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Re: Comment letter from WAFWA to FWS regarding the proposed listing of the Lesser Prairie-Chicken

To whom this may concern:

This letter is written in response to the United States Fish and Wildlife Service's (USFWS) June 1, 2021 notice of its proposed rule to list the lesser prairie-chicken (LPC) as a threatened and endangered species under the Endangered Species Act and of the proposed 4(d) rule for the LPC. I am the Chair of Western Association of Fish and Wildlife Agencies (WAFWA)'s LPC Initiative Council and appreciate the opportunity to comment on both the proposed listing rule and the proposed 4(d) rule. WAFWA is a strong advocate for the rights of states and provinces to manage fish and wildlife within their borders. WAFWA's membership includes 19 states, 3 Canadian provinces and 2 territories, spanning from Alaska to Texas and Saskatchewan to Hawaii. It also includes the five states that are home to the LPC. Our Association has been a key organization in promoting the principles of sound resource management and the building of partnerships at the regional, national, and international levels to enhance wildlife conservation efforts and the conservation of associated habitats in the public interest. While each state, reserves the right to its individual comments, WAFWA would like to provide the following comments.

In 2006, WAFWA entered into a memorandum of understanding with its members to be the umbrella organization to oversee and report on a comprehensive conservation strategy for prairie ecosystems, which included the LPC. The participating agencies agreed that cooperation is necessary to collect and analyze data on these species and their habitats, and to plan and implement actions necessary to maintain viable populations sufficient to preclude present or future endangerment, within the constraints of approved budgets. Ever since, WAFWA has been successfully coordinating LPC conservation efforts across the states of Colorado, Kansas, New Mexico, Oklahoma, and Texas.

For the past 25 years, WAFWA's LPC Interstate Working Group has been recognized as a reliable scientific data source on LPC ecology and its annual population survey, funded by WAFWA's Species Restoration Foundation and by the states, is the reference for LPC population trends. WAFWA has been a leader in LPC conservation[1] through its Western Grassland Initiative — active since 2006 — and the Lesser Prairie Chicken Range-Wide Conservation Plan (RWP). In addition, WAFWA is leading innovation in proactive conservation through administration and implementation of WAFWA Conservation Agreements for the LPC (WCA) and the Range-Wide Oil and Gas Candidate Conservation Agreement with Assurances for the Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*) in Colorado, Kansas, New Mexico, Oklahoma and Texas (CCAA).

USFWS should continue to accept comments and new data before making a final determination of whether or not an Endangered Species Act (ESA) listing is warranted. The USFWS analysis depends in large part on the population data that is collected and analyzed annually by WAFWA and the states. The result of the population survey for 2021 is attached in Appendix A. States are currently securing funding for surveys to continue in 2022, before the deadline for a listing decision by USFWS and that information should be included in USFWS rationale for its decision. For this and a variety of reasons, we ask that the comment period remain open during the decision process.

WAFWA does not agree with the USFWS approach to LPC viability. The USFWS clearly recognizes the importance of habitat quality in the proposed listing decision and in its Species Status Assessment. However, its approach to LPC population viability is focused primarily on the amount of habitat acres available regardless of their quality or of their location in critical areas (CHAT 1 and 2). The effects of climate change will continue to alter conservation priorities for LPC at the population level. WAFWA, through its RWP, WCA and CCAA, has focused its initiatives on creating population focal areas by targeting conservation across large tracts of land in critical areas and by improving the LPC habitat quality on these parcels. In addition, WAFWA is proactively managing LPC habitat for the uncertainty of climate change by using a shifting mosaic of iterative-term conservation properties. This approach is based on empirical evidence and allows the LPC opportunity to adapt to changing conditions and available suitable habitat. WAFWA urges the USFWS to reconsider its approach to LPC viability and mitigation to better provide incentives to restore and manage habitat quality and to plan for the potential impacts of climate change.

[1] See https://wafwa.org/initiative-programs/lesser-prairie-chicken/

WAFWA is concerned that a listing of any kind would hamper collaborative conservation efforts led by the states. WAFWA's primary LPC and grassland objective is to foster collaboration with and between the states for the benefit of wildlife species and landowners who are integral to these efforts through their voluntary conservation efforts. A listing of the LPC by the USFWS would threaten 16 years of collaborative work by the states, landowners, and other stakeholders. Rural communities would lose incentives to continue to care for the prairie ecosystem. Instead, its future would be turned over to a much more detached and inflexible Federal system, and this precious ecosystem would disappear by the process of a thousand papercuts as landowners disengage from their important conservation efforts.

State wildlife management agencies are much better positioned than the USFWS to successfully manage the LPC. Not only do state agencies have 150 years of experience in managing this species, but they have developed monitoring and population surveys that provide the most comprehensive data available. Furthermore, states have funded and implemented the vast majority of LPC research and have access to critical population demography data and local LPC experts. These experts have established themselves within the communities working within the range of the LPC and are trusted by landowners and local non-profit groups. Therefore, they should be leading the management and recovery effort, not taking a backseat to Federal directives, and potentially fracturing these critical social connections. The success of the RWP's mitigation framework is a great example of what can be achieved by state agencies. It is a proactive, voluntary conservation effort by conservation-minded landowners and by companies in multiple economic sectors such as oil and gas, renewable energy and transmission lines, regional electrical cooperatives, and communications. Since 2014, the mitigation framework has conserved, enhanced, and restored nearly 150,000 acres of LPC habitat by working with over 16 critical landowners. Impacts by industry developments have been reduced due to the financial incentives implemented by the RWP. Since 2014, only 18,942 acres of habitat have been impacted by participating companies. The success of the RWP demonstrates the ability of state agencies to design and implement a conservation program for the LPC.

In the unfortunate event that the USFWS moves forward with a listing, WAFWA is requesting that the proposed 4(d) rule be broadened to ensure state agencies continue managing the LPC. As outlined above, the USFWS lacks the resources, expertise, and on-the-ground relationships to properly manage the LPC. Instead, the USFWS should continue its partnership with the States and remain in a monitoring and advisory role. USFWS could support States' efforts by providing financial assistance and ensuring restoration goals are achieved by all stakeholders throughout the LPC range. In addition, the RWP has already been endorsed by the USFWS and is being successfully implemented. There is no need to reinvent the wheel and the RWP should be included in the 4(d) rule and should be the species recovery plan. The States recognize that much has been learned since the inception of the RWP in 2013. The RWP already includes a process for re-evaluating and adapting to changing conditions and varying degrees of management effectiveness (5- and 10-year reviews). It can be adapted to better fit the needs of the species without being entirely rewritten. For these reasons, we believe that if the species must be listed, the best regulatory mechanism is through an updated 4(d) rule that includes the RWP mitigation framework and recommended conservation practices. WAFWA, the states, USFWS, and conservation partners could then explore alternative programmatic approaches — such as Habitat

Conservation Plans or Safe Harbor Agreements — to provide more certainty to industry partners and landowners.

Finally, if the USFWS moves forward with a listing, it is critical that it recognizes the proactive role played by ranchers in the conservation of the LPC and offer them protection through a broadened 4(d) rule and a Safe Harbor Agreement. WAFWA urges USFWS to expand the current 4(d) rule to cover all types of grazing. In most cases, grazing is beneficial to LPC. However, the habitat is under constant threat of conversion to other more profitable land uses. It is therefore imperative to continue to promote ranching in the LPC range. Creating more barriers and costs for ranching will push many operations to the brink and accelerate the trend of irreversible habitat conversion. In addition, USFWS needs to provide coverage for all the landowners who have voluntarily participated in the pre-listing protection of the LPC through the CCAA and the WCA. These landowners have demonstrated, often at a direct cost to them, their commitment to conservation. It would be extremely counterproductive if they were negatively affected by their conservation efforts because of an oversight by the USFWS who did not include such protections in the CCAA. In addition, WAFWA urges the USFWS to provide coverage for all industry participants in the RWP mitigation strategy through the WCA. These companies have invested in protecting the LPC to avoid a listing and should be recognized for their proactive conservation actions.

In conclusion, WAFWA strongly believes that the LPC is better managed by states than by the USFWS, and a listing would thwart such efforts. If the USFWS moves forward with a listing, the proposed 4(d) rule needs to be broadened to include the Range Wide Plan conservation actions and mitigation framework and make it central to all LPC conservation efforts. In addition, USFWS should recognize the important role played by ranchers and companies participating in the WCA in proactively conserving LPC habitat prior to listing decisions. WAFWA is requesting that grazing activities be included under the 4(d) rule. Finally, landowners who participated in the RWP and companies who provided funding under the WCA should be offered exemption through an extension of the 4(d) rule and/or Safe Harbor Agreements.

Brad Loveless

Brad Loveless, Chair
Lesser Prairie-Chicken Initiative Council
Western Association of Fish and Wildlife Agencies

RANGE-WIDE POPULATION SIZE OF THE LESSER PRAIRIE-CHICKEN: 2012 TO 2021

Photos: Colorado Parks and Wildlife

Prepared for:

Western Association of Fish and Wildlife Agencies

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WEST

EXECUTIVE SUMMARY

- We estimated lesser prairie-chicken population sizes annually from 2012 to 2018, 2020, and 2021 in the 2011 estimated occupied range of the lesser prairie-chicken as defined by the LPC Interstate Working Group and mapped on the Western Association of Fish and Wildlife Agencies' web site (LPCIWG 2011, McDonald et al. 2012) in Kansas, Colorado, New Mexico, Oklahoma, and Texas.
- We estimated lesser prairie-chicken population sizes and abundances of leks in four ecoregions of the estimated occupied range.
- There were 536 total grid cells in the study area from 2012 to 2017 and 514 total grid cells in the study area in 2018, 2020, and 2021. The study area was reduced in 2018 by dropping grid cells in the Mixed-Grass Prairie Region of central Kansas where no lesser prairie-chickens or leks were observed from 2012 to 2017.
- Sample cells were selected by an equal probability procedure. In 2012, 256 grid cells were surveyed, and 283 grid cells were surveyed from 2013 through 2016. In 2017, 2018, and 2021, 303 cells were surveyed, and 302 cells were surveyed in 2020. A rotating panel design was implemented in 2017, 2018, 2020, and 2021 by selecting new grid cells for approximately 20% of the sampled area in each of the ecoregions. The same field survey methods were used from 2012 to 2021; two transects were surveyed in each grid cell and the two transects covered 8% of the grid cell.
- On estimated parameters, 90% confidence intervals (CI) were computed to account for variation in the estimates due to unsampled grid cells, detection probability, and surveying two transects in each sampled grid cell.
- From 2012 to 2021, 1,284 prairie-chicken clusters were detected; 58.2% of the observations were in short-grass grassland, 22.4% were in cropland, 10.5% were in tall-grass grassland including Conservation Reserve Program (CRP) grassland (with little or no shrubs), 5.6% were in sand-sage prairie, 2.7% were in shinnery oak (including other shrub dominated land), and 0.5% were on bare ground.
- We estimated probability of detection on transects using a pooled data set of 1,284 prairie-chicken clusters. Probability of detection increased as the size of prairie-chicken cluster increased. Probability of detection decreased as distance from the transect line increased.
- We estimated the probability of detection of clusters of all prairie-chicken using distance sampling models scaled by the estimated probability of detection on the inside edge of the field of view of the rear seat observers. We adjusted counts of lesser prairie-chicken, greater prairie-chicken, and hybrid prairie-chicken by covariate-specific, scaled probabilities of detection to estimate population sizes in ecoregions and the total study area.

- For the study of trends, we estimated the total population sizes of lesser prairie-chicken to be:
    - 29,382 (90% CI: 20,381, 39,934) lesser prairie-chicken in 2012
    - 15,913 (90% CI: 9,723, 23,527) in 2013
    - 18,987 (90% CI: 12,608, 25,997) in 2014
    - 23,540 (90% CI: 16,559, 31,623) in 2015
    - 20,739 (90% CI: 14,878, 27,375) in 2016
    - 26,916 (90% CI: 19,003, 36,316) in 2017
    - 34,825 (90% CI: 25,448, 46,932) in 2018
    - 34,568 (90% CI: 24,081, 45,431) in 2020
    - 30,461 (90% CI: 20,137, 41,923) in 2021
- There was a statistically significant annual rate of increase of 2,616 (standard error = 522) in the total lesser prairie-chicken population size from 2013 to 2021 (p-value less than 0.01) using a generalized simple linear regression model with random error terms following a first-order autoregressive process
    - A prediction for 2019 was 30,976 (90% Prediction Interval: 23,302, 38,651) when surveys were not conducted.
- We estimated a total population decrease of 4,107 lesser prairie-chicken from 2020 to 2021 (11.9% decrease); however, the decrease was not statistically significant at the 80% confidence level. The 90% CI around the estimated increase ranged from negative (-19,325) to positive (10,314), indicating there was not a statistically significant decrease in lesser-prairie chicken between 2020 and 2021. In addition, there was not a statistically significant decrease in lesser-prairie chicken between 2020 and 2021 when the 80% CI was evaluated.
- We observed a stable to increasing population of lesser prairie-chickens from 2015 to 2020 and a decrease from 2020 to 2021 in the Shinnery Oak Prairie Region of eastern New Mexico and western Panhandle of Texas.
- We observed a stable to increasing population of lesser prairie-chickens from 2014 to 2018 in the Sand Sage Prairie Region of southeastern Colorado, southwestern Kansas, and the northwest Oklahoma Panhandle, with a decrease in lesser prairie-chicken from 2019 to 2020, and a slight increase from 2020 to 2021. Note that the survey was designed to measure trends in the range-wide population of lesser prairie-chicken over time, and estimates can be variable in low-density ecoregions such as the Sand Sage Prairie Region.
- We observed an increasing population of lesser prairie-chickens from 2013 to 2015 in the Mixed Grass Prairie Region of northeast Panhandle of Texas, northwest Oklahoma, and south-central Kansas. There was a slight decrease in the population of lesser-prairie

chickens in 2016, the population was stable in 2017 and 2018, and a decrease was observed in 2020 and 2021.

- We observed a stable to increasing population of lesser prairie-chickens from 2013 to 2021 in the Short Grass CRP Prairie Region of northwest Kansas.
- To further evaluate trends in the lesser prairie-chicken population, annual estimates of lesser prairie-chicken were averaged over three years:
  - 21,427 (90% CI: 17155, 26594) estimated average annual LPC population from 2012 – 2014;
  - 19,480 (90% CI: 15,352, 23,826) from 2013 – 2015;
  - 21,089 (90% CI: 17,200, 25,627) from 2014 – 2016;
  - 23,732 (90% CI: 19,442, 28,600) from 2015 – 2017;
  - 27,493 (90% CI: 22,527, 33,616) from 2016 – 2018;
  - 30,871 (90% CI: 24,578, 39,093) from 2017 – 2018 (no surveys in 2019);
  - 34,697 (90% CI: 27,379, 43,092) from 2018 – 2020 (no surveys in 2019); and
  - 32,515 (90% CI: 25,318, 40,674) from 2020 – 2021 (no surveys in 2019).
- The abundances of lesser prairie-chicken leks in the total population were estimated to be:
  - 2,823 (90% CI: 1,712, 4,153) lesser prairie-chicken leks in 2012
  - 1,801 (90% CI: 1,043, 2,752) in 2013
  - 2,253 (90% CI: 1,415, 3,227) in 2014
  - 1,425 (90% CI: 838, 2,034) in 2015
  - 1,723 (90% CI: 908, 2,607) in 2016
  - 2,588 (90% CI: 1,721, 3,513) in 2017
  - 2,600 (90% CI: 1,738, 3,688) in 2018
  - 4,737 (90% CI: 3,141, 6,388) in 2020
  - 3,152 (90% CI: 2,035, 4,333) in 2021
- We observed an increase in lesser prairie-chicken leks from 2018 to 2020 and a decrease in lesser prairie-chicken leks from 2020 to 2021.

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INTRODUCTION

Ascertaining estimates of wildlife population size is valuable information for natural resource agencies in the management of harvested and non-harvested species (Rabe et al. 2002). Acquiring precise and unbiased estimates of population size requires either a complete census or probabilistic sample of subunits with which to infer population size (Johnson 2002); however, limited funding and staffing have often precluded implementation of these sampling designs. The result has been the development of population indices to monitor population trends or to estimate a minimum population size. The limitation of such data is the unknown relationship to population size. Further, it must be assumed that population indices track population dynamics (McKelvey and Pearson 2001). These assumptions can be problematic when knowing the population size is critical to decision makers either in the context of harvest or population recovery of sensitive species.

Our objectives were to implement consistent, statistically robust survey and analysis methods to estimate lesser prairie-chicken (*Tympanuchus pallidicinctus*; LPC) population size from 2012 to 2018, 2020, and 2021. To achieve this, we addressed issues of regional variation as well as the co-occurrence of greater prairie-chicken (*T. cupido*; GPC) and of hybrid prairie-chickens (HPC) in northwestern Kansas. We estimated LPC abundance for four ecoregions: 1) Shinnery Oak Prairie Region (SOPR), located in eastern New Mexico and the southwest Texas Panhandle, 2) Sand Sagebrush Prairie Region (SSPR), located in southeastern Colorado, southwestern Kansas, and the western Oklahoma Panhandle, 3) Mixed-Grass Prairie Region (MGPR), located in the northeastern Texas Panhandle, north-western Oklahoma, and south-central Kansas, and 4) Short Grass Conservation Reserve Program (CRP) Prairie Region (SGPR), located in northwestern Kansas (Figure 1).

STUDY AREA

Our study area included the 2011 estimated occupied range (EOR) of LPC as defined by the LPC Interstate Working Group (LPCIWG) and mapped on the Western Association of Fish and Wildlife Agencies' (WAFWA) web site (2021; LPCIWG 2011, McDonald et al. 2012). In addition, we included habitats with relatively high probability of lek occurrence in northwest Kansas as measured by the Western Governors' Association Southern Great Plains Crucial Habitat Assessment Tool (WAFWA 2021). The study area for 2021 is illustrated in Figure 1, indicating grid cells (cells) selected and not selected for surveys. In 2018, the study area was reduced by 22 cells in the MGPR where LPC were not observed from 2012 to 2017. The 2018, 2020, and 2021 estimates accounted for the reduced survey area.

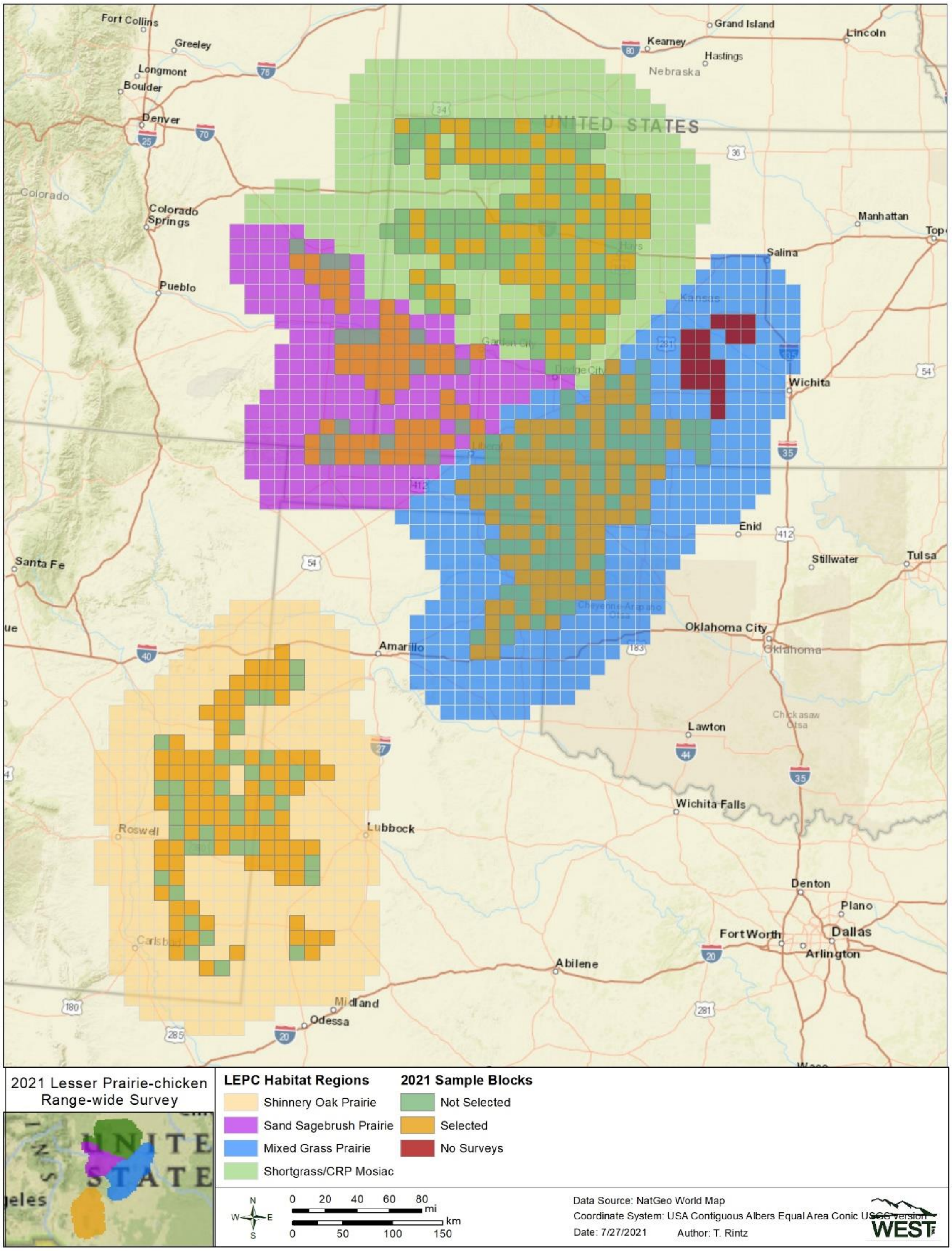

Figure 1. Study area for 2021 lesser prairie-chicken surveys illustrated with grid cells selected for surveys. The colored areas surrounding the study areas indicate an approximate 48.3-kilometer (30.0-mile) buffer into which the survey may be expanded in the future.

METHODS

Probabilistic Samples for Trend

We ranked 15.0- × 15.0-kilometer (km; 9.3- × 9.3-mile [mi]) cells in the study area from one to 536 by an equal probability sampling procedure known as the Generalized Random Tessellation Stratified (GRTS) sampling (Stevens and Olsen 2004, McDonald et al. 2012, 2014). Cells selected by the GRTS sampling procedure maintained a spatially balanced sample for aerial resources such that any contiguous subset, if taken in order, was an equal probability sample of the target population.

In 2012, 256 cells were selected for survey (Table 1). From 2013 to 2016, 283 cells were surveyed. Details on the sampling design and strata for these survey years are outlined in McDonald et al. (2012, 2014).

In 2017, 2018, 2020, and 2021 funds became available to survey additional cells in two of the ecoregions. Ten additional cells were surveyed in the SOPR (nine in 2020) and 10 additional cells were surveyed in the MGPR for a total sample size of 303 (302 in 2020) probabilistically selected cells. A rotating panel design was also implemented in 2017, 2018, 2020, and 2021 within each ecoregion. A panel of approximately 20% of the top ranked cells on the GRTS list were dropped and a panel of equal size cells next on the GRTS list were added from each ecoregion.

Table 1. Total number of grid cells surveyed by year and region for survey years 2012 to 2018, 2020, and 2021.

	Ecoregion				
Year	SOPR	SSPR	MGPR	SGPR	Overall
2012	75	29	72	80	256
2013	77	55	78	73	283
2014	77	55	78	73	283
2015	77	55	78	73	283
2016	77	55	78	73	283
2017	87	55	88	73	303
2018	87	55	88[1]	73	303
2020	86[2]	55	88[1]	73	302
2021	87	55	88[1]	73	303

SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas), SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle), MGPR = Mixed-Grass Prairie Region (northeastern Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass Conservation Reserve Program Prairie Region (northwest Kansas).

1. The total number of grid cells in the sampling frame in the MGPR was reduced from 176 grid cells in 2012 to 2017 to 154 grid cells in 2018.

2. One grid cell was unable to be surveyed in the SOPR.

Aerial Survey Methods

Surveys were conducted from a Raven II (R-44; Robinson Helicopter Company, Torrance, California) helicopter able to accommodate three observers; two observers in the rear left and right seats, and a third observer in the front left seat. Three helicopters and survey crews simultaneously conducted surveys within the study area each year. Transects were flown north to south or south to north a speed of 60 km/hour (37 mi/hour) and height of 25 meters (m; 82 feet [ft]) above ground. Surveys were conducted from sunrise until approximately 2.5 hours after sunrise during the lekking period from March 15 to May 15.

Two, 15-km north-south parallel transects were selected in each of the survey cells. The starting point for the first transect was randomly located from 300 to 7,200 m (984 ft to 23,622 ft) from the west side of the cell. The second transect was located 7,500 m (24,606 ft) to the east of the first transect. Survey strip width was 300 m on each side of the transect lines. The area surveyed in each grid cell was 8% of the total 225 square km (87 square mi). Survey methods were the same for all nine years of surveys. For more information regarding survey methods, please see McDonald et al. (2012).

Statistical Methods

Probability of Detection

We use the observations of all prairie-chicken by the front left and back left observers in "mark-recapture" models. For example, groups of prairie-chickens seen by the back left observer were "marked" and some of those groups were independently "recaptured" by the front left observer. These models were used to estimate the probability that at least one of the two observers detected a group given that it was in the field of view of the back left observer (i.e., greater than 4.1 m [13.5 ft] from the transect line). The data were pooled across the nine survey years to estimate the probability that at least one of the two observers detected a group. Logistic regression models were fit using perpendicular distance from the transect line to the group (distance) as a covariate and a model with no covariates was fit. The best model was selected as the most parsimonious model within two corrected Akaike Information Criterion (AICc) units of the model with the lowest AICc value.

We fit multiple covariate distance sampling detection models and conventional distance sampling detection models for the estimated probability of detection of groups of prairie-chickens. We used the package "Rdistance" in the R language and environment (4.1.0; R Development Core Team 2021) to estimate the detection models. Data were grouped into 15 intervals for fitting models for probability of detection with the all intervals encompassing 20 m (66 ft). The midpoint of each interval was used in the modeling in order to compensate for potential errors in assigning the perpendicular distance from the transect line. Perpendicular distance from the transect line to the group (distance) were included in all models and covariates used in the models for probability of detection group size (size) and the categorical variable habitat type (habitat). The negative exponential, hazard rate, and half normal distributions were considered as key distributions. The best model was selected as the most parsimonious model within two AICc units of the model with the lowest AICc value. The estimates of probability of detection were then scaled by the probability of detection on the transect line to obtain overall probabilities of detections.

Estimation of Population Parameters in the Short Grass Prairie Region

The proportion of LPC, GPC, and HPC in the SGPR in northwestern Kansas were estimated using ground survey data collected from 2008 through 2013. All ground survey data and initial data processing were provided by the Kansas Department of Wildlife, Parks and Tourism, and the Kansas Biological Survey (J. Pitman and M. Houts, pers. comm.).

Estimation of Precision of Estimated Population Parameters

We used bootstrapping techniques (Manly 2006) to estimate confidence intervals (CIs) for density and population totals of LPC, HPC, and GPC individuals and leks, by year and ecoregion. From each bootstrapped sample, we generated new estimates of densities, population totals, and differences. We calculated CIs based on the central 80% of the bootstrap distribution (the percentile method) for each estimated parameter.

Estimation of Trends in Population

To evaluate trends in LPC population over time, a generalized simple linear regression model was fit to the population estimates. The random error terms followed a first-order autoregressive process to account for autocorrelation in populations between years (Kutner et al. 2005).

RESULTS

We detected 141 clusters of LPC, GPC, and HPC in 2012, 73 in 2013, 92 in 2014, 133 in 2015, 129 in 2016, 172 in 2017 and 2018, 200 in 2020, and 172 in 2021 while surveying on transects (i.e., within 300 m of the transect line) for 1,284 detections of prairie-chickens in the combined data set (Table 2). Of the 1,284 prairie-chicken clusters detected from 2012 to 2021, 58.2% were in short-grass grassland, 22.4% were in cropland, 10.5% were in tall-grass grassland including CRP grassland (with little or no shrubs), 5.6% were in sand-sage prairie, 2.7% were in shinnery oak (*Quercus havardii*; including other shrub dominated land), and 0.5% were on bare ground (Table 2).

There were 368 LPC detected in 2012, 203 in 2013, 224 in 2014, 276 in 2015, 251 in 2016, 336 in 2017, 493 in 2018, 438 in 2020, and 378 in 2021 (Table 3). Note that fewer cells were surveyed in 2012 (256 cells), while survey effort increased to 283 cells from 2013 to 2016, then to 303 cells in 2017, 2018, and 2021, and to 302 cells in 2020.

Estimates of LPC population size were calculated for 2021. Counts of observed LPC were adjusted for LPC missed in the 600-m (1,969-ft) transects using the estimated probability that at least one of the two observers detected a cluster, and the estimated probability of detection of the cluster as a function of distance from transect and covariates. Estimates of LPC population size and density were also updated from 2012 to 2018 and 2020.

Table 2. Trends in numbers and percent of detections of leks and non-lekking clusters of lesser prairie-chicken, greater prairie-chicken, and hybrid prairie-chicken by habitat type in the data sets for survey years 2012 to 2018, 2020, and 2021.

	Habitat						
Year	Bare Ground	Cropland	Short-Grass Grassland	Shinnery Oak (including other shrub dominated land)	Sand-Sage Prairie	Tall-Grass Grassland Including CRP Grassland (with little or no shrubs)	Total
2012	0 (0%)	27 (19.1%)	91 (64.5%)	6 (4.3%)	3 (2.1%)	14 (9.9%)	141
2013	0 (0%)	14 (19.2%)	49 (67.1%)	2 (2.7%)	7 (9.6%)	1 (1.4%)	73
2014	0 (0%)	11 (12.0%)	66 (71.7%)	2 (2.2%)	2 (2.2%)	11 (12.0%)	92
2015	0 (0%)	21 (15.8%)	85 (63.9%)	1 (0.8%)	10 (7.5%)	16 (12.0%)	133
2016	1 (0.8%)	32 (24.8%)	63 (48.8%)	1 (0.8%)	17 (13.2%)	15 (11.6%)	129
2017	2 (1.2%)	49 (28.5%)	92 (55.8%)	5 (2.9%)	4 (2.3%)	20 (11.6%)	172
2018	3 (1.7%)	37 (21.5%)	93 (54.1%)	8 (4.7%)	3 (1.7%)	28 (16.3%)	172
2020	1 (0.5%)	47 (23.5%)	107 (53.5%)	1 (0.5%)	23 (11.5%)	21 (10.5%)	200
2021	0 (0%)	50 (29.1%)	101 (58.7%)	9 (5.2%)	3 (1.7%)	9 (5.2%)	172
Total	**7 (0.5%)**	**288 (22.4%)**	**747 (58.2%)**	**35 (2.7%)**	**72 (5.6%)**	**135 (10.5%)**	**1,284**

CRP = Conservation Reserve Program.

Table 3. Trends in numbers of lesser prairie-chickens detected by ecoregion (estimated number detected in SGPR) and overall for survey years 2012 to 2018 and 2020.

	Ecoregion									
	SOPR		SSPR		MGPR		SGPR (estimated[1])		Total	
Year	On transect	Off transect	On transect	Off transect	On transect	Off transect	On transect	Off transect	On transect	Off transect
2012	44	7	22	6	86	0	216	16	**368**	**29**
2013	24	12	35	5	39	4	105	12	**203**	**33**
2014	17	10	8	7	70	2	129	9	**224**	**28**
2015	10	7	14	13	87	19	165	9	**276**	**48**
2016	42	12	22	0	61	0	126	0	**251**	**12**
2017	35	18	23	1	80	0	198	2	**336**	**21**
2018	90	1	57	3	95	4	251	15	**493**	**23**
2020	81	6	3	12	61	2	293	55	**438**	**75**
2021	26	30	8	0	41	0	303	129	**378**	**159**

1. Estimated to account for greater prairie-chicken and hybrid prairie-chicken in the Short Grass Conservation Reserve Program Prairie Region (SGPR).

SORP = Shinnery Oak Prairie Region; SSPR = Sand Sagebrush Prairie Region; MGPR = Mixed-grass Prairie Region.

Note: “On transect” indicated observations were made between start and end points of transects. “Off transect” indicated observations were made while traveling to and from selected transect lines or greater than 300 meters from the transect. In 2012, 256 cells were surveyed, 283 cells were surveyed in 2013 to 2016, 303 cells were surveyed in 2017, 2018, and 2021, and 302 cells were surveyed in 2020.

Mark-recapture Models

We used the observations of LPC, GPC, and HPC by the front left and back left observers in “mark-recapture” models. For example, clusters of prairie-chickens seen by the front left observer were “marked”; some of those same clusters were “recaptured” by the back left observer. These models estimated the probability that at least one of the two observers would detect a cluster given that it was in the field of view of the back left observer (i.e., greater than the nominal value 6.8 m [22.3 ft] from the transect line). The observations from each observer were 455 and 484, for the back left and front left observers, respectively (Table 4). The top model for both the back left and front left observer included distance as a covariate (Table 5).

Table 4. Sample sizes recorded and used for logistic regression models in order to estimate the probability at least one of the two observers will detect a cluster for survey year 2012 to 2018, 2020, and 2021.

Year	Back Left	Front Left
2012	50	57
2013	28	24
2014	40	33
2015	46	49
2016	46	54
2017	50	64
2018	61	53
2020	68	78
2021	66	72
Total	**455**	**484**

Table 5. Logistic Regression models used for estimation of probabilities of detection on the inside edge of the field of view of the back left and front left observers.

Back Left Observer Model		Front Left Observer Model	
Covariates	**AICc**	**Covariates**	**AICc**
Distance*	605.19	Distance*	652.02
None	607.37	None	660.35

AICc = corrected Akaike Information Criterion.

Distance = perpendicular distance to detected clusters.

None = no covariates.

*Selected Model.

Probability of Detection – Distance Sampling Analysis

We dropped 21 (1.6%) observations from the distance sampling analysis greater than 300 m from the transect line as they were outside the viewshed specified in the survey protocol. Buckland et al. (2001) recommended dropping up to 5% of observations with the largest distances to the transect line to remove the influence of outliers prior to modeling probability of detection.

Data collected from surveys in 2012 (256 cells), 2013 to 2016 (283 cells), 2017 to 2018 (303 cells), 2020 (302 cells), and 2021 (303 cells) were used to estimate the detection function. Probability of detection was estimated as a function of distance from the transect (Figures 2a, 2b, and 2c).

In addition, cluster size and habitat were considered as covariates in the distance sampling model. Cluster size of prairie-chickens detected varied by year and ecoregion (Table 6). The average cluster size of LPC detected increased from 3.3 to 3.6 LPC per cluster from 2020 to 2021 (Table 6). An increase in average cluster size was observed in the SSPR and SGPR and a decrease in average cluster size was observed from the MGPR from 2020 to 2021. The average cluster size in the SOPR remained the same from 2020 to 2021.

Table 6. Trends in average cluster sizes of lesser prairie-chicken detected by ecoregion and overall for survey years 2012 to 2018, 2020, and 2021.

	Ecoregion				
Year	**SOPR**	**SSPR**	**MGPR**	**SGPR**	**Overall**
2012	3.4	7.3	6.6	4.3	**4.6**
2013	2.4	5.8	5.6	4.9	**4.7**
2014	2.4	4.0	4.4	3.9	**3.9**
2015	1.4	1.8	3.0	3.8	**3.3**
2016	2.5	2.8	3.8	3.6	**3.4**
2017	2.7	3.3	3.5	3.3	**3.3**
2018	3.5	3.8	3.8	4.6	**4.2**
2020	2.6	1.0	2.4	3.7	**3.3**
2021	2.6	2.0	1.7	4.2	**3.6**

SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas), SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle), MGPR = Mixed-grass Prairie Region (northeastern Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass Conservation Reserve Program Prairie Region (northwest Kansas).

We pooled data collected from 2012 to 2021 to estimate the probability of detection of clusters of prairie-chickens because the survey methods remained unchanged between years and the models accommodated changes in cluster size and habitat by year. The probability of detection for all clusters of prairie-chickens was estimated as a function of distance from transect and the top model included the size covariate with a negative exponential key function (Table 7 and Figure 3).

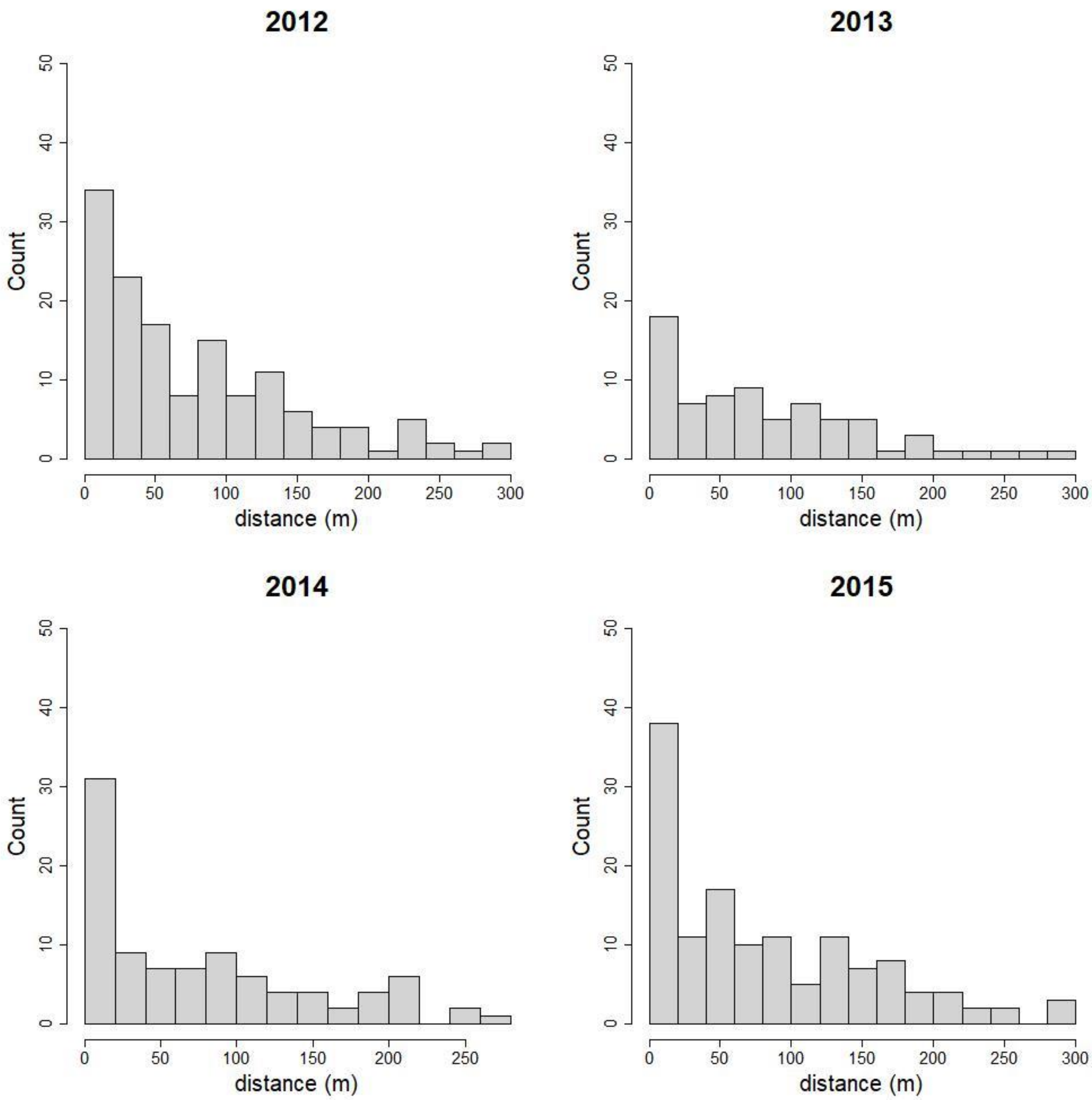

Figure 2a. Histograms showing the counts of observed distances of detected clusters of all prairie-chickens from the transect line to the center of the clusters (density of detections in 20-meter [m] bins) from 2012 to 2015.

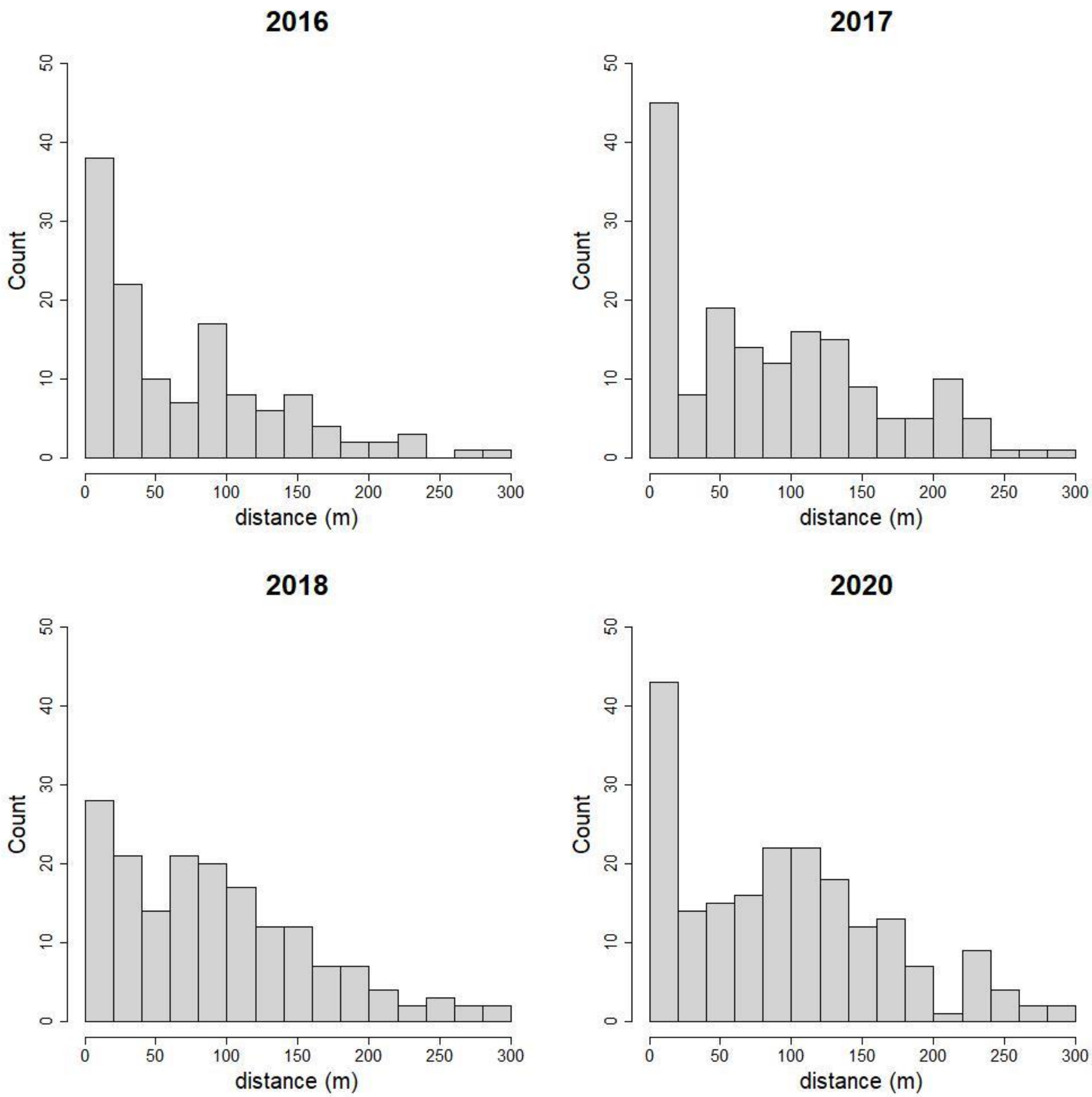

Figure 2b. Histograms showing the counts of observed distances of detected clusters of all prairie-chickens from the transect line to the center of the clusters (density of detections in 20-meter [m] bins) from 2016 to 2020.

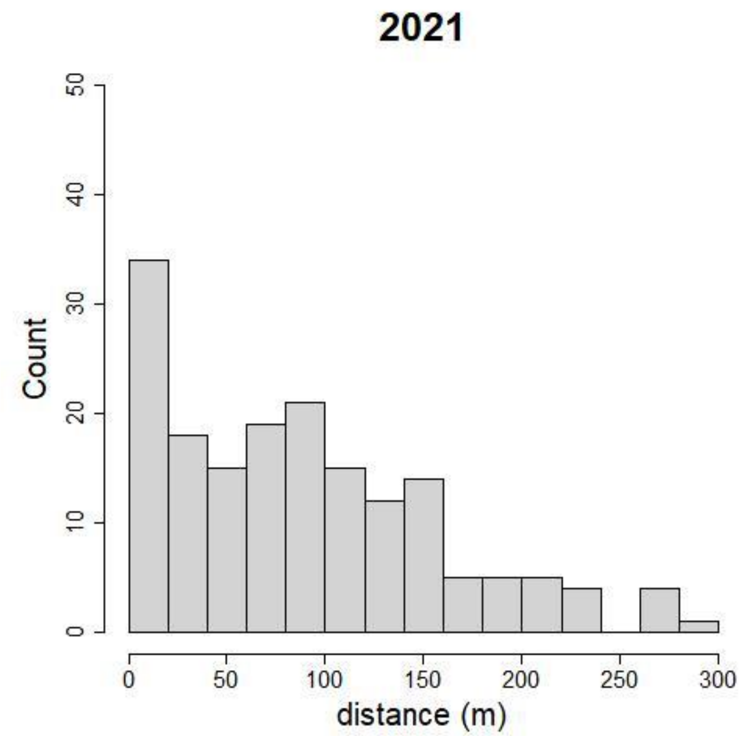

Figure 2c. Histograms showing the counts of observed distances of all detected clusters of prairie-chickens from the transect line to the center of the clusters (density of detections in 20-meter [m] bins) in 2021.

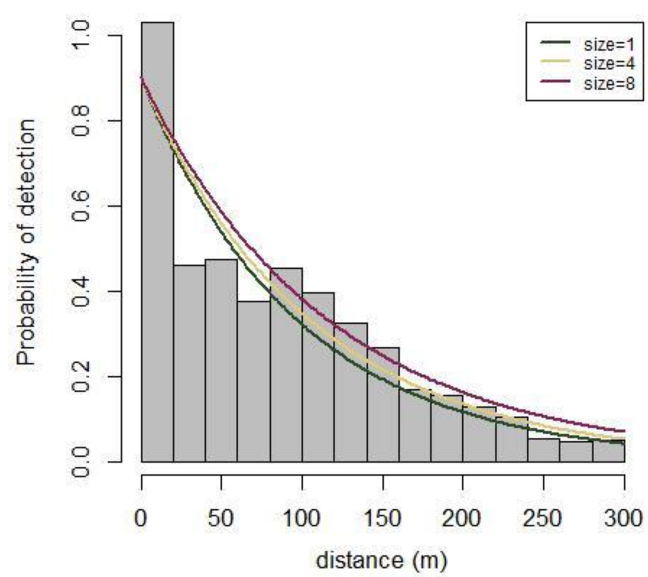

Figure 3. Probability of detection for clusters of one, four, and eight prairie-chickens (size), plotted by distance from transect line.

Table 7. Distance sampling models used to estimate probability of detection as a function of distance from the transect line and other covariates. Distance to detected clusters was in all models.

Model Covariates	Key Function	AICc
Size	ne	13,855.05*
None	ne	13,859.53
Habitat	ne	13,864.60
Size	hn	13,878.24
Size + Habitat	hn	13,882.97
None	hn	13,887.17
Habitat	hn	13,891.19
Size	hr	13,900.14
None	hr	13,909.24
Size + Habitat	hr	13,912.69
Habitat	hr	13,914.01

AICc = corrected Akaike Information Criterion.

Size = size of cluster.

Habitat = habitat occupied by detected clusters.

None = no covariates.

Pooled data from 2012 to 2021 were used to fit the distance sampling models.

Key Functions were ne = negative exponential model, hr = hazard rate, hn = half normal.

*Selected Model.

Estimated Trends in Densities and Abundances of Lesser Prairie-chicken

We adjusted counts of LPC by covariate specific, scaled, model averaged probabilities of detection to estimate population sizes in four ecoregions and the original study area (Tables 8, 9, 10, and Figures 3, 4a, and 4b). We estimated the total population size of LPC to be:

- 29,382 (90% CI: 20,381, 39,934) LPC in 2012
- 15,913 (90% CI: 9,723, 23,527) in 2013
- 18,987 (90% CI: 12,608, 25,997) in 2014
- 23,540 (90% CI: 16,559, 31,623) in 2015
- 20,739 (90% CI: 14,878, 27,375) in 2016
- 26,916 (90% CI: 19,003, 36,316) in 2017
- 34,825 (90% CI: 25,448, 46,932) in 2018
- 34,568 (90% CI: 24,081, 45,431) in 2020
- 30,461 (90% CI: 20,137, 41,923) in 2021

To evaluate trends in the LPC population over time, a generalized simple linear regression model with random error terms following a first-order autoregressive process was fit to LPC population estimates from 2013 to 2021. The estimated average rate of increase of 2,616 (standard error = 522) LPC in total LPC by year was statistically significant (p-value less than 0.01). Using this model, a prediction for 2019 was 30,976 (90% Prediction Interval: 23,302, 38,651) when surveys were not conducted.

An estimated total population decrease of 4,107 LCP was observed from 2020 to 2021 (11.9% decrease); however, this decrease was not statistically significant at the 90% confidence level (90% CI: -19,325, 10,314; Table 10). The 80% confidence level was also evaluated and this decrease was also not statistically significant at the 80% confidence level.

Table 8. Trends in estimated densities of lesser prairie-chickens per 100 km^2 (39 mi^2) by ecoregion and overall for survey years 2012 to 2018, 2020, and 2021. Bootstrapped 90% confidence intervals were reported on the densities of lesser prairie-chicken per 100 km^2.

	Ecoregion				
Year	SOPR	SSPR	MGPR	SGPR	Overall
2012	10.66 (4.37, 18.50)	12.89 (1.69, 27.53)	19.79 (8.67, 34.57)	44.27 (27.09, 64.94)	24.36 (16.9, 33.11)
2013	5.96 (2.75, 9.59)	11.07 (3.79, 20.76)	8.72 (3.25, 15.99)	24.21 (9.91, 40.00)	13.20 (8.06, 19.51)
2014	4.18 (1.22, 7.92)	2.72 (0.00, 5.94)	15.00 (4.98, 27.06)	30.67 (16.88, 45.59)	15.74 (10.45, 21.56)
2015	2.55 (0.54, 4.69)	4.85 (1.44, 9.52)	20.34 (12.75, 28.68)	37.49 (21.55, 56.71)	19.52 (13.73, 26.22)
2016	10.13 (4.76, 17.48)	7.37 (1.80, 14.22)	13.97 (7.15, 22.01)	30.05 (17.46, 44.28)	17.20 (12.34, 22.70)
2017	7.38 (2.88, 13.07)	7.72 (1.88, 15.15)	16.05 (7.61, 26.37)	46.27 (28.69, 67.83)	22.32 (15.76, 30.11)
2018	17.89 (6.81, 33.61)	18.05 (7.51, 31.62)	18.67 (9.74, 29.42)	54.95 (32.53, 81.82)	30.11 (22.00, 40.58)
2020	17.62 (8.79, 29.44)	1.09*	13.03 (4.80, 22.83)	66.94 (41.86, 94.01)	29.89 (20.82, 39.28)
2021	5.68 (2.28, 9.68)	2.75 (0.35, 6.03)	9.04 (4.87, 14.08)	67.79 (40.41, 97.27)	26.34 (17.41, 36.25)

SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas), SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle), MGPR = Mixed-grass Prairie Region (northeastern Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass Conservation Reserve Program Prairie Region (northwest Kansas).

*Confidence Interval not calculated due to low sample size of observed lesser prairie-chickens (n < 5).

km^2 = square kilometers; mi^2 = square miles.

Table 9. Trends in estimated population sizes of lesser prairie-chickens by ecoregion and overall for survey years 2012 to 2018, 2020, and 2021. Bootstrapped 90% confidence intervals were reported on the population sizes of lesser prairie-chicken.

	Ecoregion				
Year	SOPR	SSPR	MGPR	SGPR	Overall
2012	2,950 (1,208, 5,120)	2,059 (269, 4,398)	7,839 (3,433, 13,688)	16,534 (10,116, 24,256)	29,382 (20,381, 39,934)
2013	1,649 (761, 2,655)	1,768 (605, 3,316)	3,452 (1,285, 6,334)	9,044 (3,702, 14,941)	15,913 (9,723, 23,527)
2014	1,156 (338, 2,193)	435 (0, 949)	5,941 (1,971, 10,717)	11,454 (6,306, 17,027)	18,987 (12,608, 25,997)
2015	706 (150, 1,298)	774 (231, 1,521)	8,056 (5,048, 11,358)	14,003 (8,050, 21,182)	23,540 (16,559, 31,623)
2016	2,803 (1,318, 4,838)	1,177 (287, 2,272)	5,533 (2,832, 8,717)	11,225 (6,521, 16,537)	20,739 (14,878, 27,375)
2017	2,041 (798, 3,617)	1,234 (301, 2,421)	6,357 (3,015, 10,441)	17,284 (10,717, 25,336)	26,916 (19,003, 36,316)
2018	4,950 (1,885, 9,300)	2,884 (1,200, 5,052)	6,470 (3,374, 10,194)	20,522 (12,150, 30,558)	34,825 (25,448, 46,932)
2020	4,878 (2,432, 8,147)	174*	4,516 (1,662, 7,912)	25,000 (15,634, 35,112)	34,568 (24,081, 45,431)
2021	1,571 (630, 2,678)	440 (55, 963)	3,132 (1,688, 4,877)	25,318 (15,092, 36,329)	30,461 (20,137, 41,923)

SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas), SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle), MGPR = Mixed-grass Prairie Region (northeastern Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass Conservation Reserve Program Prairie Region (northwest Kansas).

*Confidence Interval not calculated due to low sample size of observed lesser prairie-chickens (n < 5).

Table 10. Estimated differences in population estimates for lesser prairie-chickens between years with bootstrapped 90% confidence intervals on the differences (Δ Year).

Δ Year	Ecoregion				Total
	SOPR	SSPR	MGPR	SGPR	
2013 minus 2012	-1,301 (-3,566, 736)	-291 (-2,866, 1,976)	-4,386 (-10,667, 979)	-7,490 (-16,829, 1,153)	-13,469 (-25,455, -2,426)
2014 minus 2013	-493 (-1,784, 804)	-1,333 (-2,949, -99)	2,489 (-2,280, 8,064)	2,411 (-5,718, 9,805)	3,073 (-6,441, 12,234)
2015 minus 2014	-450 (-1,673, 529)	339 (-398, 1,206)	2,115 (-3,923, 7,180)	2,549 (-5,575, 10,687)	4,554 (-5,776, 14,371)
2016 minus 2015	2,096 (544, 4,241)	403 (-791, 1,566)	-2,523 (-6,827, 1,913)	-2,778 (-10,912, 5,098)	-2,802 (-12,371, 6,560)
2017 minus 2016	-761 (-3,161, 1,333)	57 (-1,401, 1,472)	824 (-3,572, 5,888)	6,058 (-2,316, 15,024)	6,177 (-3,807, 16,736)
2018 minus 2017	2,909 (-545, 7,177)	1,650 (-417, 4,052)	113 (-4,693, 5,067)	3,239 (-7,973, 14,488)	7,909 (-4,403, 21,395)
2020 minus 2018	-72 (-5,029, 4,315)	-2,710*	-1,953 (-6,603, 2,663)	4,478 (-8,238, 17,326)	-257 (-15,122, 14,825)
2021 minus 2020	-3,306 (-6,564, -507)	266*	-1,385 (-6,603, 2,663)	318 (-14,478, 14,052)	-4,107 (-19,325, 10,314)

SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas), SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle), MGPR = Mixed-grass Prairie Region (northeastern Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass Conservation Reserve Program Prairie Region (northwest Kansas).

*Confidence Interval not calculated in 2020 due to low sample size of observed lesser prairie-chickens (n < 5).

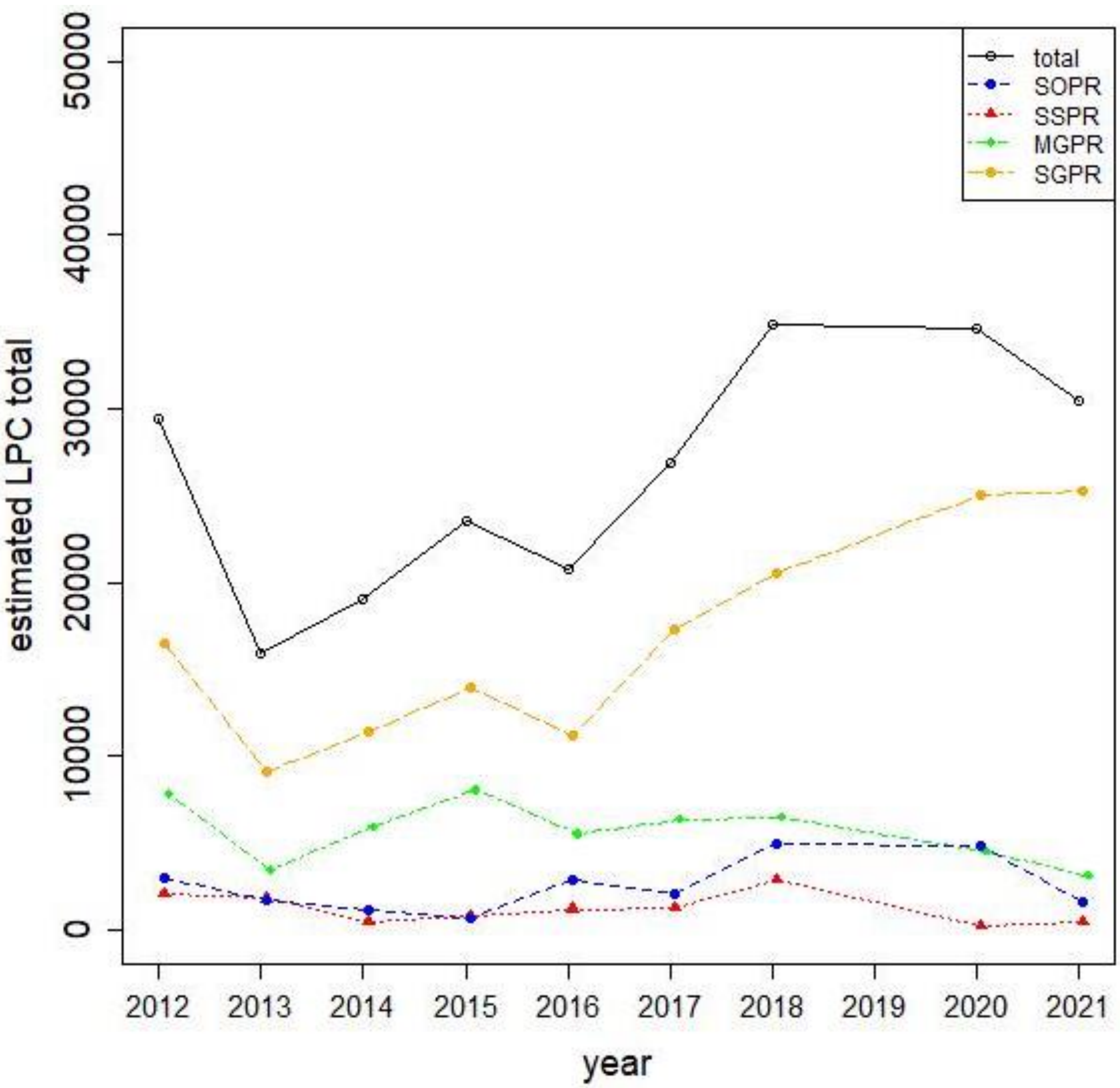

Figure 4. Trends in estimated total population sizes of lesser prairie-chicken for survey years 2012 to 2018 and 2020.

Note: SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas), SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle), MGPR = Mixed-grass Prairie Region (northeastern Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass Conservation Reserve Program Prairie Region (northwest Kansas).

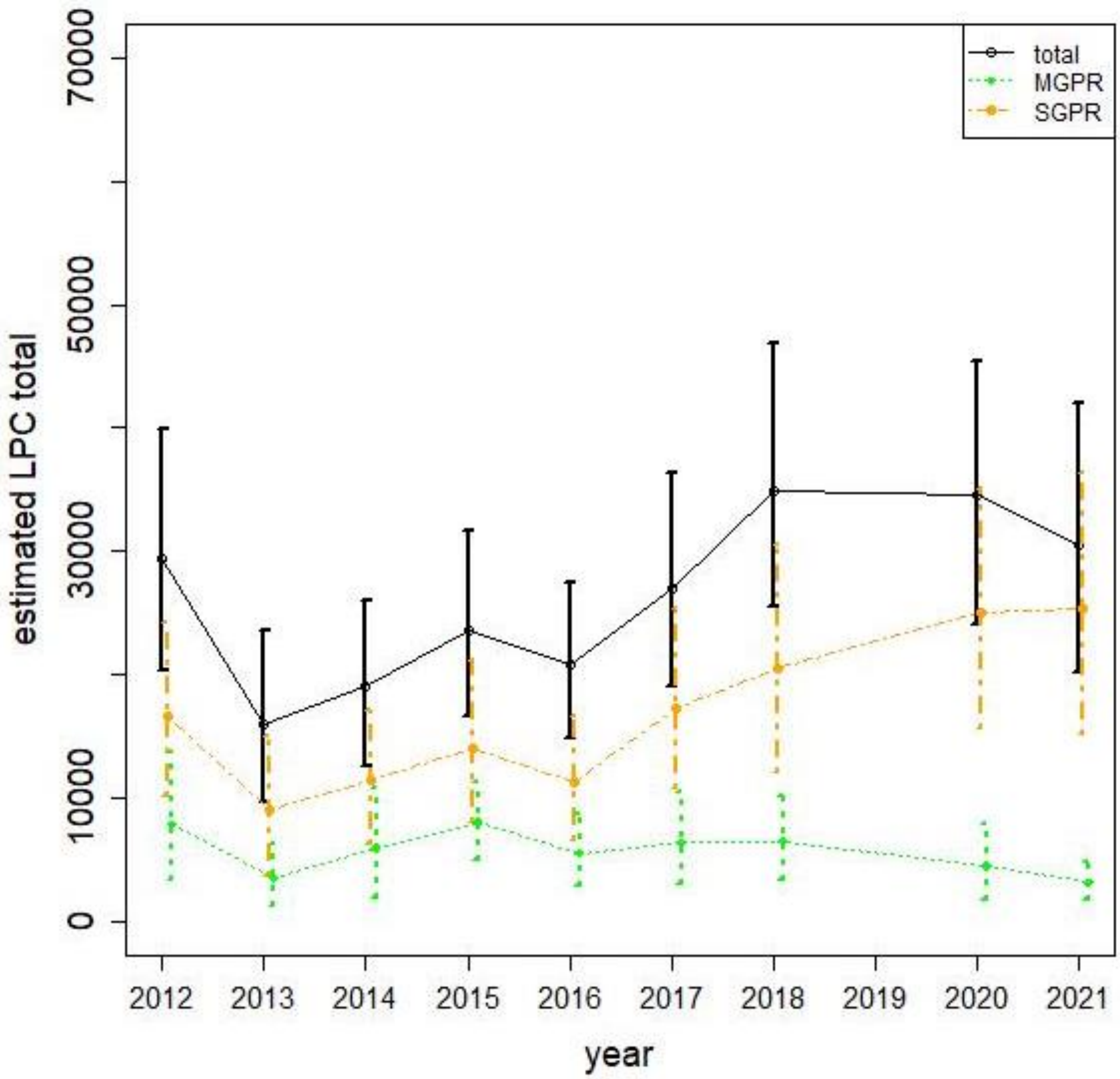

Figure 5a Trends in estimated total population sizes of lesser prairie-chickens for survey years 2012 to 2018 and 2020 with 90% confidence intervals for the original study area.

Note: MGPR = Mixed-grass Prairie Region (northeast Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass Conservation Reserve Program Prairie Region (northwestern Kansas).

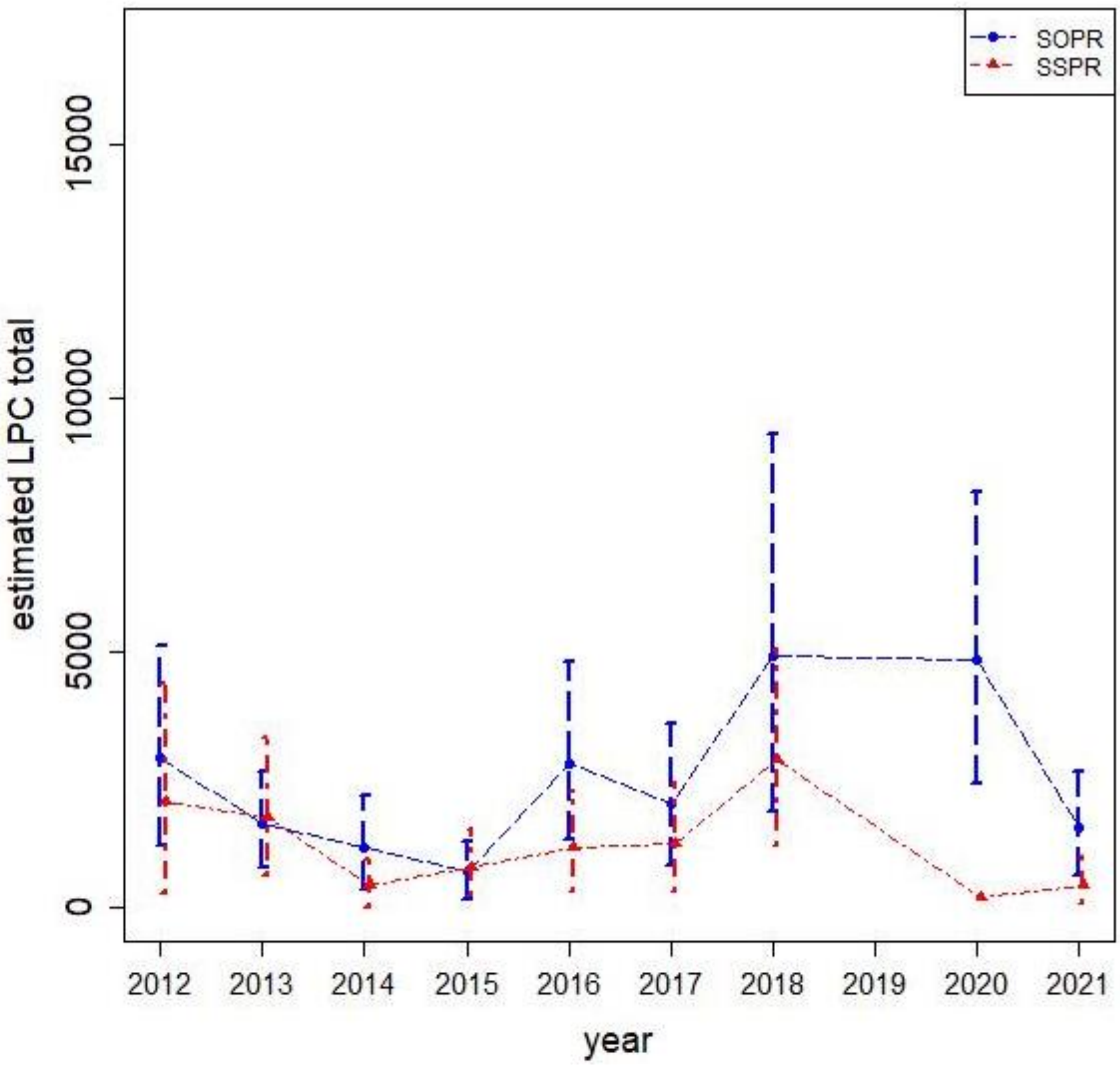

Figure 5b. Trends in estimated total population sizes of lesser prairie-chickens (LPC) for survey years 2012 to 2018 and 2020 with 90% confidence intervals in the SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas) and SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle).

Note that confidence intervals were not calculated for the SSPR due to a low sample size of observed LCP (n < 5).

Estimated Trends in Lesser Prairie-chicken Leks

We estimated a decrease in the density and abundance of LPC leks in 2021 relative to 2020 (Tables 11 and 12). The abundance of LPC leks was estimated to be:

- 2,823 (90% CI: 1,712, 4,153) in 2012
- 1,801 (90% CI: 1,043, 2,752) in 2013
- 2,253 (90% CI: 1,415, 3,227) in 2014

- 1,425 (90% CI: 838, 2,034) in 2015
- 1,723 (90% CI: 908, 2,607) in 2016
- 2,588 (90% CI: 1,721, 3,513) in 2017
- 2,600 (90% CI: 1,738, 3,688) in 2018
- 4,737 (90% CI: 3,141, 6,388) in 2020
- 3,152 (90% CI: 2,035, 4,333) in 2021

DISCUSSION

We estimated LPC population sizes annually from 2012 to 2018, 2020, and 2021 in the 2011 EOR of the LPC in Kansas, Colorado, New Mexico, Oklahoma, and Texas to evaluate trends in the population. The objective of the study was to estimate the annual range-wide population size of LPC and evaluate trends in time of the range-wide population size of LPC. This objective was met and we determined there was a statistically significant (p-value less than 0.01) annual rate of increase of the total LPC population size from 2013 to 2021 with the average rate of increase being 2,616 LPC per year (standard error = 522).

Annual estimates within each ecoregion were also calculated; however, there is more uncertainty in these estimates relative to the range-wide population estimates, especially for ecoregions with a low density of LPC, and should be interpreted with caution. In addition, the study area was defined as the 2011 EOR of the LPC. In 2018, the study area was reduced by dropping cells in the MGPR of central Kansas where no LPC were observed. There may be additional changes to the EOR of LCP in the future, e.g., LPC located outside of the 2011 EOR of the LPC; therefore, range-wide population estimates of the LPC, may be larger in an expanded survey area.

Table 11. Estimated trends in densities of lesser prairie-chicken leks per 100 km^2 (39 mi^2) by ecoregion and overall for survey years 2012 to 2018 and 2020. Bootstrapped 90% confidence intervals were reported on the densities of lesser prairie-chicken leks per 100 km^2.

	Ecoregion				
Year	SOPR	SSPR	MGPR	SGPR	Overall
2012	1.21 (0.47, 2.15)	1.17 (0, 2.68)	2.03 (0.94, 3.46)	4.01 (1.62, 7.04)	2.34 (1.42, 3.44)
2013	0.50 (0, 1.07)	1.97 (0.87, 3.46)	0.88 (0.22, 1.66)	2.67 (0.93, 4.73)	1.49 (0.86, 2.28)
2014	0.74 (0.22, 1.52)	0.34 (0, 1.00)	1.80 (0.69, 3.12)	3.43 (1.67, 5.59)	1.87 (1.17, 2.68)
2015	0.26 (0, 0.78)	0.33 (0, 0.98)	1.82 (0.92, 2.85)	1.55 (0.49, 2.67)	1.18 (0.69, 1.69)
2016	0.71 (0.19, 1.45)	0.31 (0, 0.95)	1.35 (0.60, 2.34)	2.52 (0.76, 4.73)	1.43 (0.75, 2.16)
2017	0.86 (0.16, 1.79)	0.99 (0.30, 2.01)	1.90 (0.87, 3.08)	3.86 (2.22, 6.00)	2.15 (1.43, 2.91)
2018	1.84 (0.68, 3.33)	0.90 (0, 2.12)	2.46 (1.30, 3.91)	2.94 (1.30, 4.95)	2.25 (1.50, 3.19)
2020	1.71 (0.41, 3.44)	0.36*	1.95 (0.41, 3.91)	9.46 (5.72, 13.77)	4.10 (2.72, 5.52)
2021	0.89 (0.22, 1.65)	0.70 (0, 1.70)	0.89 (0.20, 1.83)	6.66 (4.04, 9.43)	2.73 (1.76, 3.75)

SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas), SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle), MGPR = Mixed-grass Prairie Region (northeastern Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass Conservation Reserve Program Prairie Region (northwest Kansas).

*Confidence Interval not calculated due to low sample size of observed lesser prairie-chickens (n < 5).

km^2 = square kilometers; mi^2 = square miles.

Table 12. Estimated trends in abundances of lesser prairie-chicken leks by ecoregion and overall for survey years 2012 to 2018, 2020, and 2021. Bootstrapped 90% confidence intervals were reported on the abundances of lesser prairie-chicken leks.

	Ecoregion				
Year	SOPR	SSPR	MGPR	SGPR	Overall
2012	335 (130, 596)	187 (0, 429)	803 (370, 1,370)	1,498 (606, 2,628)	2,823 (1,712, 4,153)
2013	138 (0, 296)	315 (140, 553)	349 (89, 659)	999 (349, 1,768)	1,801 (1,043, 2,752)
2014	204 (61, 421)	54 (0, 160)	714 (274, 1,237)	1,281 (626, 2,086)	2,253 (1,415, 3,227)
2015	72 (0, 215)	52 (0, 157)	722 (364, 1,129)	579 (183, 997)	1,425 (8,38, 2,034)
2016	196 (52, 401)	50 (0, 152)	536 (237, 925)	941 (284, 1,765)	1,723 (908, 2,607)
2017	238 (45, 495)	158 (48, 322)	752 (343, 1,220)	1,440 (828, 2,241)	2,588 (1,721, 3,513)
2018	509 (188, 922)	143 (0, 339)	851 (451, 1,353)	1,097 (484, 1,850)	2,600 (1,738, 3,688)
2020	472 (114, 953)	58*	675 (140, 1,356)	3,532 (2,138, 5,141)	4,737 (3,141, 6,388)
2021	246 (62, 457)	111 (0, 271)	308 (70, 636)	2,487 (1,509, 3522)	3,152 (2,035, 4,333)

SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas), SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle), MGPR = Mixed-grass Prairie Region (northeastern Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass Conservation Reserve Program Prairie Region (northwest Kansas)

*Confidence Interval not calculated due to low sample size of observed lesser prairie-chickens (n < 5).

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Appendix A. Estimated Densities and Abundances of Greater Prairie-Chicken and Hybrid Prairie-Chicken

Densities (Table A-1, Table A-2, and Figure A-1) and abundances (Table A-3) of GPC and HPC were estimated in the SGPR of northwest Kansas. The population sizes of the GPC in the SGPR were estimated to be:

- 27,361 (90% CI: 18,492, 37,756) in 2012;
- 13,088 (90% CI: 8,099, 18,440) in 2013;
- 14,116 (90% CI: 9,302, 20,031) in 2014;
- 19,164 (90% CI: 13,199, 26,350) in 2015;
- 23,560 (90% CI: 15,003, 33,401) in 2016;
- 29,391 (90% CI: 21,610, 38,984) in 2017;
- 29,907 (90% CI: 19,410, 41,589) in 2018;
- 26,281 (90% CI: 18,634, 35,453) in 2020; and
- 27,825 (90% CI: 19,120, 36,636) in 2021.

An increase of 1,544 GPC was observed from 2020 to 2021; however, this decrease was not statistically significant (90% CI: -10,512, 13,124; Table A-4). There was a statistically significant annual rate of increase of abundance for the GPC in the SGPR in northwest Kansas from 2013 to 2021 (p-value < 0.01). The average rate of increase was 2,405 (standard error = 533) greater prairie-chickens per year in the SGPR.

We estimated the number of HPC in the SGPR (Figure A-2) to be:

- 282 (90% CI: 167, 417) in 2012;
- 106 (90% CI: 45, 192) in 2013;
- 80 (90% CI: 45, 119) in 2014;
- 211 (90% CI: 117, 327) in 2015;
- 250 (90% CI: 138, 399) in 2016;
- 349 (90% CI: 212, 504) in 2017;
- 249 (90% CI: 140, 369) in 2018;
- 179 (90% CI: 101, 267) in 2020; and
- 272 (90% CI: 165, 396) in 2021.

Table A-1. Estimates of greater prairie-chicken (GPC) and hybrid prairie chicken (HPC) densities per 100 kilometer^2 (km^2; 39 miles^2) for survey years 2012 to 2018, 2020, and 2021 in the Short Grass Conservation Reserve Program Region of northwestern Kansas. Bootstrapped 90% confidence intervals were reported on the densities of GPC and HPC per 100 km^2.

Year	GPC	HPC
2012	73.26 (49.51, 101.09)	0.76 (0.45, 1.12)
2013	35.04 (21.68, 49.37)	0.28 (0.12, 0.51)
2014	37.79 (24.91, 53.63)	0.21 (0.12, 0.32)
2015	51.31 (35.34, 70.55)	0.57 (0.31, 0.88)
2016	63.08 (40.17, 89.43)	0.67 (0.37, 1.07)
2017	78.69 (57.86, 104.38)	0.93 (0.57, 1.35)
2018	80.07 (51.97, 111.35)	0.67 (0.37, 0.99)
2020	70.36 (49.89, 94.92)	0.48 (0.27, 0.72)
2021	74.5 (51.19, 98.09)	0.73 (0.44, 1.06)

Table A-2. Estimates of greater prairie-chicken (GPC) and hybrid prairie-chicken (HPC) population sizes from 2012 to 2018, 2020, and 2021 in the Short Grass Conservation Reserve Program Region of northwestern Kansas. Bootstrapped 90% confidence intervals were reported on the population sizes of GPC and HPC.

Year	GPC	HPC
2012	27361 (18492, 37756)	282 (167, 417)
2013	13088 (8099, 18440)	106 (45, 192)
2014	14116 (9302, 20031)	80 (45, 119)
2015	19164 (13199, 26350)	211 (117, 327)
2016	23560 (15003, 33401)	250 (138, 399)
2017	29391 (21610, 38984)	349 (212, 504)
2018	29907 (19410, 41589)	249 (140, 369)
2020	26281 (18634, 35453)	179 (101, 267)
2021	27825 (19120, 36636)	272 (165, 396)

Table A-3. Estimates of greater prairie-chicken (GPC) lek densities per 100 kilometer^2 (km^2; 39 miles^2) and abundances of GPC leks for survey years 2012 to 2018, 2020, and 2021 in the Short Grass Conservation Reserve Program Prairie Region of northwestern Kansas. Bootstrapped 90% confidence intervals were reported on the population sizes of GPC and abundances of GPC leks per 100 km^2.

Year	Density	Abundance
2012	5.25 (3.28, 7.58)	1960 (1224, 2833)
2013	3.76 (2.11, 5.45)	1403 (786, 2037)
2014	4.27 (2.67, 6.05)	1595 (998, 2258)
2015	3.4 (1.74, 5.29)	1271 (650, 1978)
2016	6.34 (3.80, 9.26)	2368 (1420, 3458)
2017	5.47 (3.68, 7.56)	2044 (1376, 2824)
2018	6.31 (3.86, 8.91)	2358 (1440, 3328)
2020	10.05 (7.04, 13.51)	3752 (2629, 5045)
2021	6.15 (3.85, 8.54)	2297 (1439, 3188)

Table A-4. Estimated differences in population estimates for greater prairie-chickens between years with bootstrapped 80% confidence intervals on the differences.

Δ Year	Estimate (90% Confidence Interval)
2013 minus 2012	-14,273 (-25,767, -4,278)
2014 minus 2013	1,028 (-6,014, 8,942)
2015 minus 2014	5,048 (-3,141, 13,366)
2016 minus 2015	4,396 (-6,140, 16,077)
2017 minus 2016	5,831 (-6,206, 17,320)
2018 minus 2017	516 (-12,454, 13,511)
2020 minus 2018	-3,626 (-17,266, 9,554)
2021 minus 2020	1544 (-10,512, 13,124)

Δ Year = change in year

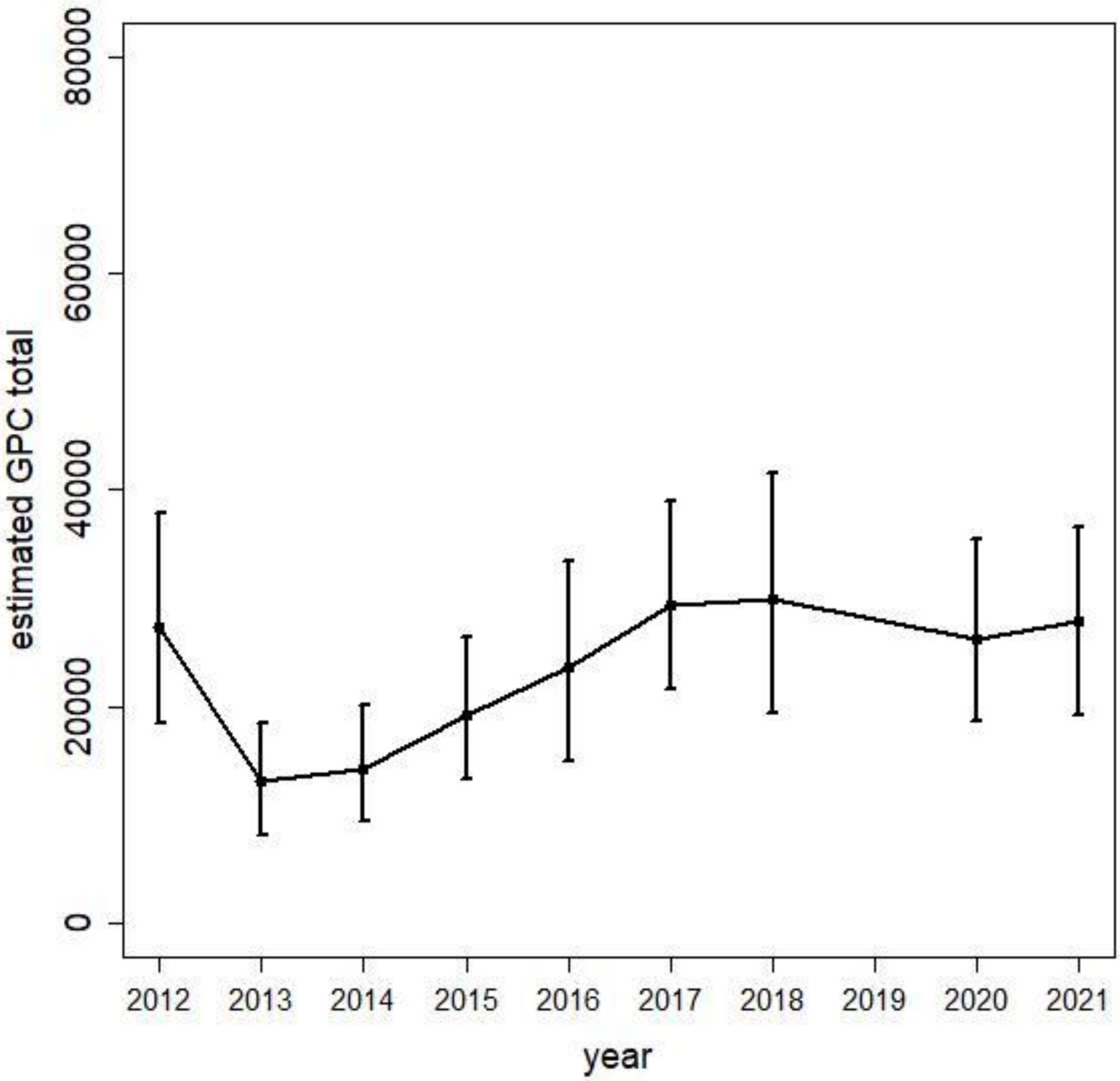

Figure A-1. Estimated population sizes of greater prairie-chickens (GPC) with 90% confidence intervals for survey years 2012 to 2018, 2020, and 2021 in the Short Grass Conservation Reserve Program Prairie Region (northwestern Kansas).

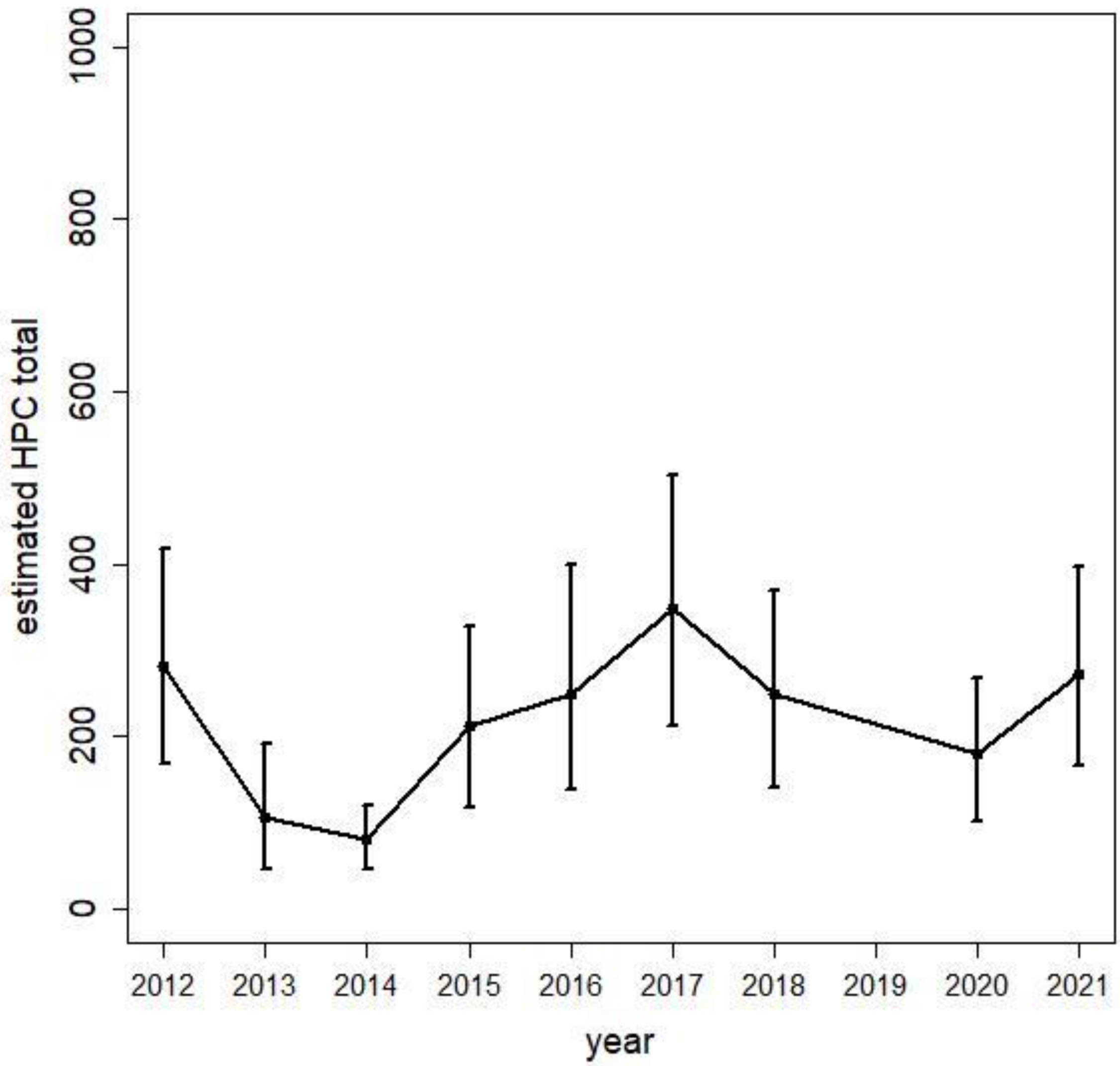

Figure A-2. Estimated population sizes of hybrid prairie-chickens (HPC) with 90% confidence intervals for survey years 2012 to 2018, 2020, and 2021 in the Short Grass / Conservation Reserve Program Prairie Region (northwestern Kansas).

Appendix B. Evaluating Trends in Lesser-Prairie Chicken Populations

To further evaluate trends in the LPC population, annual estimates of LPC were averaged over three years (Table B-1 and Figures B-1 and B-2):

- 21,427 (90% CI: 17155, 26594) estimated average annual LPC population from 2012 – 2014;
- 19,480 (90% CI: 15,352, 23,826) from 2013 – 2015;
- 21,089 (90% CI: 17,200, 25,627) from 2014 – 2016;
- 23,732 (90% CI: 19,442, 28,600) from 2015 – 2017;
- 27,493 (90% CI: 22,527, 33,616) from 2016 – 2018;
- 30,871 (90% CI: 24,578, 39,093) from 2017 – 2018 (no surveys in 2019);
- 34,697 (90% CI: 27,379, 43,092) from 2018 – 2020 (no surveys in 2019); and
- 32,515 (90% CI: 25,318, 40,674) from 2020 – 2021 (no surveys in 2019).

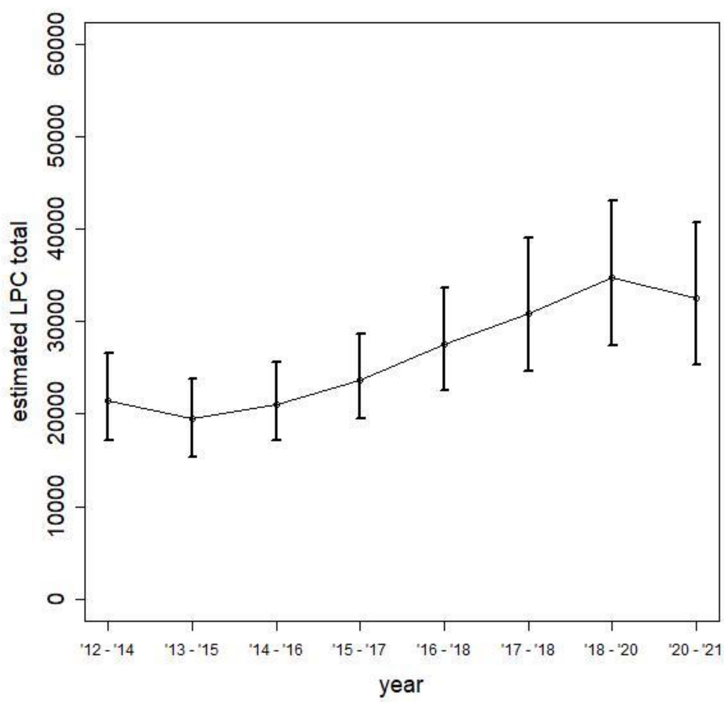

Figure B-1. Estimated three-year average annual population sizes of lesser prairie-chickens (LPC) with 90% confidence intervals for survey years from 2012 to 2021.