WILDLIFE BIOLOGY

Research article

Patterns in lek persistence and attendance by lesser prairie-chicken (*Tympanuchus pallidicinctus*) near a wind energy facility in southern Kansas

Chad LeBeau, Renae Sattler, Kyle Ebenhoch, Matthew Crane and and Sierra Pugh

Western EcoSystems Technology, Inc., Laramie, WY, USA

Correspondence: Chad LeBeau (clebeau@west-inc.com)

Wildlife Biology
2025: e01438
doi: 10.1002/wlb3.01438

Subject Editor: Sonja Christine Ludwig
Editor-in-Chief: Ilse Storch
Accepted 17 March 2025

As wind energy development expands across the Great Plains, there is potential to adversely affect species that require undisturbed tracts of native grasslands, such as the lesser prairie-chicken *Tympanuchus pallidicinctus*. Effects of wind development on lesser prairie-chicken (LEPC) movement and demographic rates have been minimal when turbines are sited in cultivated cropland and grassland habitats are available nearby, but there are gaps in the overall understanding of how LEPC populations will respond to wind energy development over the long term. Reducing these knowledge gaps and improving our decision-making process is key to balancing the needs of the wind energy industry and conservation of the species. We evaluated trends in LEPC lek attendance and persistence following construction of the Cimarron Bend Wind Resource Area (CBWRA) in southern Kansas, USA, from 2017 to 2024. We used Bayesian generalized linear regression models to evaluate lek stability and the probability of lek abandonment with various environmental and anthropogenic covariates. We modeled total lek attendance with years since facility construction as a predictor. Of the 37 leks included in analysis, we found leks located in areas with relatively higher density of turbines and had lower annual attendance were less stable, and leks located in areas with relatively higher grass cover were less likely to be abandoned over our eight years of monitoring. However, these effects did not seem to negatively impact the local LEPC population at CBWRA, given that the total lek attendance had a positive trend across the 8-year study, providing additional support that siting turbines in cultivated croplands and conserving large intact tracts of grasslands appear to be important minimization measures for LEPC. Regardless, it remains to be seen how LEPC would be impacted by wind energy development in intact grassland-dominated landscapes (i.e. core habitat).

Keywords: lesser prairie-chicken, renewable energy, *Tympanuchus pallidicinctus*, wind energy

NORDIC SOCIETY OIKOS

www.wildlifebiology.org

Introduction

Wind energy generation in the USA has increased by 134% (243 580 GWh) in the last decade alone (Climate Central 2024), and development in response to demand is only expected to grow. This growth presents a range of challenges, including the need to avoid or minimize impacts to wildlife (Allison et al. 2019). Since wind energy is a relatively new form of energy development, there are gaps in understanding of its impacts on wildlife, complicating the balance of societal demand for low-carbon energy with wildlife conservation (Arnett et al. 2016, Smith and Dwyer 2016, Lloyd et al. 2022). Currently, this scenario is being played out with the intersection of lesser prairie-chicken *Tympanuchus pallidicinctus* conservation and the rapid growth of wind energy occurring in US states that overlap the species' range (Vhay et al. 2024).

Lesser prairie-chicken (LEPC) are ground-nesting, upland game birds that require large tracts of undisturbed grass and shrubland habitat containing a diversity in grassland structure and few vertical structures (e.g. trees and anthropogenic features; USFWS 2022). Such areas are increasingly scarce in the LEPC range due to widespread conversion of grasslands for agriculture and energy development (e.g. infrastructure for oil and gas extraction, transmission, and wind energy), and the disruption of natural fire regimes that has facilitated encroachment of woody shrubs (Van Pelt et al. 2013). As a result, today, LEPC occupy 10–20% of their historic range (Rodgers 2016) and are found only within four ecoregions that occur in parts of Colorado, Texas, Oklahoma, New Mexico, and Kansas (USFWS 2022). LEPC were recently listed as threatened (northern population – mixed-grass, short-grass, and sand sagebrush prairie ecoregions) and endangered (southern population – sand shinnery oak prairie ecoregion) under the Endangered Species Act of 1973 (ESA, 87 Federal Register 72674 [25 November 2022]).

Despite concerns about the role of wind energy development as a driver of habitat loss and fragmentation for LEPC, the scientific community's current understanding of the effects of wind energy development on LEPC is based on a single study (LeBeau et al. 2023a), which found that LEPC used habitats close to turbines if turbine density was low, and that avoidance behavior was driven more by the presence of cultivated cropland than by turbines. Additionally, nest success and individual survival were not affected by turbines during breeding or non-breeding seasons (LeBeau et al. 2023a). While these results provide direct evidence of the potential impacts of wind energy infrastructure on LEPC populations, they are specific to a particular location and may not be generalizable. As such, managers tasked with identifying actions to support LEPC recovery and minimize any future habitat loss or fragmentation from future wind energy facilities have had to rely on evidence derived from studies of wind energy interactions with other grouse species (McNew et al. 2014, Winder et al. 2015, Smith et al. 2016, LeBeau et al. 2017a, 2017b, Kelly 2023) or that has been inferred from grouse response to other forms of energy development (Van Pelt et al. 2013, Hovick et al. 2014, USFWS 2022, LeBeau et al. 2023b).

Meta-analyses on the impacts of anthropogenic features (e.g. fences, turbines, oil and gas infrastructure) on various grouse species have consistently found negative effects on lek attendance, resource selection, and survival (Hovick et al. 2014, LeBeau et al. 2023b), and the negative impacts of non-renewable energy (e.g. oil and gas) development and electricity transmission on LEPC populations are well established (Hunt 2004, Pitman et al. 2005, Plumb et al. 2019, Sullins et al. 2019, Peterson et al. 2020, Lawrence et al. 2021, 2022). These patterns suggest similarities in how grouse respond to anthropogenic land-use change. However, the assumption that the response of LEPC to wind energy development can be predicted based on how other species respond, or on how LEPC respond to other forms of disturbance, is untested. Accurately understanding impacts to LEPC populations from wind energy development will require long-term, species-specific research to better inform decision making (Lloyd et al. 2022).

To address this question, we evaluated trends in LEPC lek persistence and attendance by conducting post-construction lek counts at the Cimarron Bend Wind Resource Area (CBWRA), the same study area as in LeBeau et al. (2023a), in southern Kansas, USA, from 2017 to 2024. Trends in counts of LEPC attending leks are often used to inventory and monitor LEPC populations (Garton et al. 2016, Nasman et al. 2022). While key population fitness metrics were evaluated at the CBWRA, it is unknown how these metrics influenced the number of LEPC attending leks, and thus, overall population trends. Our objectives were to 1) evaluate trends in lek attendance and persistence following the facility becoming operational, 2) determine if these trends can be explained by environmental characteristics (e.g. land cover, number of turbines near leks), and 3) compare findings on facility impacts to those of LeBeau et al. (2023a). We used generalized linear models within a Bayesian framework to model the local LEPC population within the study area over eight years and predicted that trends in lek attendance would be stable given that impacts to survival and nest success were not detected during six years of study following construction of the facility (LeBeau et al. 2023a).

Material and methods

Study area

Our study area, the CBWRA, and aerial survey methods to document LEPC leks in the area, are described in detail in Rintz and Kosciuch (2016) and LeBeau et al. (2023a). In brief, the CBWRA is composed of 274 wind turbines built in cultivated cropland, a substation and associated transmission line, and county and turbine-access roads, all contained in an approximately 336 km^2 area in southern Kansas (Fig. 1). The facility became operational in March 2017 with 200 turbines, and an additional 74 turbines were constructed in

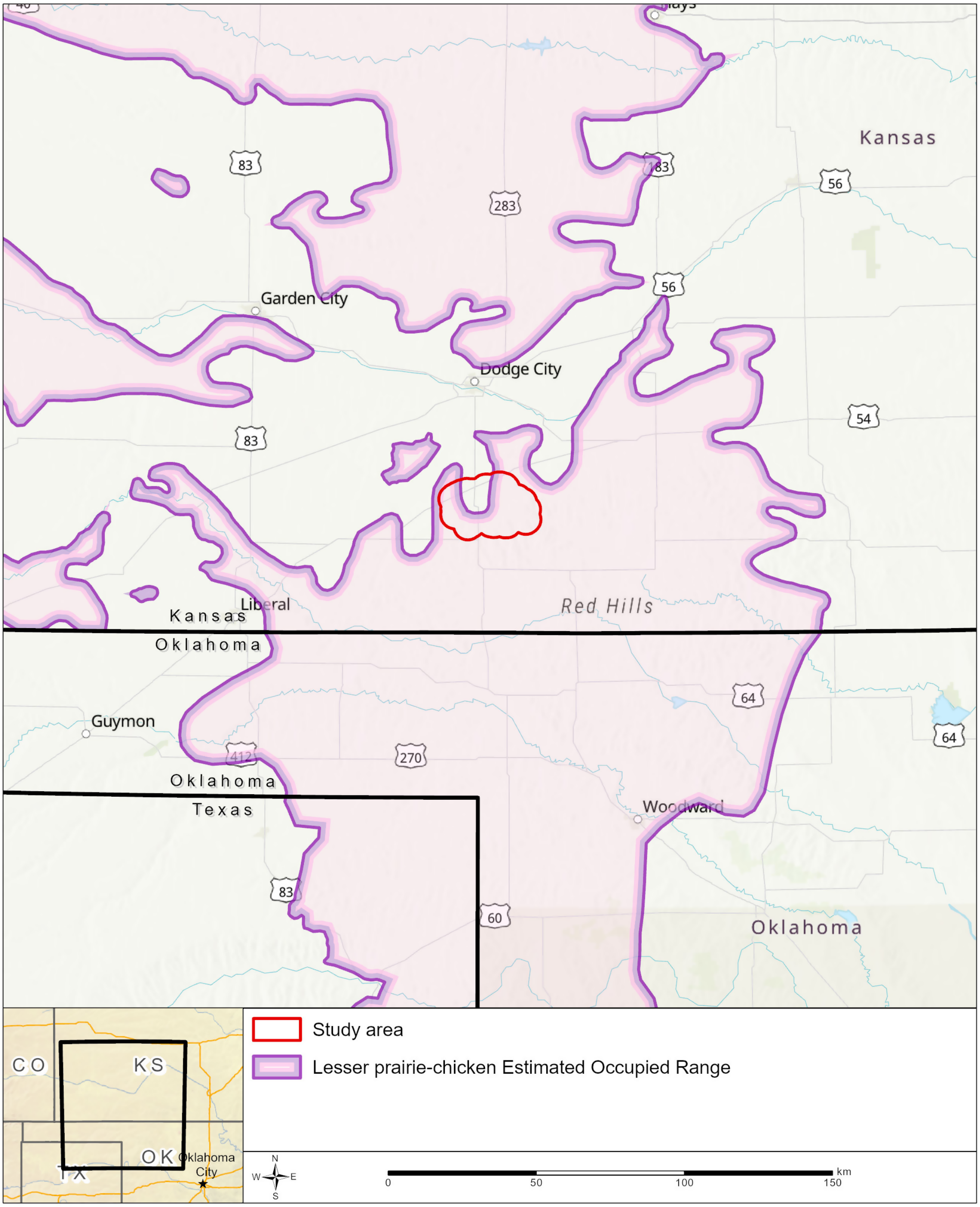

Figure 1. Lesser prairie-chicken lek study area relative to the species' estimate occupied range at the Cimarron Bend Wind Resource Area in southern Kansas, USA, from 2017 to 2024.

2020. Land cover in CBWRA is primarily cultivated cropland interspersed with native mixed grass drainages (NLCD [National Land Cover Database] 2021, LeBeau et al. 2023a).

Prior to major facility construction activities (e.g. wind turbine assembly), a comprehensive aerial search to locate LEPC leks within 4.8 km of CBWRA was conducted March–April 2016 (Rintz and Kosciuch 2016, LeBeau et al. 2023a). This distance was selected because LEPC habitat use principally occurs within 4.8 km of a lek (Giesen 1994, Pirius et al. 2013).

Data collection

We defined a lek as having two or more males displaying or vocalizing on at least one occasion. The location of leks and the number of individual LEPC attending leks were collected by conducting ground-based surveys under USFWS permit no. ESPER0057787. Each breeding season (15 March–7 May; 2017–2024), locations of previously known leks were visited three times to determine activity and number of individuals attending each lek. In addition, we searched for new leks within 4.8 km of CBRWA, as per the USFWS Survey Protocol for Lesser Prairie Chickens (2016, 2023). Lek surveys occurred between 30 min prior to and 120 min after sunrise and were spaced a minimum of 5 days apart. Once a lek was identified, lek counts were facilitated by flushing birds from the lek (where land access was granted) prior to LEPC being listed under the ESA in 2022 (87 FR 72674). Following ESA listing, flushing was no longer conducted, and biologists performed lek counts from a distance, scanning with binoculars for up to 5 min and recording the maximum number of LEPC. Surveys were not conducted if winds exceeded 12.0 mph (5.4 m s^{-1}), visibility was less than 1.0 mi (1.6 km), or there was active precipitation (USFWS 2016, 2023). The maximum number of LEPC counted at each lek over the three survey visits was used in analysis. The original lek location was used if annual variability was detected within 50 m of the original location.

Habitat variables

We used environmental covariates developed by LeBeau et al. (2023a) for their long-term telemetry study of LEPC response to wind-energy infrastructure. We calculated grass cover for the study area from 1-m resolution National Agricultural Imagery Program image mosaics using Emi-automated object-oriented analysis developed by Image Spatial Consulting in the ERDAS Imagine software (LeBeau et al. 2023a). We calculated the percent cover of cultivated cropland using the 30-m resolution (NLCD 2021). Because grass and cultivated cropland were calculated from data acquired in 2017 and 2021, we used the average value of cells within 1.0 km of each lek for both metrics. This distance was derived as twice the average daily distance traveled by LEPC in the study area over an annual period (LeBeau et al. 2023a), under the conservative assumption that it captures variability in habitat likely used by LEPC during the breeding period around a lek location. In addition, this distance was also evaluated in a study that evaluated the effects of wind energy infrastructure on greater prairie-chicken in Kansas (Winder et al. 2015). We developed a turbine count variable that described the maximum number of wind turbines within 1.0 km of each lek.

Data analysis

For the purposes of our analysis, we considered a lek to be active if one or more individuals were recorded. We assumed a 100% detection probability for leks active starting in 2017, such that new leks identified from 2018 to 2024 were assumed to not have been active previously and were assigned a count of zero for previous years. We characterized lek persistence based on two measures of temporal variability: the consistency of a lek being active over the study period (stability) and the probability that LEPC would temporarily or permanently abandon a lek ('blink out') over the study period.

To model lek stability, we used Bayesian binomial regression to model the number of years each lek was active relative to the number of years they were surveyed. We considered percent grass cover, percent agriculture cover, turbine count, and the median count of LEPC when a lek was active as predictor variables. The percentage of grass and percentage of cultivated cropland were highly correlated, and we thus did not include them together in any one model.

Prior to modeling, we categorized leks into two categories based on the proportion of years a lek was active. For example, we determined if each lek had 'blinked out' if the proportion of years a lek was active from 2017 to 2020 was greater than the proportion of years a lek was active from 2021 to 2024, or if the lek was inactive from 2017 to 2024. The four-year time period comparison provided an equal sample size of years and captured any potential time lags that may have existed in this population. We ran a Bayesian Bernoulli regression to model leks 'blinking out' and considered the same predictor variables as the lek stability models but required the model to retain the maximum turbine count to evaluate the impact of turbines on 'blinking out'.

Lastly, to assess the impacts of turbines on the annual LEPC count at CBWRA, we used Bayesian Poisson regression to model the sum of the maximum LEPC counts across all leks within each year. We used the number of years since facility construction (i.e. since 2016) as the sole predictor variable. We did not consider additional variables such as land use or proximity to turbines, as these remained largely unchanged throughout the study period (e.g. distance to turbines in 2017 was the same as in 2024).

We used the 'brms' package (Bürkner 2017) within R statistical software ver. 4.3.2 (www.r-project.org) to run each analysis. For each model, we ran four chains of 7000 iterations, with the first 2000 discarded as burn-in. For each model, we used the default, non-informative prior from the 'brms' package: flat priors for the coefficients and a Student's t distribution for the intercept with three degrees of freedom, a SD of 2.5, and a mean of 0 for the binomial and 4.9 for the Poisson. We assessed convergence via traceplots, effective sample sizes, and $\hat{R}$ values (Vehtari et al. 2020, Supporting information). We selected the top models using a leave-one-out variable selection (Vehtari et al. 2017), for both the stability and 'blink-out' analyses.

Results

We identified 41 leks within 4.8 km of CBWRA from 2017 to 2024, though land access issues prevented consistent and consecutive survey effort at four leks, which were therefore excluded from analysis (Fig. 2, Supporting information). The minimum distance between leks regardless of activity status was 0.62 km and the mean distance to the nearest lek was 1.87 km with a SD of 0.15 km (Fig. 1). Overall, annual lek attendance averaged 140.75 birds (± 34.3 SD), ranging from

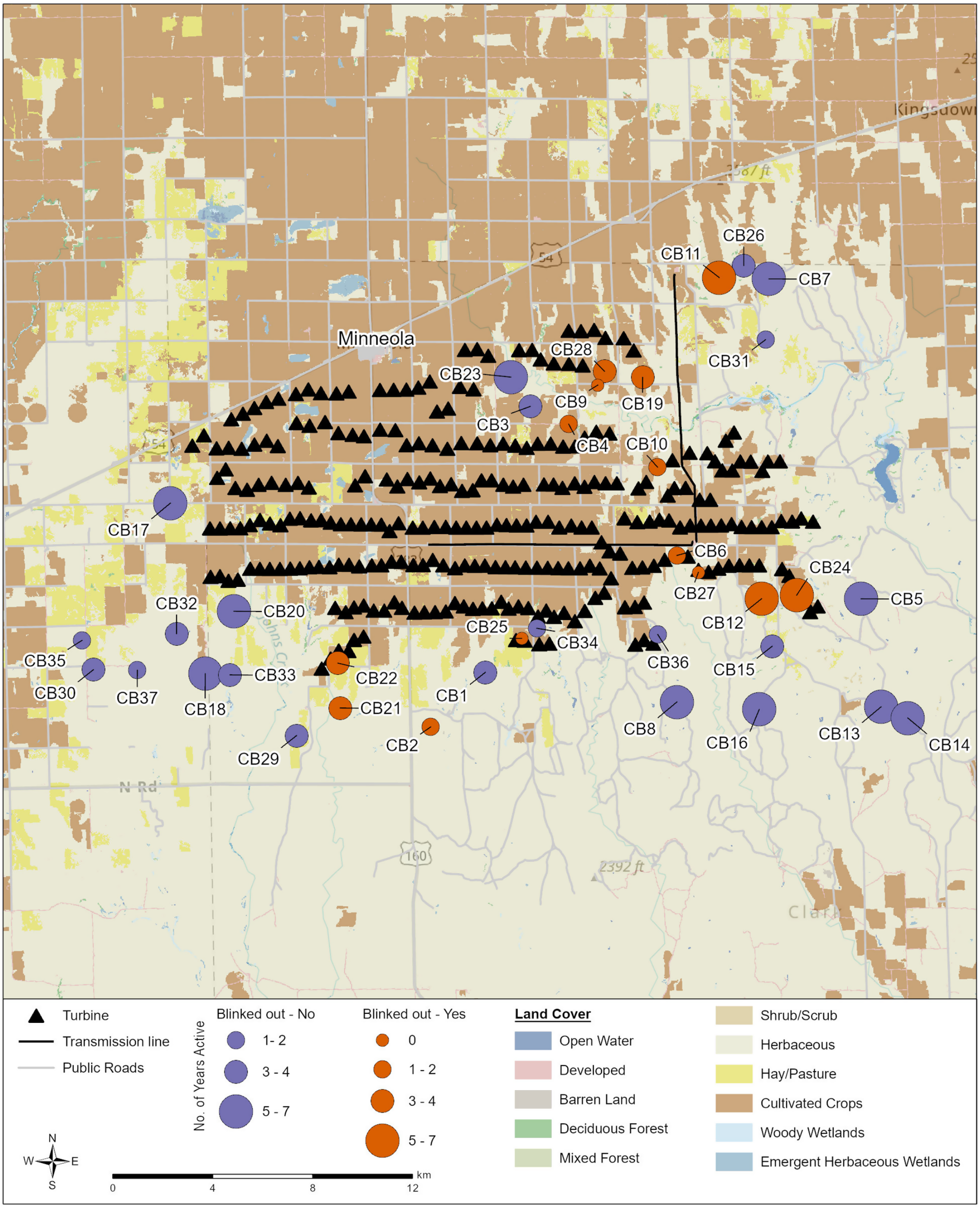

Figure 2. Land cover and number of years when lesser prairie-chicken leks were active (graduated circle size) and their persistence (colored circles) in the Cimarron Bend Wind Resource Area from 2017 to 2024. Leks that had a decrease in the frequency of use from 2017 to 2020 compared to 2021–2024 or if the lek was only active in 2016 but had no observed LEPC from 2017 to 2024 'blinked out' (red circles) compared to those where frequency of use was the same or increased (blue circles).

110 birds in 2018 to 217 birds in 2022 (Supporting information). The number of active leks each year varied from 11 in 2018 to 23 leks in 2023 (± 4.4 SD). The mean percent grass and cropland within 1.0 km of each lek was 26.9% (± 8.1 SD) and 27.7% (± 19.1 SD), respectively. Of the 37 leks included in persistence modeling, 70.3% had zero turbines within 1.0 km, 8.1% leks had 1–4 turbines, 18.9% had 6–8 turbines, and 5.4% had 9–16 turbines within 1.0 km (Supporting information). Fourteen leks (37.8%) 'blinked out' over the course of the study period, including the CB9, CB25, and CB27 leks, which were the only leks documented during the 2016 aerial survey that were inactive during all

Table 1. Model statistics for analyses on lesser prairie-chicken (LEPC) lek persistence in the Cimarron Bend Wind Resource Area from 2017 to 2024. Columns describe the model coefficients, posterior mean (Est.), posterior SD (Est. SD), 95% equal-tail credible interval (Lower 95% CI and Upper 95% CI), convergence diagnostic ($\hat{R}$), and effective sample sizes (ESS).

	Regression coefficients	Est.	Est. SD	Lower 95% CI	Upper 95% CI	$\hat{R}$	Bulk ESS	Tail ESS
Stability	Intercept	−1.36	0.56	−2.50	−0.27	1	16 425	13 408
	Grass cover	0.76	0.49	−0.17	1.71	1	17 523	14 096
	Count of turbines	−0.13	0.05	−0.22	−0.04	1	17 842	15 241
	Median max LEPC count	0.08	0.03	0.02	0.13	1	19 101	14 868
Blink out	Intercept	2.77	1.71	−0.40	6.36	1	15 716	12 354
	Count of turbines	0.15	0.13	−0.09	0.42	1	16 122	13 067
	Grass cover	−3.84	1.72	−7.43	−0.70	1	15 805	12 313
Total lek abundance	Intercept	4.69	0.07	4.55	4.83	1	14 346	11 840
	Years since construction	0.06	0.01	0.03	0.08	1	15 255	12 303

subsequent surveys (Fig. 2). Leks were most commonly active for three years (mean = 3.4 ± 2.1 SD) from 2016 to 2024, with 54% of leks being active for ≤ 3 years and 46% active for ≥ 4 years (Supporting information).

The top model for lek stability included percentage of grass cover and maximum turbine count within 1.0 km, and the median count of LEPC when the lek was active (Table 1, Supporting information). Relatively higher grass cover, higher median LEPC counts, and lower turbine counts predicted more stable leks (Table 1, Fig. 3). Although the 95% coefficient credible interval for grass cover overlapped zero, there was a 0.942 posterior probability that higher grass cover predicted higher lek stability.

The top model for predicting the probability of a lek 'blinking out' included percentage of grass cover and maximum turbine count within 1.0 km as predictors (Table 1). Based on the top model, lower grass cover and higher turbine count predicted a higher probability that a lek would 'blink out' (Table 1, Fig. 4). Although the 95% credible interval for the turbine count coefficient overlapped zero, there was an 0.884 posterior probability that higher turbine counts increased the probability of a lek 'blinking out' (Table 1).

The annual LEPC count model showed a positive trend in lek attendance from 2017–2024 with a 95% credible interval from 0.03–0.08 (Table 1, Fig. 5). The posterior probability of a negative trend was < 0.0001. The high maximum counts in 2022 contributed to the strength in the overall trend, but excluding 2022 from the analysis still resulted in a positive trend, with a posterior mean for the year coefficient of 0.04 and a 95% credible interval from 0.01–0.06.

Discussion

We detected negative effects of wind infrastructure on lek persistence (i.e. 'blinking out' and stability), though the magnitude of these effects depended on the amount of available grassland and median lek size. Specifically, leks with greater proportion of grassland had a lower probability of 'blinking out' regardless of presence of turbines, and larger leks were more likely to persist than smaller leks. Wind turbines did not appear to have an impact on overall population abundance of LEPC in CBWRA over eight years. This suggests that LEPC population persistence depended more on the availability of preferred habitat than the presence of wind turbines, at least in this study area, where existing intact grassland has been maintained by siting turbines in cultivated cropland.

We are unaware of studies that evaluate LEPC lek persistence relative to wind energy infrastructure, although studies of the closely related greater prairie-chicken (GPC) *T. cupido* have yielded findings that are qualitatively similar to those reported here. Wind turbines did not affect lek attendance of female GPC in Nebraska, but did reduce the time that males spent engaged in breeding behaviors at leks closer to turbines (Smith et al. 2016). At a facility in Kansas, lek abandonment by GPC was twice as likely for leks < 1.0 km from a turbine compared to leks 3–8 km away and was greater for leks located in cropland compared to those located in grassland

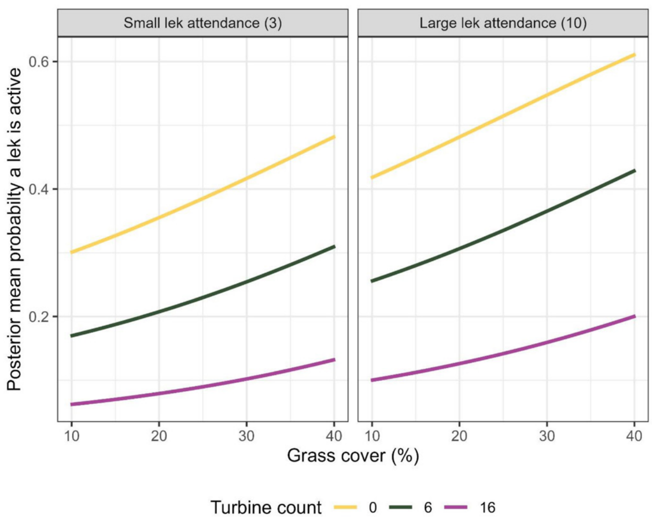

Figure 3. Posterior mean probability a lek is active as a function of grass cover and turbine density within 1.0 km of a lek in the Cimarron Bend Wind Resource Area from 2017 to 2024. The left panel demonstrates the relationship using a small lesser prairie-chicken (LEPC) lek count (i.e. 3, the 0.25 quantile of the observed median data), whereas the right panel uses a large LEPC lek count (i.e. 10, the 0.75 quantile of the observed median data). Line color indicates the turbine count within 1.0 km of a lek for the minimum, median of counts, and maximum turbine counts observed in our data.

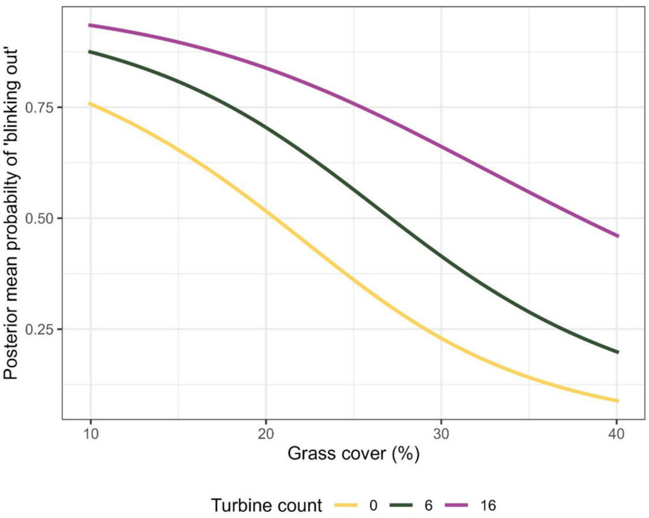

Figure 4. Posterior mean probability of a lek 'blinking out' as a function of grass cover and turbine density within 1.0 km of a lek in the Cimarron Bend Wind Resource Area from 2017 2024. Line color indicates the turbine count within 1.0 km of a lek for the minimum, median of counts, and maximum turbine counts observed in our data.

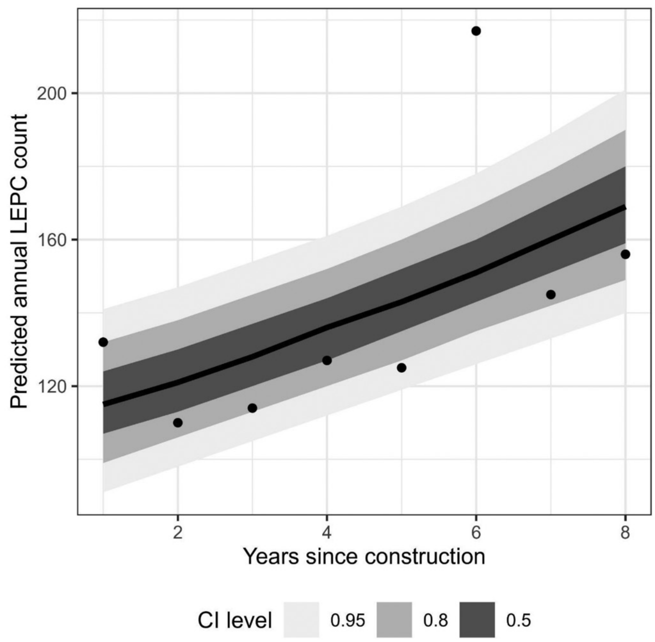

Figure 5. Posterior median of the annual lesser prairie-chicken (LEPC) count (black line) as a function of the number of years since facility construction in the Cimarron Bend Wind Resource Area from 2017 to 2024. Black circles represent the total annual count of LEPC on leks, and bands represent the 50% (dark grey), 80% (medium grey), and 95% (light grey) credible predictive intervals.

(Winder et al. 2015). We found that density of wind turbines did affect lek persistence, but the magnitude of that effect was lower in areas with high proportion of grasslands similar to other studies (Gregory et al. 2011, Winder et al. 2015). For example, leks with 40% grass cover and zero turbines within 1.0 km had a 0.09 (low) posterior probability of 'blinking out'. That probability increased to 0.20 and 0.46 with six and 16 turbines within 1.0 km, respectively, whereas leks located in areas with 20% grass cover and zero turbines had a 0.52 probability of 'blinking out'. This suggests that leks with a greater proportion of grassland have a lower probability of 'blinking out' regardless of the presence of turbines, highlighting the influence of available intact grasslands on LEPC population resilience (Ross et al. 2016). The probability of a lek being stable followed a similar trend but was also influenced by the median size of the lek, suggesting leks with consistently higher counts of individuals are more stable, which was to be expected based on grouse biology (Winder et al. 2015).

Abundance of LEPC attending leks increased over time in the CBWRA, even as an increased density of turbines was negatively associated with lek persistence, suggesting that lek abandonment does not necessarily translate into population-level impacts at CBWRA during the study period. LEPC populations are dynamic in nature; the number of LEPC attending leks may fluctuate and the spatial extent shift from year to year (Garton et al. 2016). Indeed, that the number of individuals attending leks near the CBWRA did not decline suggests individuals were lekking at new locations or attending other, previously established leks. This idea is supported by the results of a concurrent telemetry study, in which LEPC avoided areas with a higher density of wind energy infrastructure but without any associated reduction in survival probability (LeBeau et al. 2023a). Similarly, GPC in Kansas were displaced during the breeding season but neither nest nor female survival were affected by the presence of wind turbines. Furthermore, similar to what we found with LEPC, GPC leks closer to wind turbines had a lower probability of persisting, but proximity to a turbine had no effect on the abundance of lekking males (Winder et al. 2015). Greater sage-grouse (GRSG) *Centrocercus urophasianus* occupy shrub-steppe, not prairie, but are sensitive to landscape change like LEPC, and also seem to exhibit a similar suite of responses to wind turbines: areas near turbines were avoided during the brooding and summer period, but male lek attendance was not affected by the presence of wind turbines, nor did turbines have a detectable effect on nest or adult survival (LeBeau et al. 2017a, b, Smith et al. 2024).

Our study adds to the body of knowledge regarding the impacts of wind energy on LEPC populations and addresses an important shortcoming of much existing research on wind energy and grouse: most studies of grouse at wind facilities were of short duration, often less than four years (Lloyd et al. 2022, USFWS 2022). This presents challenges when making management recommendations for future wind energy facilities occurring in LEPC habitat because the importance of time lags is potentially ignored (Harju et al. 2010). Our study begins to address this shortcoming by following this population of LEPC for eight years following construction of the wind facility. During this time, multiple generations of LEPC have occupied these habitats and it is likely that we would have detected any negative population trends, if such trends existed, as new individuals are recruited to the population. Although our findings are based on a relatively long time-series, our research – like most studies of grouse and wind energy (Lloyd et al. 2022) – did not benefit from pre-construction data, which limits our ability to compare our results to pre-existing conditions. However, the information gained from the pre-construction aerial survey was crucial in identifying the spatial extent of LEPC leks on the landscape relative to future turbine locations, and the study duration was essential to understand potential impacts to multiple LEPC generations.

Another potential weakness of our study design was the reliance on lek counts. Although individual lek counts are traditionally used as an index of population size and trends (Dahlgren et al. 2016, Garton et al. 2016), they can yield biased indices of population size due to variability in the detection probability of leks (McRoberts et al. 2011) and individuals attending leks (Walsh et al. 2004, Johnson and Rowland 2007). We attempted to reduce these uncertainties by maintaining consistent observers and conducting multiple surveys spaced at least five days apart to optimize the probability of capturing peak attendance. In addition, our choice to model individual lek persistence versus individual lek counts was purposeful: by doing so, our analysis was less dependent on an accurate count of individuals at each lek and more concerned with the ability of a lek to persist on the landscape. It is possible that we undercounted individuals at leks once flush counts were discontinued following the 2022 listing decision, but the stability of counts over the study period indicates that the change in approaches to counting individuals at leks did not systematically bias our estimates of abundance. In addition, the trends observed in this population reflected those seen at larger, regional scales (Nasman et al. 2022). For example, the average annual percent change in the estimated population size of LEPC occupying the mixed-grass prairie ecoregion from 2017 to 2022 was 5% compared to 14% observed in the average annual maximum count of LEPC at CBWRA during the same time period. Nonetheless, modeling lek persistence, rather than lek counts, may reduce some of the uncertainty associated with lek count data.

Wind energy development within the range of the LEPC will likely increase as the demand for low-carbon electricity increases. Our results, and those of LeBeau et al. (2023a), suggest that careful siting of new wind energy facilities (e.g. concentrating turbines in cultivated croplands) in the LEPC range is compatible with efforts to restore the species while balancing the societal need for renewable energy. However, caution is warranted in applying our study results to future wind energy facilities that may differ in site characteristics, such as grassland cover and facility infrastructure configuration, or LEPC population characteristics, such as lek density. The CBWRA was located on the edge of intact grassland with relatively large amounts of available habitat that is likely not characteristic across the species range. Rather than directly extending our results to different places or times, the findings of this study are better used within a body-of-evidence approach as one of many tools that should inform future wind energy development.

Acknowledgements – We appreciate the support from many landowners allowing access to their properties. We thank William White, Melissa Nicholas, Aaron Hoeing, and others who assisted with data collection. We appreciate the reviews by Dr John Lloyd and Joshua Zalewski, which markedly improved our manuscript.
Funding – Funding for this research was provided by Renewable Energy Wildlife Research Fund, Enel Green Power, National Fish and Wildlife Federation, and Pattern Energy administered by the Renewable Energy Wildlife Institute. The funders did not have any additional role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.
Permits – The number of individual LEPC attending leks were collected by conducting ground-based surveys under USFWS permit no. ESPER0057787.

Author contributions

Chad LeBeau: Project administration (lead); Supervision (lead): Writing – original draft (lead); Methodology (supporting). **Renae Sattler**: Formal analysis (supporting); Project administration (equal); Supervision (equal); Writing – original draft (equal). **Kyle Ebenhoch**: Formal analysis (supporting); Methodology (supporting); Writing – original draft (equal). **Matthew Crane**: Formal analysis (lead); Writing – original draft (supporting). **Sierra Pugh**: Formal analysis (supporting); Methodology (supporting); Software (lead); Writing – original draft (supporting).

Transparent peer review

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/wlb3.01438.

Data availability statement

Data are available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.msbcc2g91 (LeBeau et al. 2025).

Supporting information

The Supporting information associated with this article is available with the online version.

References

Allison, T. D., Diffendorfer, J. E., Baerwald, E. F., Beston, J. A., Drake, D., Hale, A. M., Hein, C. D., Huso, M. M., Loss, S. R., Lovich, J. E. and Strickland, M. D. 2019. Impacts to wildlife of wind energy siting and operation in the US. – Issues Ecol. 21: 2–18.

Arnett, E. B., Baerwald, E. F., Mathews, F., Rodrigues, L., Rodríguez-Durán, A., Rydell, J., Villegas-Patraca, R. and Voigt, C. C. 2016. Impacts of wind energy development on bats: a global perspective. – In: Voigt, C. C. and Kingston, T. (eds), Bats in

the Anthropocene: conservation of bats in a changing world. Springer, pp. 295–323.
Bürkner, P.-C. 2017. brms: an R package for Bayesian multilevel models using stan. – J. Stat. Softw. 80: 1–28.
Climate Central. 2024. A decade of growth in solar and wind power: trends across the US. – Climate Central, Inc.
Dahlgren, D. K., Guttery, M. R., Messmer, T. A., Caudill, D., Dwayne Elmore, R. D., Chi, R. and Koons, D. N. 2016. Evaluating vital rate contributions to greater sage-grouse population dynamics to inform conservation. – Ecosphere 7: e01249.
Endangered Species Act. 1973. 16 US code sections (§§) 1531-1544. [As amended by Public Law (PL) 93-205, §2, December 28, 1973, 87 Statute (Stat.) 884; PL 96-159, §1, December 28, 1979, 93 Stat. 1225; PL 97-304, §9(a), October 13, 1982, 96 Stat. 1426; PL. 100-478, Title I, §1013(a), October 7, 1988, 102 Stat. 2315.].
Garton, E. O., Hagen, C. A., Beauprez, G. M., Kyle, S. C., Pitman, J. C., Schoeling, D. D. and Van Pelt, W. E. 2016. Population dynamics of the lesser prairie-chicken. – In: Haukos, D. A. and Boal, C. W. (eds), Ecology and conservation of lesser prairie-chickens. CRC Press, pp. 49–76.
Giesen, K. M. 1994. Movements and nesting habitat of lesser prairie-chicken hens in Colorado. – Southwest. Nat. 39: 96–98.
Gregory, A. J., McNew, L. B., Prebyl, T. J., Sandercock, B. K. and Wisely, S. M. 2011. Hierarchical modeling of lek habitats of greater prairie-chickens. – In: Sandercock, B. K., Martin, K. and Segelbacher, G. (eds), Ecology, conservation, and management of grouse. Studies in avian biology, vol. 39. Univ. California Press, pp. 21–32.
Harju, S. M., Dzialak, M. R., Taylor, R. C., Hayden-Wing, L. D. and Winstead, J. B. 2010. Thresholds and time lags in effects of energy development on greater sage-grouse populations. – J. Wildl. Manage. 74: 437–448.
Hovick, T. J., Elmore, R. D., Dahlgren, D. K., Fuhlendorf, S. D. and Engle, D. M. 2014. Evidence of negative effects of anthropogenic structures on wildlife: a review of grouse survival and behaviour. – J. Appl. Ecol. 51: 1680–1689.
Hunt, J. L. 2004. Investigation into the decline of populations of the lesser prairie-chicken (*Tympanuchus pallidicinctus* Ridgway) in southeastern New Mexico. – MSc thesis, Auburn Univ., Auburn, Alabama, USA.
Johnson, D. H. and Rowland, M. M. 2007. The utility of lek counts for monitoring greater sage-grouse. – Univ. of Idaho College of Natural Resources Experiment Station Bulletin 88, Univ. of Idaho.
Kelly, C. S. 2023. Plains sharp-tailed grouse response to wind energy development in Northeastern South Dakota. – MSc thesis. Univ. of Wyoming, Laramie, Wyoming.
Lawrence, A. J., Carleton, S. A., Gould, W. R. and Nichols, C. T. 2021. Lesser prairie-chicken survival in varying densities of energy development. – J. Wildl. Manage. 85: 1256–1266.
Lawrence, A. J., Boggie, M. A., Gould, W. R., Carleton, S. A. and Nichols, C. T. 2022. Differential seasonal avoidance of anthropogenic features and woody vegetation by lesser prairie-chickens. – Ornithol. Appl. 124: duac022.
LeBeau, C. W., Johnson, G. D., Holloran, M. J., Beck, J. L., Nielson, R. M., Kauffman, M. E., Rodemaker, E. J. and McDonald, T. L. 2017a. Greater sage-grouse habitat selection, survival, and wind energy infrastructure. – J. Wildl. Manage. 81: 690–711.
LeBeau, C. W., Beck, J. L., Johnson, G. D., Nielson, R. M., Holloran, M. J., Gerow, K. G. and McDonald, T. L. 2017b. Greater sage-grouse male lek counts relative to a wind energy development. – Wildl. Soc. Bull. 41: 17–26.
LeBeau, C., Smith, K. and Kosciuch, K. 2023a. Lesser prairie-chicken habitat selection and survival relative to a wind energy facility located in a fragmented landscape. – Wildl. Biol. 2023: e01091.
LeBeau, C., Smith, K., Howlin, S., Tredennick, A. and Kosciuch, K. 2023b. A meta-analysis investigating the effects of energy infrastructure proximity on grouse demography and space use. – Wildl. Biol. 2023: e01087.
LeBeau, C., Sattler, R., Ebenhoch, K., Crane, M. and Pugh, S. 2025. Data from: Patterns in lek persistence and attendance by lesser prairie-chicken *Tympanuchus pallidicinctus* near a wind energy facility in southern Kansas. – Dryad Digital Repository, https://doi.org/10.5061/dryad.msbcc2g91.
Lloyd, J. D., Aldridge, C. L., Allison, T. D., LeBeau, C. W., McNew, L. B. and Winder, V. L. 2022. Prairie grouse and wind energy: the state of the science and implications for risk assessment. – Wildl. Soc. Bull. 46: e1305.
McNew, L. B., Hunt, L. M., Gregory, A. J., Wisely, S. M. and Sandercock, B. K. 2014. Effects of wind energy development on nesting ecology of greater prairie-chickens in fragmented grasslands. – Conserv. Biol. 28: 1089–1099.
McRoberts, J. T., Butler, M. J., Ballard, W. B., Whitlaw, H. A., Haukos, D. A. and Wallace, M. C. 2011. Detectability of lesser prairie-chicken leks: a comparison of surveys from aircraft. – J. Wildl. Manage. 75: 771–778.
Nasman, K., Rintz, T., DiDonato, G. and Kulzer, F. 2022. Range-wide population size of the lesser prairie-chicken: 2012 to 2022. – Prepared for the Western Association of Fish and Wildlife Agencies by Western EcoSystems Technology.
NLCD (National Land Cover Database). 2021. National Land Cover Database 2021. Landcover and imperviousness. As cited includes: Dewitz, J. 2023. National Land Cover database (NLCD) 2021 products. – US Geological Survey Data Release, https://www.mrlc.gov/data.
Peterson, J. M., Earl, J. E., Fuhlendorf, S. D., Elmore, R. D., Haukos, D. A., Tanner, A. M. and Carleton, S. A. 2020. Estimating response distances of lesser prairie-chickens to anthropogenic features during long-distance movements. – Ecosphere 11: e03202.
Pirius, N. E., Boal, C. W., Haukos, D. A. and Wallace, M. C. 2013. Winter habitat use and survival of lesser prairie-chickens in west Texas. – Wildl. Soc. Bull. 37: 759–765.
Pitman, J. C., Hagen, C. A., Robel, R. J., Loughin, T. M. and Applegate, R. D. 2005. Location and success of lesser prairie-chicken nests in relation to vegetation and human disturbance. – J. Wildl. Manage. 69: 1259–1269.
Plumb, R. T., Lautenbach, J. M., Robinson, S. G., Haukos, D. A., Winder, V. L., Hagen, C. A., Sullins, D. S., Pitman, J. C. and Dahlgren, D. K. 2019. Lesser prairie-chicken space use in relation to anthropogenic structures. – J. Wildl. Manage. 83: 216–230.
Rintz, T. and Kosciuch, K. 2016. Lesser prairie-chicken survey for Cimarron Bend. Draft report: June 2016. – Prepared for Tradewind Energy Inc. by Western EcoSystems Technology. .
Rodgers, R. D. 2016. A history of lesser prairie-chickens. – In: Haukos, D. A. and Boal, C. W. (eds), Ecology and conservation of lesser prairie-chickens. CRC Press, pp. 15–38.
Ross, B. E., Haukos, D. A., Hagen, C. A. and Pitman, J. C. 2016. Landscape composition creates a threshold influencing lesser prairie-chicken population resilience to extreme drought. – Global Ecol. Conserv. 6: 179–188.

Smith, J. A. and Dwyer, J. F. 2016. Avian interactions with renewable energy infrastructure: an update. – Condor Ornithol. Appl. 118: 411–423.
Smith, J. A., Whalen, C. E., Bomberger Brown, M. and Powell, L. A. 2016. Indirect effects of an existing wind energy facility on lekking behavior of greater prairie-chickens. – Ethology 122: 419–429.
Smith, K. T., LeBeau, C. W., Hoskovec, L. and Beck, J. L. 2024. Trends in greater sage-grouse lek counts relative to existing wind energy development in Wyoming. – Wildl. Soc. Bull. 48: e1526.
Sullins, D. S., Haukos, D. A., Lautenbach, J. M., Lautenbach, J. D., Robinson, S. G., Rice, M. B., Sandercock, B. K., Kraft, J. D., Plumb, R. T., Reitz, J. H., Hutchinson, J. M. S. and Hagen, C. A. 2019. Strategic conservation for lesser prairie-chickens among landscapes of varying anthropogenic influence. – Biol. Conserv. 238: article 108213.
US Fish and Wildlife Service (USFWS) 2016. – US Fish and Wildlife Service survey protocol for the lesser prairie-chicken.
US Fish and Wildlife Service (USFWS) 2022. Species status assessment report for the lesser prairie-chicken (*Tympanuchus pallidicinctus*), ver. 2.3. – USFWS Southwest and Mountain-Prairie Regions.
US Fish and Wildlife Service (USFWS) 2023. US Fish and Wildlife Service survey protocol for the lesser prairie-chicken. Updated – USFWS, March 2023.
Van Pelt, W. E., Kyle, S., Pitman, J., Klute, D., Beauprez, G., Schoeling, D., Janus, A. and Haufler, J. 2013. The lesser prairie-chicken range-wide conservation plan. – Western Association of Fish and Wildlife Agencies.
Vehtari, A., Gelman, A. and Gabry, J. 2017. Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. – Stat. Comput. 27: 1413–1432.
Vehtari, A., Gelman, A., Simpson, D., Carpenter, B. and Bürkner, P.-C. 2020. Rank-normalization, folding, and localization: an improved $\hat{R}$ for assessing convergence of MCMC (with discussion). – Bayesian Anal. 16: 667–718.
Vhay, M. P., Haukos, D. A., Sullins, D. S. and Rice, M. B. 2024. Broad-scale changes in lesser prairie-chicken habitat. – PLoS One 19: e0304452.
Walsh, D. P., White, G. C., Remington, T. E. and Bowden, D. C. 2004. Evaluation of the lek-count index for greater sage-grouse. – Wildl. Soc. Bull. 32: 56–68.
Winder, V. L., Gregory, A. J., McNew, L. B. and Sandercock, B. K. 2015. Responses of male greater prairie-chickens to wind energy development. – Condor 117: 284–296.