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**RANGE-WIDE POPULATION SIZE OF THE
LESSER PRAIRIE-CHICKEN:
2012, 2013, 2014, 2015, AND 2016**



Photos: Colorado Parks and Wildlife

**Prepared for:
Western Association of Fish and Wildlife Agencies**

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July 21, 2016



EXECUTIVE SUMMARY, DISCUSSION AND RECOMMENDATIONS

- We estimated lesser prairie-chicken (LPC) population sizes and lek abundances for four ecoregions of Kansas, Colorado, New Mexico, Oklahoma, and Texas in 2012, 2013, 2014, 2015, and 2016.
- There were 536 total grid cells in the study area. Sample cells were selected by an equal probability procedure. Two-hundred-fifty-six (256) grid cells were selected in 2012 and 2 transects covering 8% of each cell were surveyed for LPC. Two transects were surveyed in 283 common cells in 2013, 2014, 2015, and 2016. The same field survey and analysis methods were used in 2012, 2013, 2014, 2015, and 2016.
- In 2016, additional funding was available from Pheasants Forever to increase the number of grid cells surveyed. Two transects were surveyed in: 20 additional cells in the Shinnery Oak Prairie Region of eastern New Mexico and western Texas, 16 additional cells in the Sand Sage Prairie Region of southeast Colorado, southwest Kansas, and western Panhandle of Oklahoma, and one additional cells was inadvertently surveyed in the Mixed Grass Prairie Region of northeast Texas Panhandle, northwest Oklahoma, and south-central Kansas.
- Ninety percent confidence intervals were computed on estimated parameters to account for variation in the estimates due to detection and counting errors, 8% coverage of each sampled grid cell, and un-sampled grid cells.
- For study of “trends” in LPC population sizes, only the common grid cells were considered, consisting of 256 cells in 2012 and 283 cells in 2013 through 2016. In 2016, supplementary estimates of the current “status” of LPC population sizes were given in the Shinnery Oak, Sand Sage, and Mixed Grass Prairie Regions, based on larger sample sizes made possible by one time funding from Pheasants Forever.
- The proportions of LPC, hybrid lesser-greater prairie chickens (HPC), and greater prairie chickens (GPC) in the Short Grass Prairie Region of northwest Kansas were estimated using ground survey data collected from 2008 to 2013.
- In our study of trends on 256 cells in 2012 and 283 common cells in 2013 - 2016:
 - We detected 141 clusters of LPC, GPC, and HPC in 2012, 73 in 2013, 92 in 2014, 136 in 2015, and 134 in 2016, resulting in a relatively large pooled data set of 576 detections of prairie-chickens. We estimated probability of detection in the survey strips using the pooled data set, which resulted in a slight increase in the estimates of LPC population sizes in 2012, 2013, 2014, and 2015 relative to estimates reported previously.

- Of the 576 prairie-chicken clusters detected in 2012, 2013, 2014, 2015, and 2016; 62.0% were in short-grass grassland, 18.9% were in crop land, 10.1% were in tall-grass grassland including CRP grassland (with little or no shrubs), 6.8% were in sand-sage prairie, and 2.1% were in shinnery oak (including other shrub dominated land).
- We estimated the probability of detection of clusters of prairie-chickens using weighted averages of 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 LPC, GPC, and HPC by covariate-specific, scaled, model-averaged probabilities of detection to estimate population sizes in four ecoregions and the total study area.
- For the study of trends on the common set of grid cells surveyed, we estimated the total population size of LPC to be:
 - 38,667 (90% Confidence Interval [CI]: 27251, 61363) birds in 2012;
 - 20,297 (90% CI: 12767, 29720) in 2013;
 - 23,962 (90% CI: 16373, 33592) in 2014;
 - 29,985 (90% CI: 20669, 43111) in 2015; and
 - 25,651 (90% CI: 18692, 34991) in 2016.
- The estimated decrease in total population size from 2012 to 2013 was statistically significant at the 90% confidence level.
- The overall trend since 2013 was an increase in total population size; however the average annual increases were not statistically significant at the 90% confidence level.
- We estimated an 18% increase in the abundance of LPC leks in 2016 relative to 2015.
- From 2015 to 2016, we reported:
 - a statistically significant increase in the abundance of LPC in the Shinnery Oak Prairie Region of eastern New Mexico and western Texas at the 90% confidence level,
 - an increase in abundance in the Sand Sage Prairie Region of southeast Colorado, southwest Kansas, and western Oklahoma Panhandle that was statistically significant at a confidence level slightly less than 90%, and
 - increases in the abundances of greater prairie-chicken and hybrid greater-lesser prairie-chickens in the Short Grass Prairie Region of northwest Kansas.
- For LPC within the Shinnery Oak Region of eastern New Mexico and western Texas:
 - We estimated decreases in the LPC population size from 2012 to 2013, with further estimated decreases in 2014, and 2015. The decrease was statistically significant (90% confidence level) only from 2012 to 2013.

- There was a statistically significant estimated increase in the population size from 2015 to 2016.
- For LPC within the Sand Sagebrush Region of southeast Colorado, southwest Kansas, and the western Panhandle of Oklahoma:
 - We estimated decreases in the LPC population size from 2012 to 2013 and with a further estimated decrease in 2014. The decrease was statistically significant (90% confidence level) from 2013 to 2014.
 - We estimated increases in the population size in 2015 and again in 2016, although the increases were not statistically significant at the 90% confidence level.
- For LPC within the Mixed Grass Region of northeast Texas Panhandle, northwest Oklahoma, and south-central Kansas:
 - We estimated a statistically significant decrease in the LPC population size from 2012 to 2013 (90% confidence level).
 - There were estimated increases in population size from 2013 to 2014, and from 2014 to 2015, although not significant at the 90% confidence level.
 - The overall trend from 2013 to 2016 was for an increase in population size; however, the estimated population size in 2016 was approximately equal to the 2014 value.
- For LPC within the Short Grass Prairie Region of northwest Kansas:
 - We estimated that the decrease in LPC population size from 2012 to 2013 was nearly statistically significant at the 90% confidence level.
 - There were estimated increases in population size from 2013 to 2014, and from 2014 to 2015, although not significant at the 90% confidence level.
 - The overall trend from 2013 to 2016 was for an increase in population size; however, the estimated population size in 2016 was essentially equal to the 2014 value.
- For Greater Prairie-chicken abundance within the Short Grass Prairie Region of northwestern Kansas:
 - We estimated a statistically significant decrease in population size of GPC in the SGPR from 2012 to 2013 at the 90% confidence level.
 - Since 2013, there was an increase in the estimated annual population sizes of GPC in the Short Grass Prairie Region; however, the annual changes were not statistically significant at the 90% confidence level.
- Increased sample sizes in 2016 for the Shinnery Oak, Sand Sage, and Mixed Grass Prairie Regions were available allowing for one time enhanced estimates of the “status” of LPC populations in those regions and the total study area.
 - The total estimated current status of the population of LPC increased from 25,651 to 27,926 individuals (90% CI: 20704, 37209) in 2016 based on the increased sample sizes.

- Twenty additional cells were flown in the Shinnery Oak Prairie Region of eastern New Mexico and western Texas. The estimated current status of the population increased from 3,255 to 4,584 individuals in 2016.
- Sixteen additional cells were flown in the Sand Sage Prairie Region of southeast Colorado, southwest Kansas and western Panhandle of Oklahoma. The estimated current status of the population decreased from 1,479 to 1,401 individuals in 2016.
- One additional cell was inadvertently flown in the Mixed Grass Prairie Region of northeast Texas Panhandle, northwest Oklahoma, and south-central Kansas. The estimated current status of the population increased from 6,891 to 7,800 individuals in 2016.
- The best bottom line pictures of the current status of the LPC populations in 2016 relative to previous years, with 90% confidence intervals to account for variation due to detection errors, counting errors, and un-sampled areas, are given in Figure 6a and 6b (reproduced here).

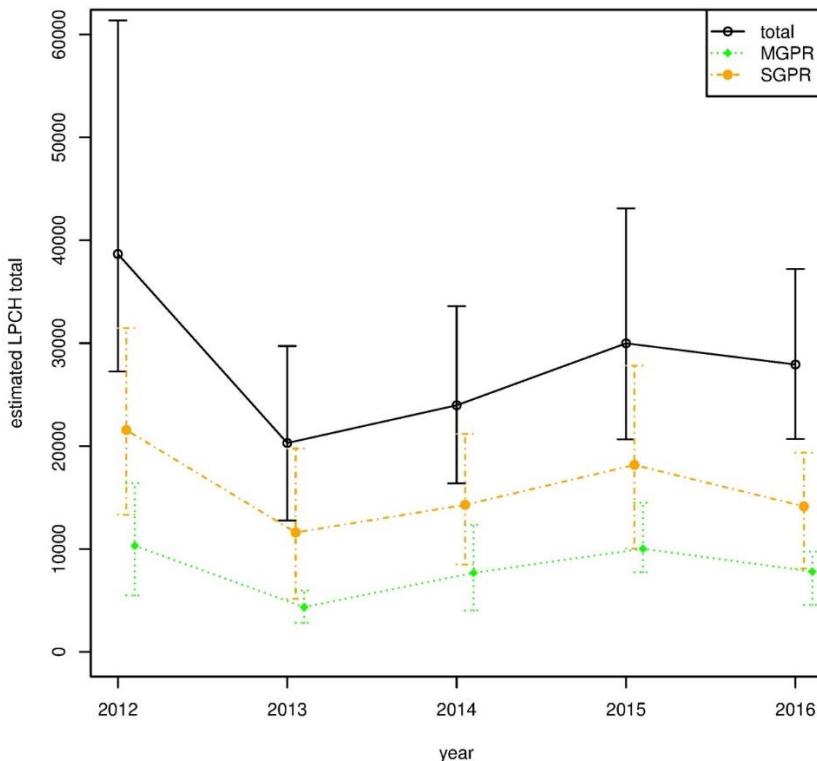


Figure 6a. Trends in estimated total population sizes of lesser prairie-chickens in 2012 (245 grid cells), 2013, 2014, and 2015 (283 grid cells), and current status in 2016 (320 grid cells) with 90% confidence intervals. MGPR = Mixed-Grass Prairie Region (northeast Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass CRP Prairie Region (northwestern Kansas).

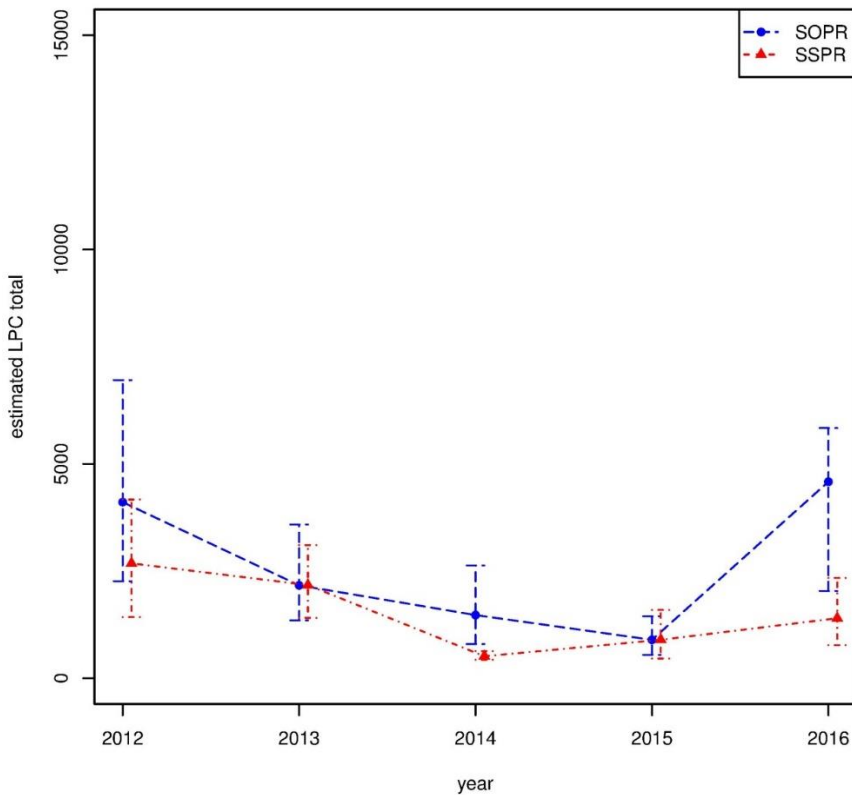


Figure 6b. Trends in estimated total population sizes of lesser prairie-chickens (LPC) in 2012 (245 grid cells), 2013, 2014, and 2015 (283 grid cells), and current status in 2016 (320 grid cells) with 90% confidence intervals. SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas) and SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle).

- Recommendations, should the range-wide LPC survey be conducted again in 2017:
 - Based on the 2016 estimates of the current status of the populations in the ecoregions, we recommend that the sample sizes be increased by 20 grid cells in each of the Shinnery Oak and Mixed Grass Prairie Regions.
 - Based on the estimate of the current status of the population in the Sand Sage Prairie Region, we recommend that the total number of surveyed grid cells remain at the 2015 level. The estimated status did not change much when the extra 16 grid cells were surveyed in 2016.

- We also recommend that the survey be modified to that of a “rotating panel” design in each ecoregion. We recommend that a panel of approximately 20% of the top ranked grid cells on the GRTS list in each ecoregion be dropped each year and a panel of equal size be added to the survey effort. Unfortunately, sample units may “wear out” for multiple reasons. For example, locations of clusters of LPC detected during the survey may become known, land owners may deliberately make changes in the habitat, and the cells and surveyed transects are no longer “representative” of the target areas.

TABLE OF CONTENTS

INTRODUCTION	1
STUDY AREA	1
METHODS.....	3
Probabilistic Samples for Trend.....	3
Probabilistic Sample for Status in 2016	3
Aerial Survey Methods	4
Statistical Methods	4
Probability of Detection	4
Estimation of Population Parameters in the Short Grass Prairie Region	5
Estimation of Precision of Estimated Population Parameters	5
RESULTS	5
Trends in Number of LPC Detected and Average Cluster size: 2013-2016.....	10
Estimated Trends in Densities and Abundances of LPC and LPC Leks.....	12
Estimated Trends in LPC Leks from 2012 to 2016.....	17
Estimated Status of LPC Population Size in 2016 Based on Increased Sample sizes	19
Estimated Densities and Abundances of GPC and HCPH.....	23
ACKNOWLEDGEMENTS	26
LITERATURE CITED.....	27

LIST OF TABLES

Table 1. 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 2012, 2013, 2014, 2015, and 2016.	8
Table 2. Sample sizes for logistic regression models to estimate the probability that at least one of the two observers will detect a cluster.....	9
Table 3. Logistic Regression models used for estimation of probabilities of detection on the inside edge of the field of view of the back left observers. Distance = perpendicular distance to detected clusters, none = no covariates, size = size of cluster, and habitat = habitat type occupied. The back left observer models estimated the probability that the back left observer detected a cluster given that the cluster was detected by the front left observer. Similarly, the front left observer models estimated the probability that the front left observer detected a cluster given that the cluster was detected by the back left observer.	10

Table 4. 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. Size = size of cluster, and habitat = habitat occupied by detected clusters. Pooled data (576 clusters) from 2012, 2013, 2014, 2015, and 2016 were used to fit the distance sampling models. Key Functions were ne = negative exponential model, hr = hazard rate, and hn = half normal.	10
Table 5. Trends in numbers of lesser prairie-chickens detected by ecoregion (estimated number detected in SGPR) and overall in 2012, 2013, 2014, 2015, and 2016. “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 m from the transect. Two-hundred-fifty-six cells were surveyed in 2012, and 283 cells were flown in 2013, 2014, 2015, and 2016.	11
Table 6. Average trends in cluster sizes of lesser prairie-chicken detected by ecoregion and overall in 2012, 2013, 2014, 2015, and 2016.	12
Table 7. Trends in estimated densities of lesser prairie-chickens per 100 km ² (39 mi ²) by ecoregion and overall in 2012, 2013, 2014, 2015, and 2016. Bootstrapped 90% confidence intervals were reported on the densities of lesser prairie-chicken per 100 km ²	13
Table 8. Trends in estimated population sizes of lesser prairie-chickens by ecoregion and overall for 2012, 2013, 2014, 2015, and 2016. Bootstrapped 90% confidence intervals were reported on the population sizes of lesser prairie-chicken.	13
Table 9. Estimated differences in population estimates for lesser prairie-chickens between years with bootstrapped 90% confidence intervals on the differences.	18
Table 10. Estimated trends in densities of lesser prairie-chicken leks per 100 km ² (39 mi ²) by ecoregion and overall in 2012, 2013, 2014, 2015, and 2016. Bootstrapped 90% confidence intervals were reported on the densities of lesser prairie-chicken leks per 100 km ²	18
Table 11. Estimated trends in abundances of lesser prairie-chicken leks by ecoregion and overall for 2012, 2013, 2014, 2015, and 2016. Bootstrapped 90% confidence intervals were reported on the abundances of lesser prairie-chicken leks.	18
Table 12. Number of grid cells flown and improved estimates of status of population sizes of lesser prairie-chickens by ecoregion (90% confidence interval [CI]) in 2016 data collected for the lesser prairie-chicken range-wide survey and the additional grid cells flown in 2016.	20
Table 13. Estimates of greater prairie-chicken (GPC) and hybrid prairie chicken (HPC) densities per 100 km ² (39 mi ²) for 2012, 2013, 2014, 2015, and 2016 in the Short Grass CRP Region of northwestern Kansas. Bootstrapped 90% confidence intervals were reported on the densities of GPC and HPC per 100 km ²	23

Table 14. Estimates of greater prairie-chicken (GPC) and hybrid prairie-chicken (HPC) population sizes for 2012, 2013, 2014, 2015, and 2016 in the Short Grass CRP Region of northwestern Kansas. Bootstrapped 90% confidence intervals were reported on the population sizes of GPC and HPC.....	23
Table 15. Estimates of greater prairie-chicken (GPC) lek densities per 100 km ² (39 mi ²) and abundances of GPC leks for 2012, 2013, 2014, 2015, and 2016 in the Short Grass CRP 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	24
Table 16. Estimated differences in population estimates for greater prairie-chickens between years with bootstrapped 90% confidence intervals on the differences.	24

LIST OF FIGURES

Figure 1. Study area for 2012, 2013, 2014, 2015, and 2016 lesser prairie-chicken surveys illustrated with grid cells selected for survey in 2013, 2014, 2015, and 2016. The colored areas surrounding the study sub-areas indicated an approximate 77.7-km (30-mi) buffer into which the survey may be expanded in the future.	2
Figure 2. Histograms of the perpendicular distance (m) from the transect line to the center of detected clusters of prairie-chickens: 2012, 2013, 2014, 2015, and 2016.....	6
Figure 3. Histogram of the perpendicular distance (m) from the transect line to the center of detected clusters of prairie-chickens pooled from 2012, 2013, 2014, 2015, and 2016.	7
Figure 4. Trends in estimated total population sizes of lesser prairie-chicken in 2012, 2013, 2014, 2015, and 2016. 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 CRP Prairie Region (northwest Kansas).	14
Figure 5a. Trends in estimated total population sizes of lesser prairie-chickens in 2012, 2013, 2014, 2015, and 2016 with 90% confidence intervals for the original study area, MGPR = Mixed-Grass Prairie Region (northeast Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass CRP Prairie Region (northwestern Kansas).	15
Figure 5b. Trends in estimated total population sizes of lesser prairie-chickens (LPC) in 2012, 2013, 2014, 2015, and 2016 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).	16

Figure 6a. Trends in estimated total population sizes of lesser prairie-chickens in 2012 (245 grid cells), 2013, 2014, and 2015 (283 grid cells), and updated status in 2016 (320 grid cells) with 90% confidence intervals. MGPR = Mixed-Grass Prairie Region (northeast Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass CRP Prairie Region (northwestern Kansas).21

Figure 6b. Trends in estimated total population sizes of lesser prairie-chickens (LPC) in 2012 (245 grid cells), 2013, 2014, and 2015 (283 grid cells), and up dated status in 2016 (320 grid cells) with 90% confidence intervals. SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas) and SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle).22

Figure 7. Estimated population sizes of greater prairie-chickens (GPC) with 90% confidence intervals in 2012, 2013, 2014, 2015, and 2016 in the Short Grass CRP Prairie Region (northwestern Kansas).25

Figure 8. Estimated population sizes of hybrid prairie-chickens (HPC) with 90% confidence intervals in 2012, 2013, 2014, 2015, and 2016 in the Short Grass CRP Prairie Region (northwestern Kansas).26

LIST OF APPENDICES

Appendix A. Study Area for Additional Grid Cells Flown in 2016 _____

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 had often precluded implementation of these sampling designs. The result had been the development of population indices to monitor population trend or estimate a minimum population size. The limitation of such data was their unknown relationship to population size. Further, it must be assumed that 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 and lek abundance from 2012 to 2016. To achieve this, we had to address issues of regional variation as well as the co-occurrence of greater prairie-chicken (*Tympanuchus cupido*; GPC) and of hybrid lesser-greater prairie-chickens (HPC) in northwestern Kansas. We estimated LPC and lek abundances for four ecoregions: 1) Shinnery Oak (*Quercus havardii*) 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). We also estimated GPC and lek abundances in the SGPR located in northwestern Kansas.

STUDY AREA

Our study area included the 2011 Estimated Occupied Range of LPC as defined by the Lesser Prairie-Chicken Interstate Working Group (LPCIWG) and mapped in the Western Association of Fish and Wildlife Agencies' web site (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 (SGP CHAT; Kansas Applied Remote Sensing [KARS] 2015). The study area for 2012, 2013, 2014, 2015, and 2016 was illustrated in Figure 1, where we indicated the grid cells selected and not selected for survey in 2013, 2014, 2015, and 2016. The buffered areas surrounding the sub-areas delineated an approximate 77.7-kilometer (km; 30-mile [mi]) buffer into which the survey may be expanded in the future.

METHODS

Probabilistic Samples for Trend

We ranked 15- × 15-km (9.3- × 9.3-mi) grid cells in the study area from 1 to 536 by an equal probability sampling procedure known as the Generalized Random Tessellation Stratified (GRTS) sampling (McDonald et al. 2012, 2014a; Stevens and Olsen 2004). Cells selected by the GRTS procedure maintain 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.

The first 180 cells in the GRTS list were selected for survey in 2012. Funds became available for survey of additional cells in two regions. Forty additional cells were selected in Kansas and 36 additional cells were selected in New Mexico and western Texas from their respective top ranked cells in the GRTS list, for a total sample size of 256 probabilistically selected cells for aerial surveys in 2012. This resulted in three strata with different sampling intensities. In addition, four ecoregions were defined and superimposed on the study area during analysis of the results, effectively re-stratifying and ultimately resulting in six strata with different sampling intensities.

The SOPR and SGPR were individual strata with equal probability sampling in 2012: 75 of 123 cells surveyed in SOPR and 80 of 165 cells surveyed in SGPR. The SSPR had two strata in the conditional design: one stratum with 13 of 37 cells surveyed and one stratum with 16 of 34 cells surveyed. The MGPR also had two strata in the conditional design: one stratum with 35 of 100 cells surveyed and one stratum with 37 of 75 cells surveyed.

Prior to the 2013 survey, we pre-stratified the study area using the four ecoregions and selected GRTS equal probability samples from each using the same GRTS list from 2012. This process resulted in 245 grid cells resurveyed from 2012 and 38 new cells, for a total sample size of 283 grid cells in 2013, 2014, 2015, and 2016. We flew the same transect lines in cells that were resurveyed in 2013, 2014, 2015, and 2016.

Probabilistic Sample for Status in 2016

In 2016, additional surveys were conducted in the SOPR and SSPR with independent funding provided by Pheasants Forever, Inc., 1783 Buerkle Circle, Saint Paul, MN 55110. Twenty grid cells were selected from the GRTS list for survey in the SOPR (Appendix A-1) and 16 grid cells were selected from the GRTS list in the SSPR (Appendix A-2) in addition to the 283 grid cells flown during the LPC range-wide survey funded by the Western Association of Fish and Wildlife Agencies (WAFWA). The total collection of blocks surveyed in each ecoregion was an equal probability sample from the ecoregion. The additional surveys were flown to enhance an occupancy modeling analysis being partially funded by Pheasants Forever; however, the additional data were also used to produce an estimate of the current “status” of the total population size of LPC in 2016 based on the larger 2016 sample sizes. Estimates of the Status of 2016 LPC

population using the data from the additional grid cells flown in SOPR and SSPR were presented in the Results Section. In addition, one additional block was inadvertently flown in the MGPR and was included in the Results Section for Status.

Aerial Survey Methods

The survey platform used for the surveys was the Raven II (R-44) (Robinson Helicopter Company, Torrance, California) helicopter accommodating two observers in the rear left and right seats, and a third observer in the front left seat. Three helicopters and survey crews operated simultaneously within the study area each year. Transects were flown north to south or south to north at nominal values of 60 km per hour (37 mi per hour) and 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 of the first transect was randomly located in the interval (200 m, 7,300 m [656 ft, 23,950 ft]) on the base of the cell and the second transect was located 7,500 m (24,606 ft) to the right of the first transect. Survey strip width is 300 meters on each side of the transect lines. Area surveyed in each grid cell is 8% of the total 225 square km.

Survey methods were the same in all five years of the surveys and were described in detail in McDonald et al. (2012, 2014a)

Statistical Methods

Probability of Detection

We pooled data from 2012, 2013, 2014, 2015, and 2016 to estimate the probabilities of detection of clusters of prairie-chickens because the numbers of detections within each year were limited and the survey methods remained unchanged. Based on the pooled data set, we estimated population sizes for 2016 and adjusted estimates of population sizes for 2012, 2013, 2014, and 2015. Estimates for 2012, 2013, 2014, and 2015 were expected to differ slightly from results reported in McDonald et al. (2012, 2014a, 2014b, 2015).

We used the R package Mark–Recapture Distance Sampling (mrds) in the R language and environment (Version 2.14.2; R Development Core Team 2012) and custom R code to fit multiple covariate distance sampling detection models and conventional distance sampling detection models for the estimated probability of detection of clusters of prairie-chickens. The estimates of probability of detection were then scaled by the probability of detection near the transect line to obtain the covariate-specific, scaled, model averaged probabilities of detection. Analysis and modeling methods were reported in detail in McDonald et al. (2014a) and remain the same.

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 (KDWPT) 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 90% confidence intervals (CIs) for density and population totals of LPC, HPC, and GPC individuals as well as leks within each ecoregion. From each bootstrapped sample we generated new estimates of densities and population totals. We calculated CIs based on the central 90% of the bootstrap distribution (the percentile method) for each estimated parameter.

RESULTS

Data collected from surveys from 2012 (256 grid cells) and 2013 to 2016 (283 grid cells) were used to estimate the trends in population sizes. Population size and density were estimated for 2016 based on the 283 common grid cells and estimates of population size and density were updated for 2012, 2013, 2014, and 2015. The data from 2012, 2013, 2014, 2015, and 2016 were pooled for estimation of probability of detection within a 600-m (1,968-ft) strip as the between year variation was minimal and pooling the data reduced the variation in the data set (Figures 2 and 3).

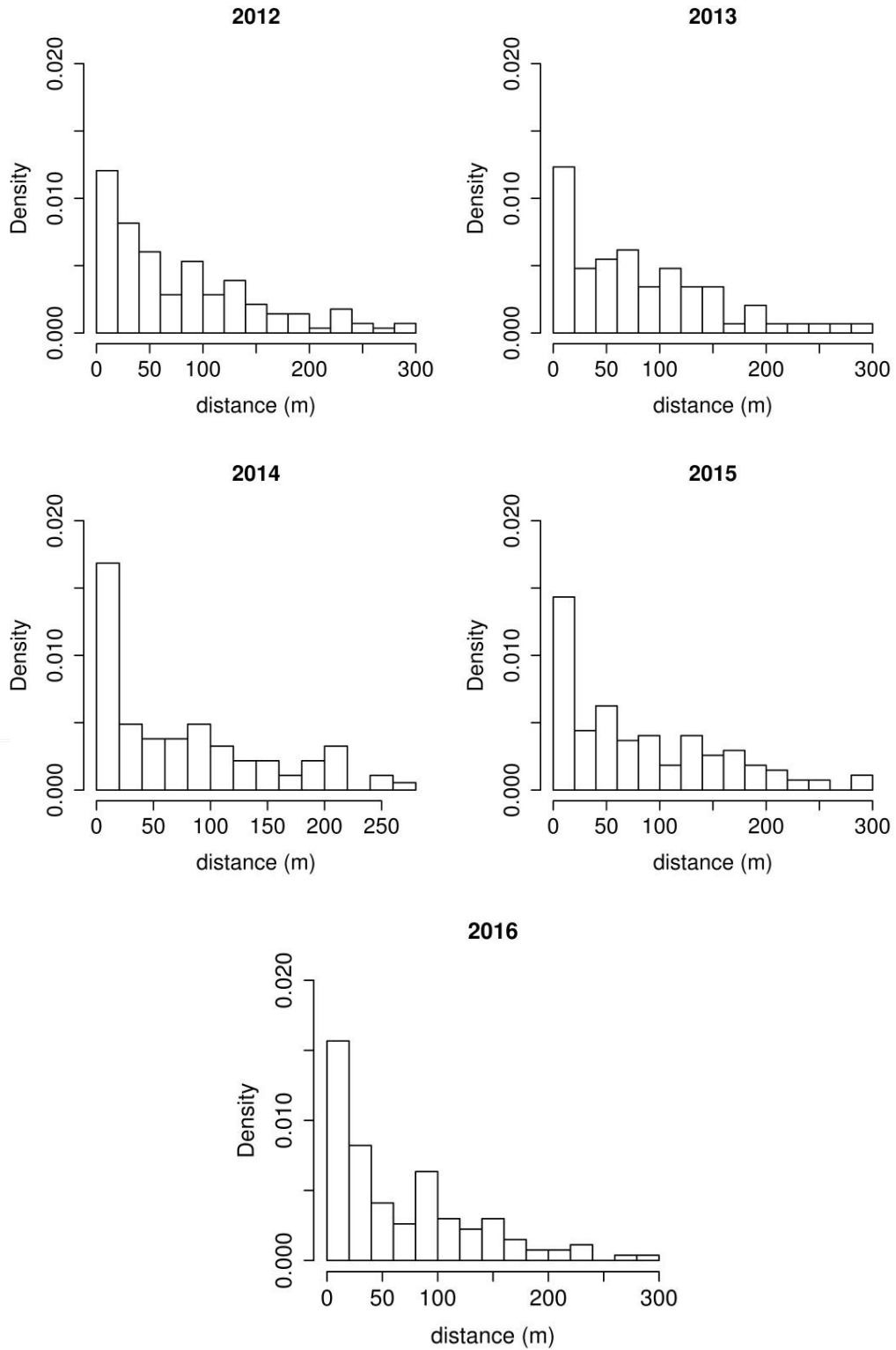


Figure 2. Histograms of the perpendicular distance (m) from the transect line to the center of detected clusters of prairie-chickens: 2012, 2013, 2014, 2015, and 2016.

2012, 2013, 2014, 2015, and 2016

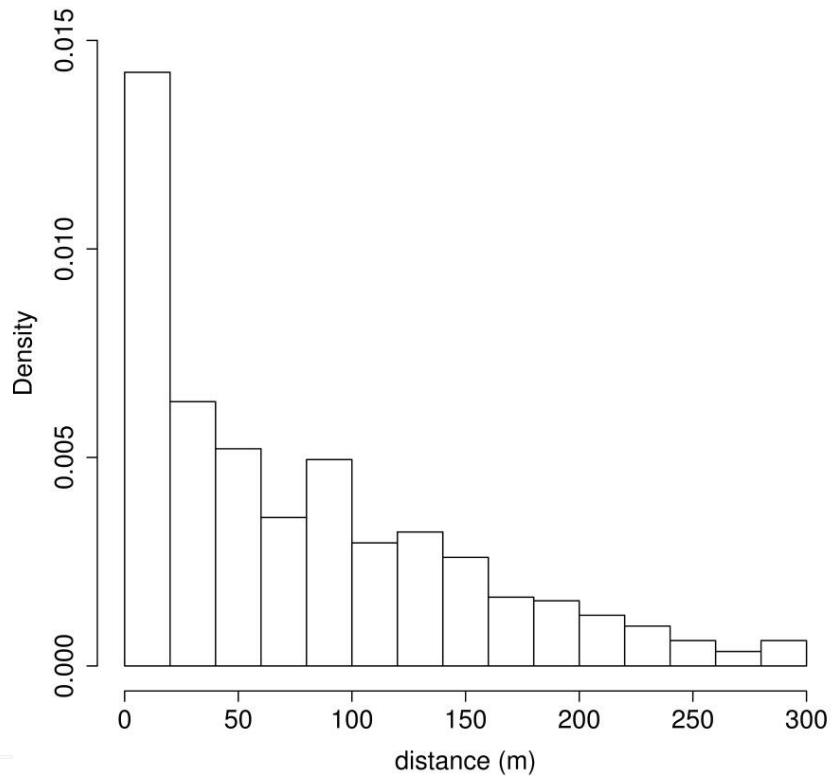


Figure 3. Histogram of the perpendicular distance (m) from the transect line to the center of detected clusters of prairie-chickens pooled from 2012, 2013, 2014, 2015, and 2016.

In the study of trends, we detected 141 clusters of LPC, GPC, and HPC in 2012, 73 in 2013, 92 in 2014, 136 in 2015, and 134 in 2016 while surveying on transects (i.e., within 300 m [984 ft] of the transect line) for a total of 576 detections of prairie-chickens in the combined data set (Table 1).

Of the 576 prairie-chicken clusters detected in 2012, 2013, 2014, 2015, and 2016, 62.0% were in short-grass grassland, 18.9% were in crop land, 10.1% were in tall-grass grassland including CRP grassland (with little or no shrubs), 6.8% were in sand-sage prairie, and 2.1% were in shinnery oak (including other shrub dominated land; Table 1).

Table 1. 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 2012, 2013, 2014, 2015, and 2016.

Year	Habitat					Total	
	Bare Ground	Crop Land	Short-Grass Grassland	Shinnery Oak (including other shrub dominated land)	Sand-Sage Prairie		Tall-Grass Grassland Including CRP Grassland (with little or no shrubs)
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%)	92
2015	0 (0%)	23 (16.9%)	85 (62.5%)	1 (0.7%)	10 (7.4%)	17 (12.5%)	136
2016	1 (0.7%)	34 (25.4%)	66 (49.3%)	1 (0.7%)	17 (12.7%)	15 (11.2%)	134
Total	1 (0.2%)	109 (18.9%)	357 (62.0%)	12 (2.1%)	39 (6.8%)	58 (10.1%)	576

We continued to use 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” and some of those clusters were “recaptured” by the back left observer. These models were used to estimate the probability that at least one of the two observers will 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 pooled data collected from 2012 through 2016 increases the sample sizes of the datasets to 216 and 209 for the front left and back left observers, respectively (Table 2). We gave the detections equal weight for modeling the components of the covariate specific, scaled, model averaged probability of detection on the inside edge of the field of view of the back left observer.

Table 2. Sample sizes for logistic regression models to estimate the probability that at least one of the two observers will detect a cluster.

Year	Front Left	Back Left
2012	57	50
2013	24	28
2014	32	39
2015	49	46
2016	54	46
Total	216	209

We dropped 10 observations greater than 300 m from the transect line as they were outside the viewshed specified in the survey protocol. Additionally, 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 were grouped into 14 intervals for fitting models for probability of detection with the first interval spanning 0-40 m (0-131 ft) and all subsequent intervals encompassing 20 m (66 ft). The first interval was defined at 0-40 m in order to compensate for potential errors in assigning distances near the transect line, thus avoiding artificial “spiking” of the detection probability on and close to the transect line.

Covariates used in the models for probability of detection were perpendicular distance to the cluster (distance), cluster size (size), and the categorical variable habitat type (habitat; Table 3 and 4). Due to the similarity of detection probability of prairie-chicken clusters in crop-land and short-grassland, we combined those habitat types into one habitat category. The four levels considered for habitat type were: short-grass/cropland, shinnery oak, sand-sage prairie, and tall-grass grassland. Another categorical variable, flushed or not flushed, was not used in the models in this report because of the very small number of observed clusters of prairie-chickens that were not flushed. Weighted average estimates of probability of detection were obtained for combinations of covariates associated with detections of leks and non-leks using model averaging with the corrected Akaike Information Criterion (AICc; Akaike 1973).

Table 3. Logistic Regression models used for estimation of probabilities of detection on the inside edge of the field of view of the back left observers. Distance = perpendicular distance to detected clusters, none = no covariates, size = size of cluster, and habitat = habitat type occupied. The back left observer models estimated the probability that the back left observer detected a cluster given that the cluster was detected by the front left observer. Similarly, the front left observer models estimated the probability that the front left observer detected a cluster given that the cluster was detected by the back left observer.

Back Left Observer Model			Front Left Observer Model		
Covariates	AICc	Model Weight	Covariates	AICc	Model Weight
distance + size	277.23	0.44	distance + size + habitat	283.17	0.47
distance	279.00	0.18	distance + size	283.55	0.39
size	279.78	0.12	size + habitat	287.15	0.06
distance + size + habitat	280.05	0.11	size	288.17	0.04
None	281.09	0.06	distance + habitat	289.85	0.02
size + habitat	281.86	0.04	distance	290.77	0.01
distance + habitat	282.35	0.03	habitat2	292.63	<0.01
habitat	283.81	0.02	None	294.01	<0.01

Table 4. 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. Size = size of cluster, and habitat = habitat occupied by detected clusters. Pooled data (576 clusters) from 2012, 2013, 2014, 2015, and 2016 were used to fit the distance sampling models. Key Functions were ne = negative exponential model, hr = hazard rate, and hn = half normal.

Model Covariates	Key Function	AICc	Model Weight
No Adj. Terms	ne	2353.05	0.987
No Adj. Terms	hr	2362.78	0.008
size	hr	2363.80	0.005
Habitat	hr	2367.89	0.001
size + habitat	hr	2369.02	< 0.001
Size	hn	2385.38	< 0.001
size + habitat	hn	2387.33	< 0.001
No Adj. Terms	hn	2389.41	< 0.001
habitat	hn	2391.11	< 0.001

Trends in Number of LPC Detected and Average Cluster size: 2013-2016.

There were 368 LPC detected in 2012, 203 in 2013, 224 in 2014, 275 in 2015, and 251 in 2016 (Table 5). Note that fewer cells were in the survey in 2012 (256 cells) while survey effort was increased to 283 cells in 2013, 2014, 2015, and 2016. The average cluster size of LPC detected was similar in 2015 and 2016, with 3.3 and 3.4 LPC per cluster, respectively (Table 6). An increase in average cluster size from 2015 to 2016 was observed in the SOPR, SSPR, and MGPR while a slight decrease in average cluster size was observed in the SGPR.

Table 5. Trends in numbers of lesser prairie-chickens detected by ecoregion (estimated number detected in SGPR) and overall in 2012, 2013, 2014, 2015, and 2016. “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 m from the transect. Two-hundred-fifty-six cells were surveyed in 2012, and 283 cells were flown in 2013, 2014, 2015, and 2016.

Year	Region									
	SOPR		SSPR		MGPR		SGPR (estimated)		Total	
	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	86	19	165	9	275	48
2016	42	12	22	0	61	0	126	0	251	12

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 CRP Prairie Region (northwest Kansas).

Table 6. Average trends in cluster sizes of lesser prairie-chicken detected by ecoregion and overall in 2012, 2013, 2014, 2015, and 2016.

Year	Region				Overall
	SOPR	SSPR	MGPR	SGPR	
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	3.7	3.3
2016	2.5	2.8	3.8	3.6	3.4

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 CRP Prairie Region (northwest Kansas).

Estimated Trends in Densities and Abundances of LPC and LPC Leks

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 7 and 8, and Figures 4, 5a, and 5b). We estimated the total population size of LPC to be

- 38,667 (90 % CI: 27251, 61363) in 2012;
- 20,297 (90% CI: 12767, 29720) in 2013;
- 23,962 (90% CI: 16373, 33592) in 2014;
- 29,985 (90% CI: 20669, 43111) in 2015; and
- 25,651 (90% CI: 18692, 34991) in 2016.

Table 7. Trends in estimated densities of lesser prairie-chickens per 100 km² (39 mi²) by ecoregion and overall in 2012, 2013, 2014, 2015, and 2016. Bootstrapped 90% confidence intervals were reported on the densities of lesser prairie-chicken per 100 km².

Year	Region				Overall
	SOPR	SSPR	MGPR	SGPR	
2012	14.84 (8.19, 25.13)	16.77 (8.93, 25.99)	26.05 (14.13, 41.31)	57.73 (33.05, 82.70)	32.06 (22.6, 50.88)
2013	7.83 (4.91, 13.97)	13.61 (8.81, 19.65)	10.99 (7.13, 15.05)	31.07 (12.01, 50.63)	16.83 (10.59, 24.64)
2014	5.33 (2.90, 10.92)	3.21 (2.70, 3.97)	19.41 (10.19, 31.16)	38.26 (22.65, 55.63)	19.87 (13.58, 27.85)
2015	3.24 (1.98, 5.24)	5.62 (2.89, 10.10)	25.32 (19.54, 38.19)	48.63 (25.85, 73.99)	24.86 (17.14, 35.75)
2016	11.76 (7.35, 22.39)	9.26 (4.77, 14.46)	17.40 (11.56, 24.73)	37.55 (22.37, 53.69)	21.27 (15.5, 29.01)

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 CRP Prairie Region (northwest Kansas).

Table 8. Trends in estimated population sizes of lesser prairie-chickens by ecoregion and overall for 2012, 2013, 2014, 2015, and 2016. Bootstrapped 90% confidence intervals were reported on the population sizes of lesser prairie-chicken.

Year	Region				Overall
	SOPR	SSPR	MGPR	SGPR	
2012	4,108 (2266, 6955)	2,680 (1426, 4151)	10,318 (5597, 16357)	21,561 (12346, 30890)	38,667 (27251, 61363)
2013	2,167 (1360, 3865)	2,173 (1408, 3140)	4,350 (2825, 5962)	11,606 (4487, 18910)	20,297 (12767, 29720)
2014	1,474 (80, 3022)	513 (432, 633)	7,686 (4034, 12338)	14,289 (8458, 20778)	23,962 (16373, 33592)
2015	896 (547, 1450)	897 (462, 1614)	10,027 (7739, 15121)	18,165 (9655, 27634)	29,985 (20669, 43111)
2016	3,255 (2035, 6198)	1,479 (762, 2310)	6,891 (4579, 9793)	14,025 (8354, 20055)	25,651 (18692, 34991)

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 CRP Prairie Region (northwest Kansas).

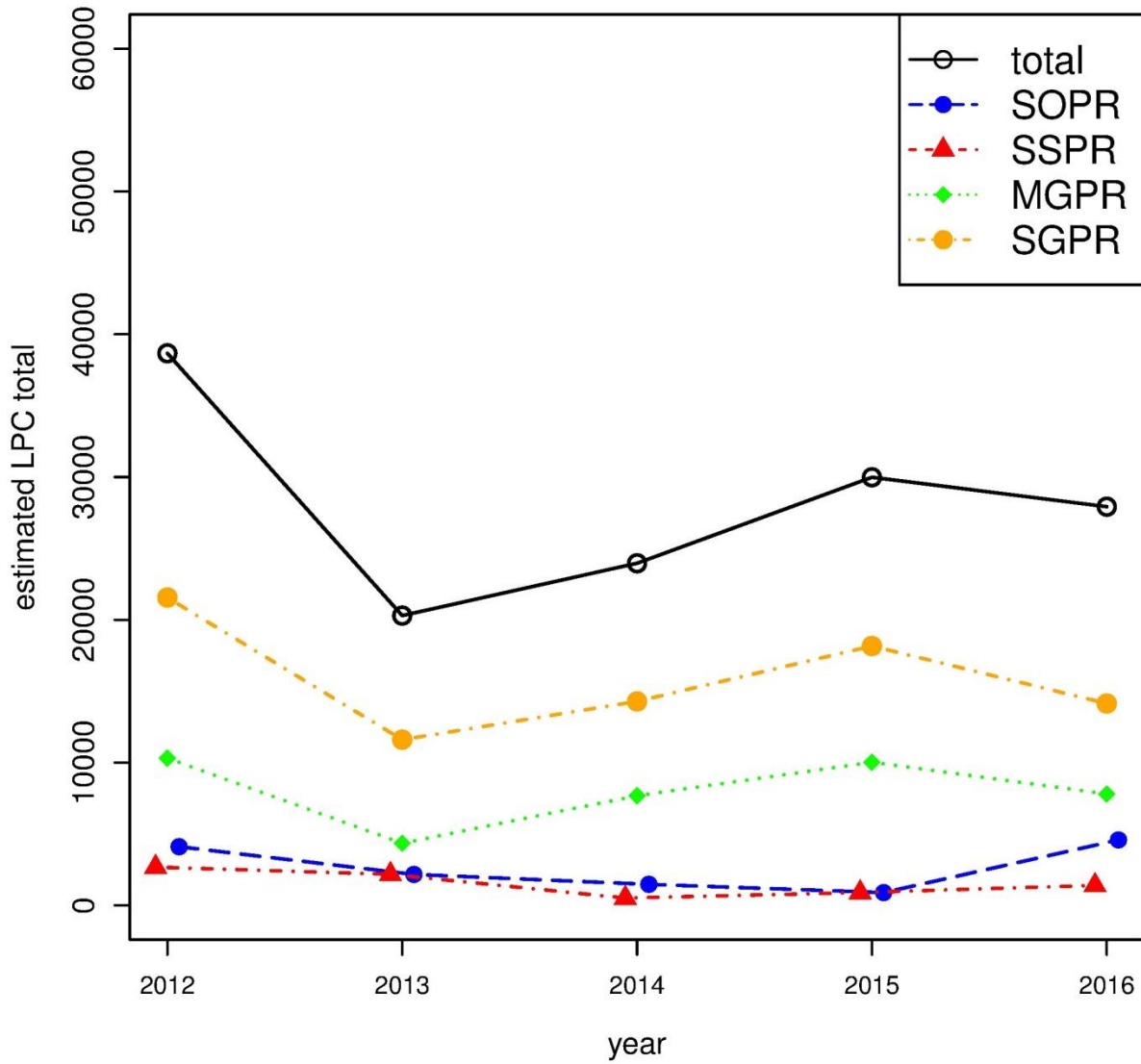


Figure 4. Trends in estimated total population sizes of lesser prairie-chicken in 2012, 2013, 2014, 2015, and 2016. SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas), SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle), MGPR = Mixed-Grass Prairie Region (northeastern Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass CRP Prairie Region (northwest Kansas).

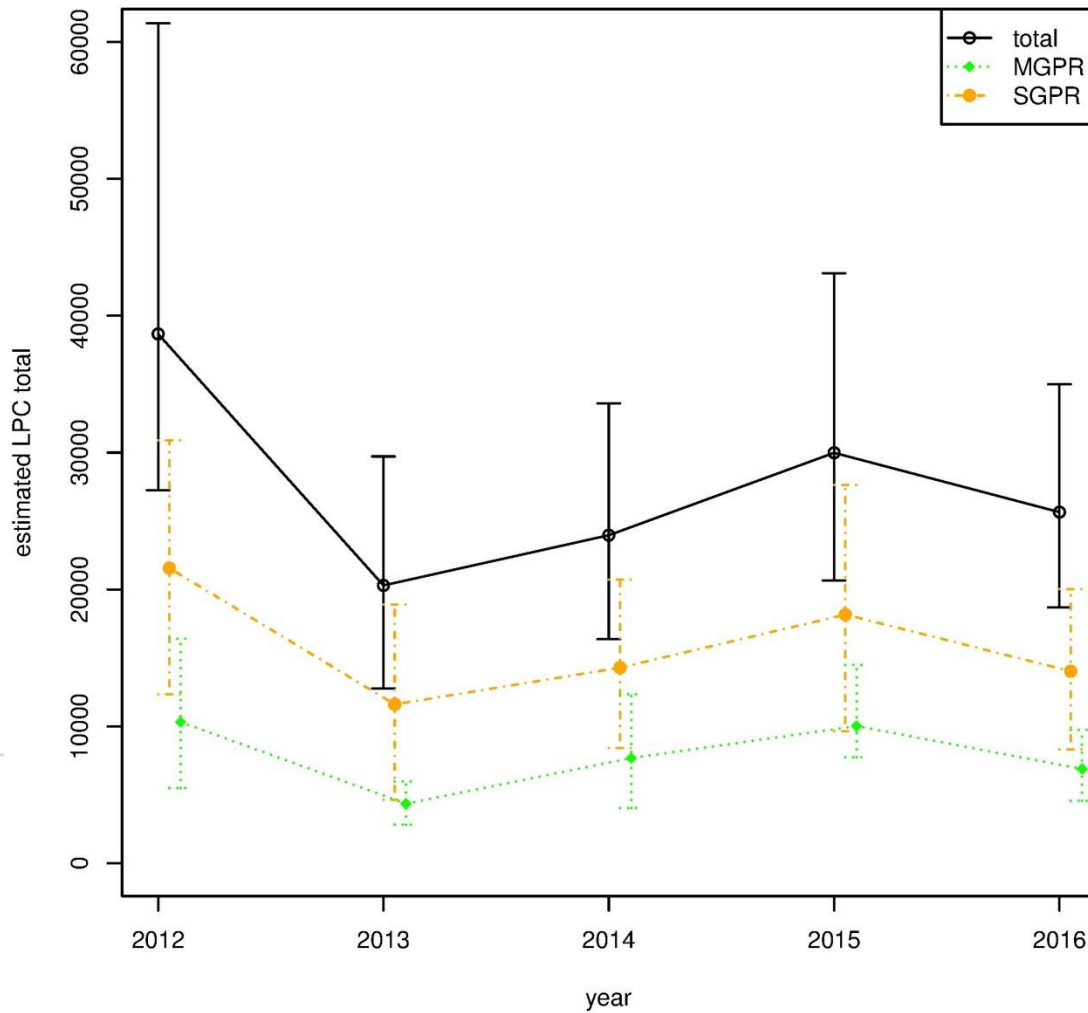


Figure 5a. Trends in estimated total population sizes of lesser prairie-chickens in 2012, 2013, 2014, 2015, and 2016 with 90% confidence intervals for the original study area, MGPR = Mixed-Grass Prairie Region (northeast Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass CRP Prairie Region (northwestern Kansas).

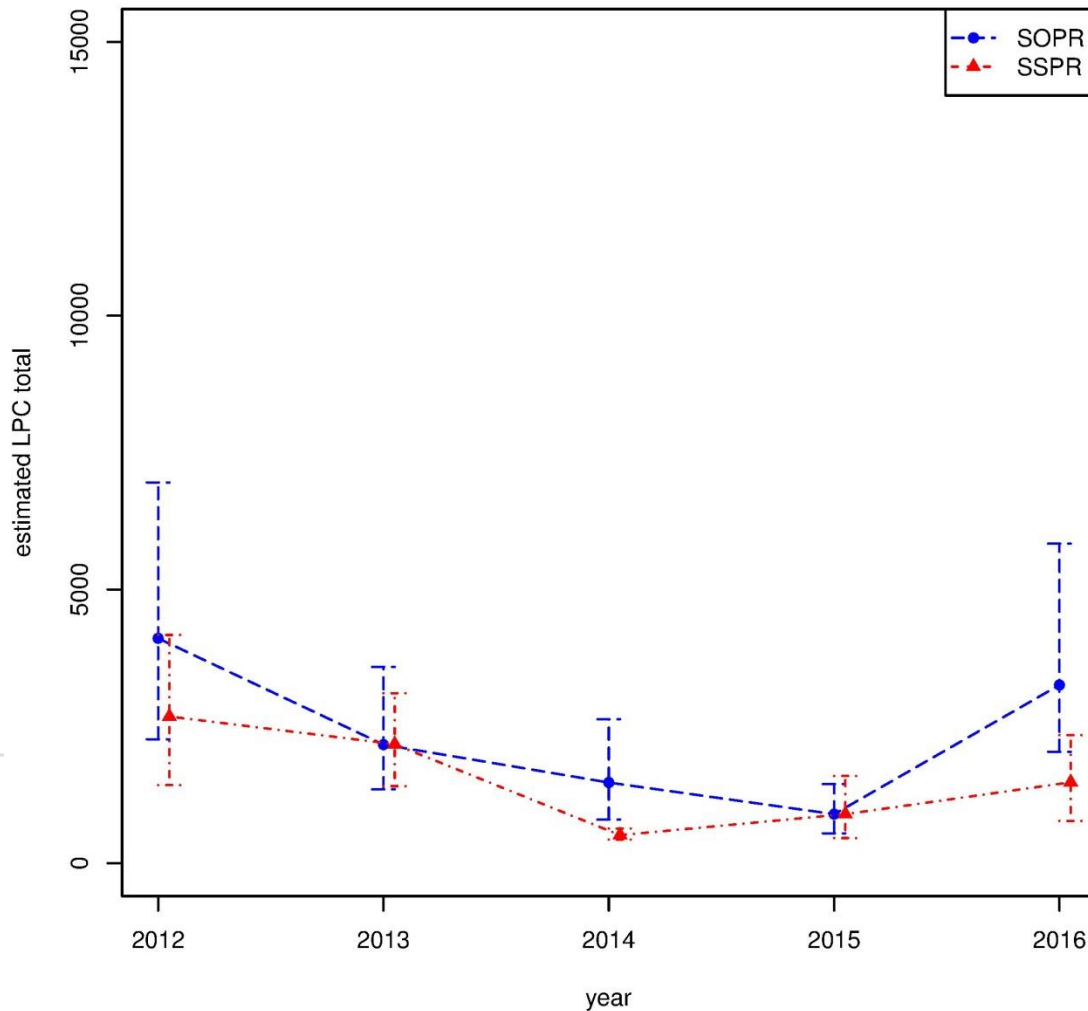


Figure 5b. Trends in estimated total population sizes of lesser prairie-chickens (LPC) in 2012, 2013, 2014, 2015, and 2016 with 90% confidence intervals in the SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas) and SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle).

The estimated trend in total population size from 2012 to 2013 was a statistically significant decrease at the 90% confidence level (an estimated decrease of 18,369.6 birds [90% CI: 5727, 40417]). Using the common 283 grid cells in 2013, 2014, 2015, and 2016, the overall population trend was an increase since 2013 (confidence intervals not reported); however, the annual changes in total population size from year to year were not significant at the 90% confidence level (Table 9).

Estimated Trends in LPC Leks from 2012 to 2016

We estimated 18% increases in the density and abundance of LPC leks in 2016 relative to 2015 (Tables 10 and 11). The abundance of LPC leks was estimated to be:

- 3,580 (90% CI: 2229, 6270) in 2012;
- 2,299 (90% CI: 1363, 3229) in 2013;
- 2,801 (90% CI: 1863, 4624) in 2014;
- 1,794 (90% CI: 1077, 2622) in 2015; and
- 2,118 (90% CI: 1162, 3311) in 2016.

Table 9. Estimated differences in population estimates for lesser prairie-chickens between years with bootstrapped 90% confidence intervals on the differences.

Δ Year	Region				Total
	SOPR	SSPR	MGPR	SGPR	
2013 minus 2012	-1941 (-4124, -209)	-506 (-2032, 1012)	-5968 (-11983, -1318)	-9955 (-21533, 1717)	-18370 (-40417, -5727)
2014 minus 2013	-693 (-232, 624)	-1660 (-2588, -915)	3335.715 (-384, 7954)	2683 (-6402, 12463)	3665 (-7944, 14711)
2015 minus 2014	-578 (-1964, 201)	384 (-52, 1107)	2340.63 (-2448, 8381)	3876 (-6179, 14322)	6023 (-4726, 19139)
2016 minus 2015	2359 (1055, 5117)	582 (-388, 1603)	-3136 (-8624, -183)	-4139 (-14642, 5560)	-4334 (-16578, 6341)

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 CRP Prairie Region (northwest Kansas).

Table 10. Estimated trends in densities of lesser prairie-chicken leks per 100 km² (39 mi²) by ecoregion and overall in 2012, 2013, 2014, 2015, and 2016. Bootstrapped 90% confidence intervals were reported on the densities of lesser prairie-chicken leks per 100 km².

Year	Region				Overall
	SOPR	SSPR	MGPR	SGPR	
2012	1.64 (0.83, 7.48)	1.53 (0.57, 2.61)	2.60 (1.50, 3.99)	4.96 (2.02, 8.52)	2.97 (1.85, 5.20)
2013	0.79 (0.00, 1.68)	2.42 (2.04, 2.87)	1.14 (0.54, 1.77)	3.32 (1.07, 5.69)	1.91 (1.13, 2.68)
2014	0.97 (0.30, 4.08)	0.42 (0.00, 0.91)	2.27 (1.36, 3.38)	4.19 (2.18, 6.57)	2.32 (1.54, 3.83)
2015	0.29 (0.00, 0.86)	0.38 (0.00, 1.08)	2.25 (1.20, 3.38)	2.04 (0.72, 3.65)	1.49(0.89, 2.17)
2016	0.82 (0.25, 1.60)	0.43 (0.00, 1.15)	1.71 (0.82, 2.69)	3.07 (0.91, 5.78)	1.76 (0.96, 2.75)

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 CRP Prairie Region (northwest Kansas)

Table 11. Estimated trends in abundances of lesser prairie-chicken leks by ecoregion and overall for 2012, 2013, 2014, 2015, and 2016. Bootstrapped 90% confidence intervals were reported on the abundances of lesser prairie-chicken leks.

Year	Region				Overall
	SOPR	SSPR	MGPR	SGPR	
2012	455 (229, 2070)	245 (91, 418)	1028 (593, 1579)	1853 (756, 3183)	3580 (2229, 6270)
2013	220 (0, 464)	386 (327, 458)	453 (214, 701)	1240 (399, 2125)	2299 (1363, 3229)
2014	269 (83, 1130)	67 (0, 146)	898 (537, 1340)	1567 (813, 2455)	2801 (1863, 4624)
2015	79 (0, 238)	61 (0, 172)	891 (475, 1339)	763 (271, 1362)	1794 (1077, 2622)
2016	228 (68, 442)	69 (0, 184)	677 (326, 1065)	1145 (338, 2159)	2118 (1162, 3311)

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 CRP Prairie Region (northwest Kansas)

Estimated Current Status of LPC Population Size in 2016 Based on Increased Sample sizes

We adjusted counts of LPC in 2016 by covariate specific, scaled, model averaged probabilities of detection to estimate population sizes in four ecoregions and the original study area using data collected in 320 grid cells using the additional survey data funded by Pheasants Forever (Table 12). Our current estimate of the status of the total population size of LPC increased to 27,926 individuals (90% CI: 20704, 37209) in 2016 based on the increased sample sizes. This estimate can be contrasted to the estimate of 25,651 individuals (90% CI: 18692, 34991) that we used for inferences on trends using only the 283 common grid cells surveyed over the period 2013 – 2016.

There were 20 additional grid cells surveyed in the SOPR resulting in a current status estimate of 4,584 individuals (90% CI: 3216, 7829) in 2016 (Table 12) compared to an estimate of 3,255 individuals (90% CI: 2035, 6198) used in the analysis of trends (Table 8). Similarly, we surveyed 16 additional grid cells in the SSPR resulting in a current status estimate of 1,401 individuals (90% CI: 794, 2160) compared to an estimate of 1,479 (90% CI: 762, 2310) in Table 8. One additional grid cell was inadvertently surveyed in the MGPR resulting in a status estimate of 7,800 individuals (90% CI: 5384, 10739) compared to an estimate of 6,891 (90% CI: 4579, 9793) in Table 8.

Our best estimate of the current status of lesser prairie-chicken populations in 2016 were:

Total, 27,926 individuals (90% CI: 20704, 37209),
SOPR, 4,584 individuals (90% CI: 3216, 7829),
SSPR, 1,401 individuals (90% CI: 794, 2160),
MGPR, 7,800 individuals (90% CI: 5384, 10739),
SGPR, 14,025 individuals (90% CI: 8354, 20055).

Table 12. Number of grid cells flown and estimates of current status of population sizes of lesser prairie-chickens by ecoregion (90% confidence interval [CI]) in 2016 data collected for the lesser prairie-chicken range-wide survey and the additional grid cells flown in 2016.

	Region				Total
	SOPR	SSPR	MGPR	SGPR	
Number of Grid Cells	97	71	79	73	320
2016 Estimate (90% CI)	4,584 (3216, 7829)	1,401 (794, 2160)	7,800 (5384, 10739)	14,141 (8107, 19352)	27,926 (20704, 37209)

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 CRP Prairie Region (northwest Kansas)

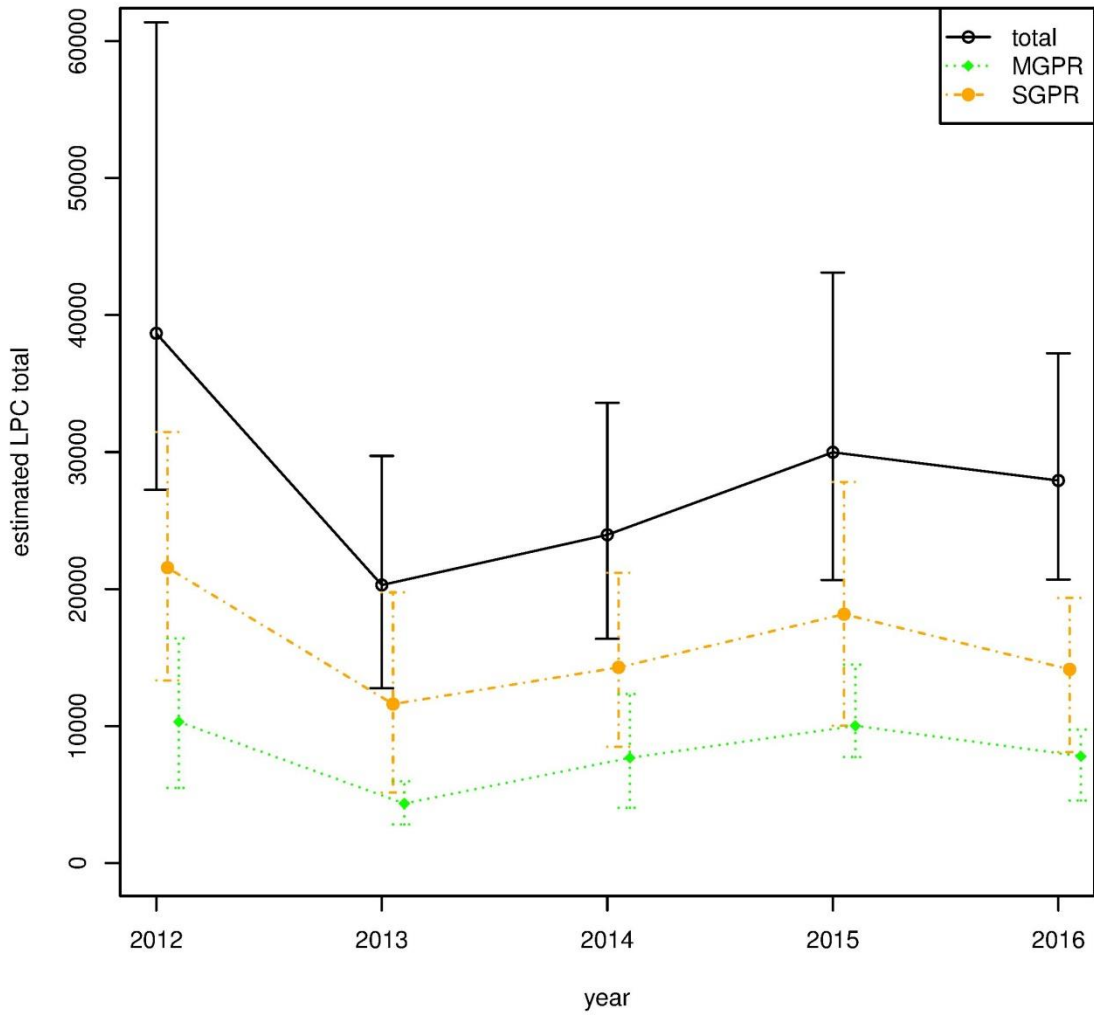


Figure 6a. Trends in estimated total population sizes of lesser prairie-chickens in 2012 (245 grid cells), 2013, 2014, and 2015 (283 grid cells), and current status in 2016 (320 grid cells) with 90% confidence intervals. MGPR = Mixed-Grass Prairie Region (northeast Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass CRP Prairie Region (northwestern Kansas).

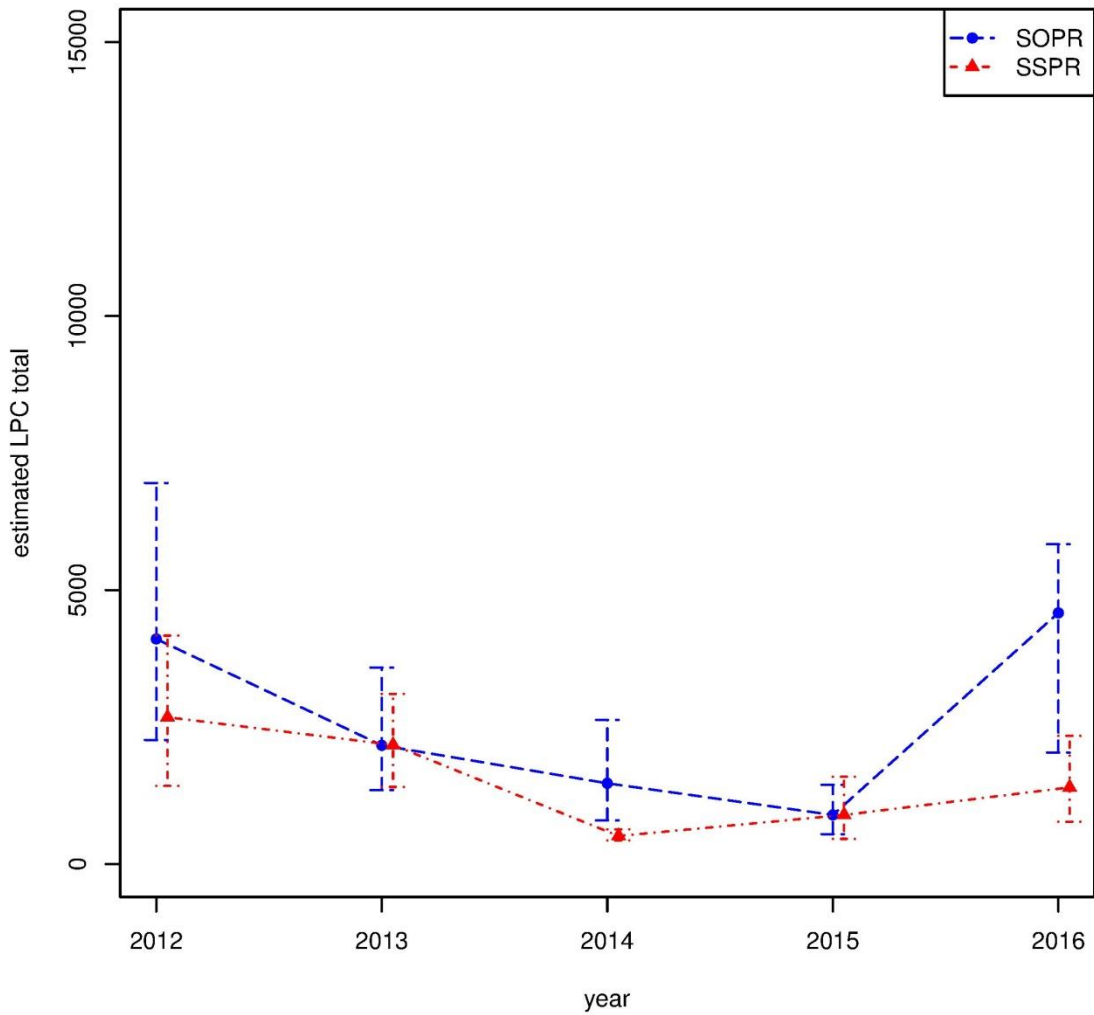


Figure 6b. Trends in estimated total population sizes of lesser prairie-chickens (LPC) in 2012 (245 grid cells), 2013, 2014, and 2015 (283 grid cells), and current status in 2016 (320 grid cells) with 90% confidence intervals. SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas) and SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle).

Estimated Densities and Abundances of GPC and HCPH

Densities (Table 13 and 15) and abundances (Table 14) 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:

- 35,033 (90% CI: 24032, 50020) in 2012;
- 16,336 (90% CI: 10723, 22296) in 2013;
- 17,633 (90% CI: 11598, 24268) in 2014;
- 24,407 (90% CI: 17233, 32283) in 2015; and
- 30,049 (90% CI: 20654, 40666) in 2016.

An increase of 5,642 GPC was observed from 2015 to 2016; however, this increase was not statistically significant (90% CI: -6572, 17476; Table 16).

We estimated the number of HPC in the SGPR to be:

- 350 (90% CI: 209, 521) in 2012;
- 130 (90% CI: 61, 216) in 2013;
- 97 (90% CI: 58, 143) in 2014;
- 261 (90% CI: 153, 385) in 2015; and
- 308 (90% CI: 158, 474) in 2016.

Table 13. Estimates of greater prairie-chicken (GPC) and hybrid prairie chicken (HPC) densities per 100 km² (39 mi²) for 2012, 2013, 2014, 2015, and 2016 in the Short Grass CRP Region of northwestern Kansas. Bootstrapped 90% confidence intervals were reported on the densities of GPC and HPC per 100 km².

Year	GPC	HPC
2012	98.30 (64.34, 133.92)	0.94 (0.56, 1.40)
2013	43.74 (28.71, 59.70)	0.35 (0.16, 0.58)
2014	47.21 (31.05, 64.97)	0.26 (0.16, 0.38)
2015	65.35 (46.14, 86.43)	0.70 (0.41, 1.03)
2016	80.45 (55.30, 108.88)	0.82 (0.42, 1.27)

Table 14. Estimates of greater prairie-chicken (GPC) and hybrid prairie-chicken (HPC) population sizes for 2012, 2013, 2014, 2015, and 2016 in the Short Grass CRP Region of northwestern Kansas. Bootstrapped 90% confidence intervals were reported on the population sizes of GPC and HPC.

Year	GPC	HPC
2012	35033 (24032, 50020)	350 (209, 521)
2013	16336 (10723, 22296)	130 (61, 216)
2014	17633 (11598, 24268)	97 (58, 143)
2015	24407 (17233, 32283)	261 (153, 385)
2016	30049 (20654, 40666)	308 (158, 474)

Table 15. Estimates of greater prairie-chicken (GPC) lek densities per 100 km² (39 mi²) and abundances of GPC leks for 2012, 2013, 2014, 2015, and 2016 in the Short Grass CRP Prairie Region of northwestern Kansas. Bootstrapped 90% confidence intervals were reported on the population sizes of GPC and abundances of GPC leks per 100 km².

Year	Density	Abundance
2012	5.97 (4.01 8.93)	2231.35 (1497.60 3335.08)
2013	4.54 (2.88, 6.51)	1694.96 (1074.02, 2431.68)
2014	5.30 (3.30, 7.39)	1979.58 (1231.98 2760.52)
2015	4.16 (2.28, 6.35)	1554.94 (851.81, 2370.52)
2016	8.07 (5.13 11.53)	3014.23 (1914.49 4305.78)

Table 16. Estimated differences in population estimates for greater prairie-chickens between years with bootstrapped 90% confidence intervals on the differences.

Δ Year	Estimate (90% Confidence Interval)
2013 minus 2012	-18,697 (-34158, -708)
2014 minus 2013	1,298 (-5879, 8700)
2015 minus 2014	6,773 (-2859, 15997)
2016 minus 2015	5,642 (-6572, 17476)

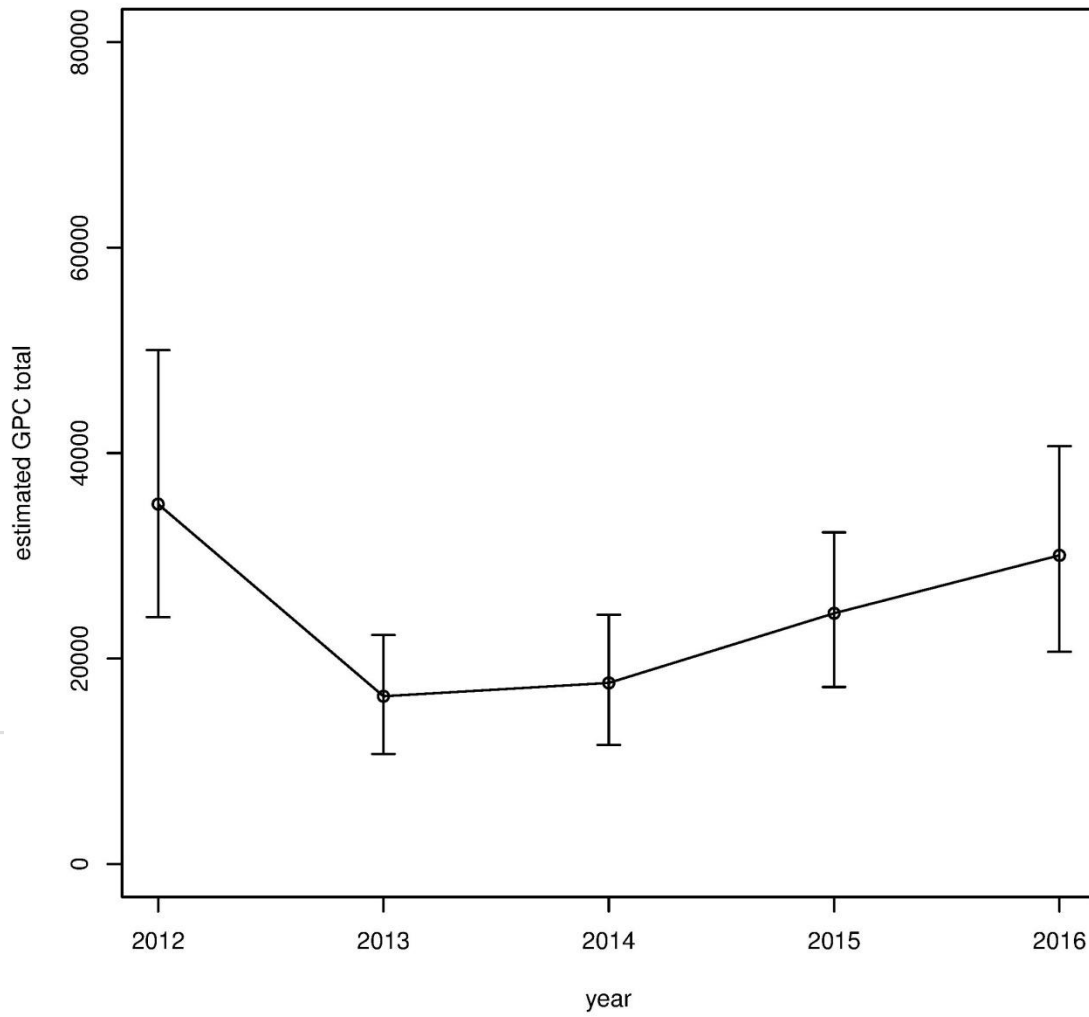


Figure 7. Estimated population sizes of greater prairie-chickens (GPC) with 90% confidence intervals in 2012, 2013, 2014, 2015, and 2016 in the Short Grass CRP Prairie Region (northwestern Kansas).

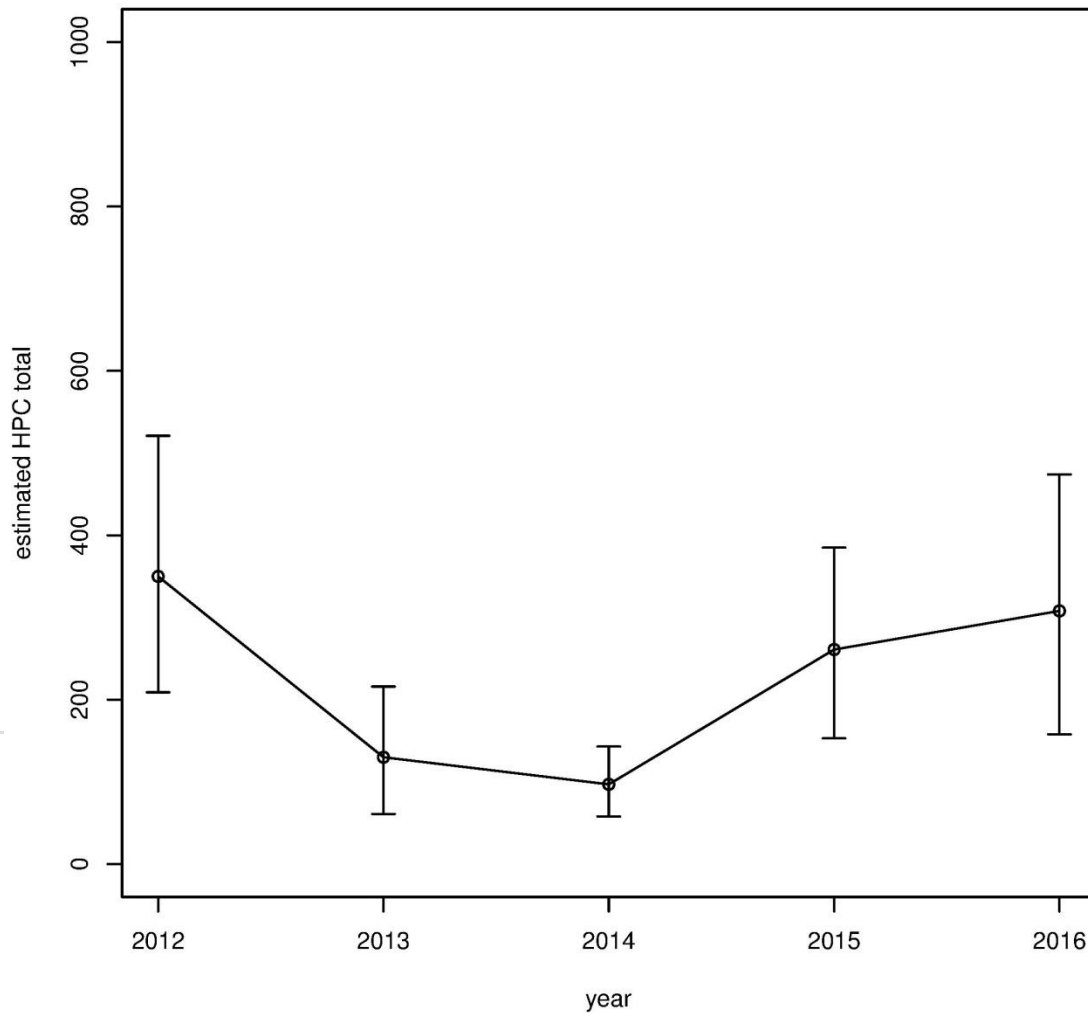


Figure 8. Estimated population sizes of hybrid prairie-chickens (HPC) with 90% confidence intervals in 2012, 2013, 2014, 2015, and 2016 in the Short Grass CRP Prairie Region (northwestern Kansas).

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associations. Pheasants Forever provided funding in 2016 for increased sample sizes in the Shinnery Oak Ecoregion of eastern New Mexico and western Texas and in the Sand Sage Ecoregion of southeast Colorado, southwest Kansas, and the western Panhandle of Oklahoma.

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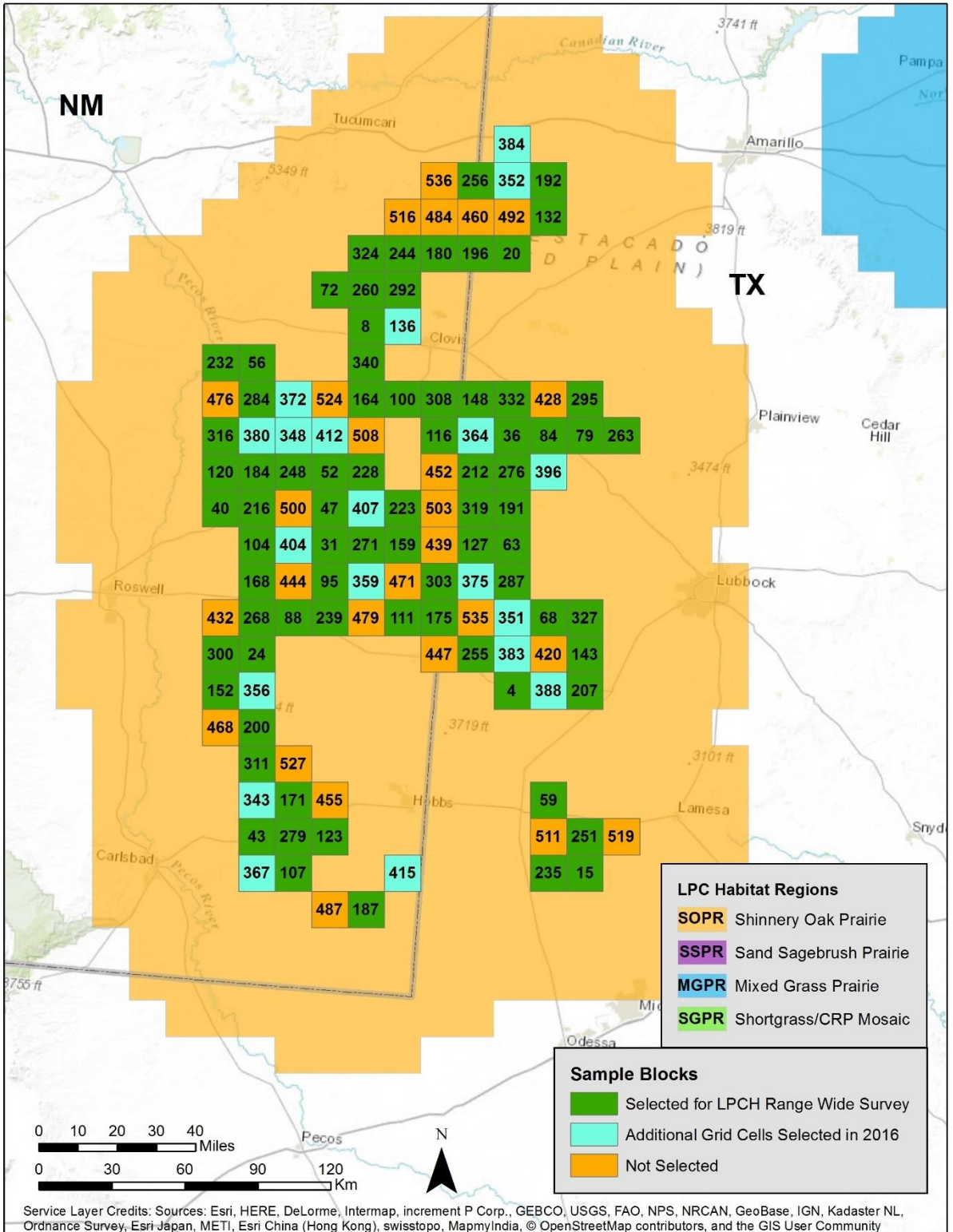
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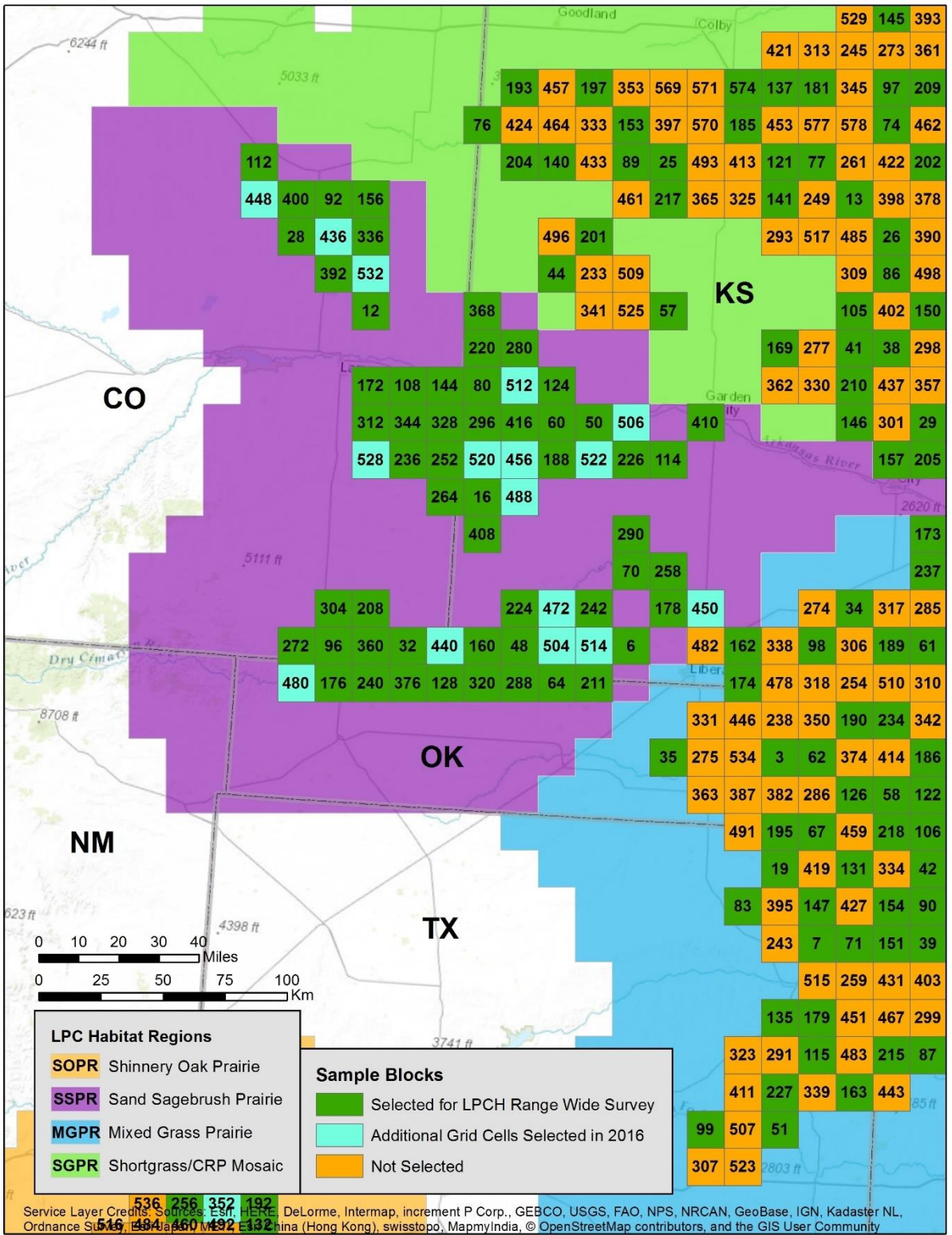
Appendix A.

Study Area for Additional Grid Cells Flown in 2016





Appendix A-1. Study area for lesser prairie-chicken surveys in the Shinnery Oak Prairie Region.



Appendix A-2. Study area for lesser prairie-chicken surveys in the Sand Sagebrush Prairie Region.