145	Above Threshold	0	Below Threshold	0	Below Threshold	76.28	Above Threshold
315	SSPR	Extinct	150	Above Threshold	0	Below Threshold	0	Below Threshold	79.63	Above Threshold
316	SSPR	Extinct	219	Above Threshold	0	Below Threshold	0	Below Threshold	72.14	Above Threshold
317	SSPR	Extinct	243	Above Threshold	0	Below Threshold	1.05	Above Threshold	77.49	Above Threshold
318	SSPR	Extinct	250	Above Threshold	0	Below Threshold	0.53	Below Threshold	87.45	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
319	SSPR	Extinct	145	Above Threshold	0	Below Threshold	0	Below Threshold	80.26	Above Threshold
320	SSPR	Extinct	230	Above Threshold	0	Below Threshold	2.89	Above Threshold	80.11	Above Threshold
321	SSPR	Extinct	140	Above Threshold	0	Below Threshold	0	Below Threshold	78.02	Above Threshold
322	SSPR	Extinct	149	Above Threshold	0	Below Threshold	0	Below Threshold	73.28	Above Threshold
323	SSPR	Extinct	145	Above Threshold	0	Below Threshold	0	Below Threshold	78.70	Above Threshold
324	SSPR	Extinct	139	Above Threshold	0	Below Threshold	0	Below Threshold	73.70	Above Threshold
325	SSPR	Extinct	209	Above Threshold	1	Below Threshold	2.89	Above Threshold	76.26	Above Threshold
326	SSPR	Extinct	264	Above Threshold	0	Below Threshold	0	Below Threshold	82.71	Above Threshold
327	SSPR	Extinct	157	Above Threshold	0	Below Threshold	0	Below Threshold	75.89	Above Threshold
328	SSPR	Extinct	290	Above Threshold	0	Below Threshold	0	Below Threshold	83.51	Above Threshold
329	SSPR	Extinct	159	Above Threshold	0	Below Threshold	0	Below Threshold	76.66	Above Threshold
330	SSPR	Extinct	219	Above Threshold	0	Below Threshold	0	Below Threshold	68.37	Above Threshold

Lek ID	Ecoregion	Lek Attendance Group	Oil/Gas Wells		Vertical Structures		Transmission Lines		Roads	
			Count	Threshold Status	Count	Threshold Status	Length	Threshold Status	Length	Threshold Status
331	SSPR	Extinct	148	Above Threshold	0	Below Threshold	0	Below Threshold	80.33	Above Threshold
332	SSPR	Extinct	225	Above Threshold	0	Below Threshold	1.34	Above Threshold	74.61	Above Threshold
333	SSPR	Extinct	144	Above Threshold	0	Below Threshold	0	Below Threshold	73.01	Above Threshold
334	SSPR	Extinct	232	Above Threshold	0	Below Threshold	2.29	Above Threshold	76.68	Above Threshold
335	SSPR	Extinct	142	Above Threshold	0	Below Threshold	0	Below Threshold	79.02	Above Threshold

