RANGE-WIDE POPULATION SIZE OF THE LESSER PRAIRIE-CHICKEN: 2012 TO 2017

Photos: Colorado Parks and Wildlife

Prepared for:

Western Association of Fish and Wildlife Agencies

Prepared by:

Lyman McDonald, Kristen Nasman, Troy Rintz, Fawn Hornsby, and Grant Gardner

Western EcoSystems Technology, Inc.
200 South 2nd St., Suite B, Laramie, Wyoming 82070

September 5, 2017

EXECUTIVE SUMMARY

- We estimated lesser prairie-chicken population sizes annually 2012 through spring 2017 for four ecoregions of Kansas, Colorado, New Mexico, Oklahoma, and Texas.
- We provided estimates of lesser prairie-chicken population sizes and abundances of leks in four ecoregions. We estimated greater prairie-chicken population sizes, abundances of hybrid lesser prairie-chicken/greater prairie-chicken, and abundances of greater prairie-chicken leks in the Short Grass Prairie Region of northwest Kansas.
- 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. Two transects were surveyed in 283 common cells in 2013, through 2016. A rotating panel design was implemented in 2017 and 303 cells were surveyed. The same field survey and analysis methods were used from 2012 to 2017; two transects covering 8% of each cell were surveyed.
- Eighty and ninety percent confidence intervals were computed on estimated parameters to account for variation in the estimates due to un-sampled grid cells, detection probability and counting errors.
- We detected 141 clusters of lesser prairie-chicken, greater prairie-chicken, and hybrid prairie-chicken in 2012, 73 in 2013, 92 in 2014, 136 in 2015, 134 in 2016, and 172 in 2017, resulting in a relatively large pooled data set of 748 detections of prairie-chickens. We estimated probability of detection in the survey strips using the pooled data set, which resulted in a slight decrease in the estimates of lesser prairie-chicken population sizes in 2012, 2013, 2014, 2015, and 2016 relative to estimates reported previously.
- Of the 748 prairie-chicken clusters detected from 2012 to 2017; 60.0% were in short-grass grassland, 21.1% were in crop land, 10.4% were in tall-grass grassland including CRP grassland (with little or no shrubs), 5.7% were in sand-sage prairie, and 2.3% 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 lesser prairie-chicken, greater prairie-chicken, and hybrid prairie-chicken 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, we estimated the total population sizes of lesser prairie-chicken to be:
    - 37,108 (90% Confidence Interval [CI]: 27854, 52280) in 2012;
    - 19,471 (90% CI: 13036, 28184) in 2013;
    - 23,064 (90% CI: 16200, 30563) in 2014;
    - 28,875 (90% CI: 20256, 38974) in 2015;
    - 24,779 (90% CI: 18580, 31193) in 2016; and
    - 33,269 (90% CI: 23619, 44325) in 2017.

- There was a statistically significant annual rate of increase in the total lesser prairie-chicken population size from 2013 to 2017 (p-value = 0.06). The average rate of increase was 2,931 lesser prairie-chicken per year in the population (standard error = 964).
- The estimated total population increase of 8490 lesser prairie-chicken from 2016 to 2017 (34% increase) was statistically significant at the 80% confidence level.
- There was a statistically significant annual rate of increase of abundance of lesser prairie-chicken in the Short Grass Prairie Region in northwest Kansas from 2013 to 2017 (p-value = 0.10). The average rate of increase was 2,045 lesser prairie-chicken per year in the Short Grass Prairie Region (standard error = 880).
- The estimated increase in abundance of 7893 lesser prairie-chicken in the Short Grass Prairie Region from 2016 to 2017 was marginally significant at the 80% confidence level.
- The abundances of lesser prairie-chicken leks in the total population were estimated to be:
    - 3,470 (90% CI: 2248, 5393) in 2012;
    - 2,228 (90% CI: 1425, 3195) in 2013;
    - 2,719 (90% CI: 1824, 3951) in 2014;
    - 1,713 (90% CI: 1066, 2391) in 2015;
    - 2,053 (90% CI: 1159, 3090) in 2016; and
    - 3,186 (90% CI: 2194, 4614) in 2017.
- The estimated increase of 1133 lesser prairie-chicken leks from 2016 to 2017 (55% increase) was statistically significant at the 80% confidence level. We note that the abundance of lesser prairie-chicken leks was estimated to increase at a faster rate than the rate of increase of individuals in the population.
- We estimated a stable to increasing population of lesser prairie-chickens since 2013 in the Mixed Grass Prairie Region of northeast Panhandle of Texas, northwest Oklahoma, and south-central Kansas. However, the increase was not statistically significantly at the 80% confidence level.
- We estimated a stable to increasing population of lesser prairie-chickens since 2014 in the Shinnery Oak Prairie Region of eastern New Mexico and western Panhandle of Texas, and in the Sand Sage Prairie Region of southeast Colorado, southwest Kansas, and part of the Panhandle of Oklahoma. However, the increases were not statistically significant at the 80% confidence level.

- The estimated total abundances and trends of greater prairie-chickens in the Short Grass/CRP of northwest Kansas corroborated our results for abundances and trends of lesser prairie-chickens (Appendix A). The estimated population sizes of the greater prairie-chicken in the Short Grass/CRP ecoregion were:
    - 33,723 (90% CI: 23786, 47165) in 2012;
    - 15,762 (90% CI: 10574, 20773) in 2013;
    - 17,113 (90% CI: 11318, 22810) in 2014;
    - 23,649 (90% CI: 16522, 30120) in 2015;
    - 28,978 (90% CI: 19940, 39867) in 2016; and
    - 36,279 (90% CI: 26720, 46543) in 2017.

- There was a statistically significant annual rate of increase of abundance of greater prairie-chickens in the Short Grass/CRP Prairie Region in northwest Kansas from 2013 to 2017 (p-value < 0.01). The average rate of increase was 5,290 greater prairie-chickens per year in the Short Grass/CRP Prairie Region (standard error = 592).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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 2017. 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 to 2017 was illustrated in Figure 1, where we indicated the grid cells selected and not selected for survey in 2017. 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.

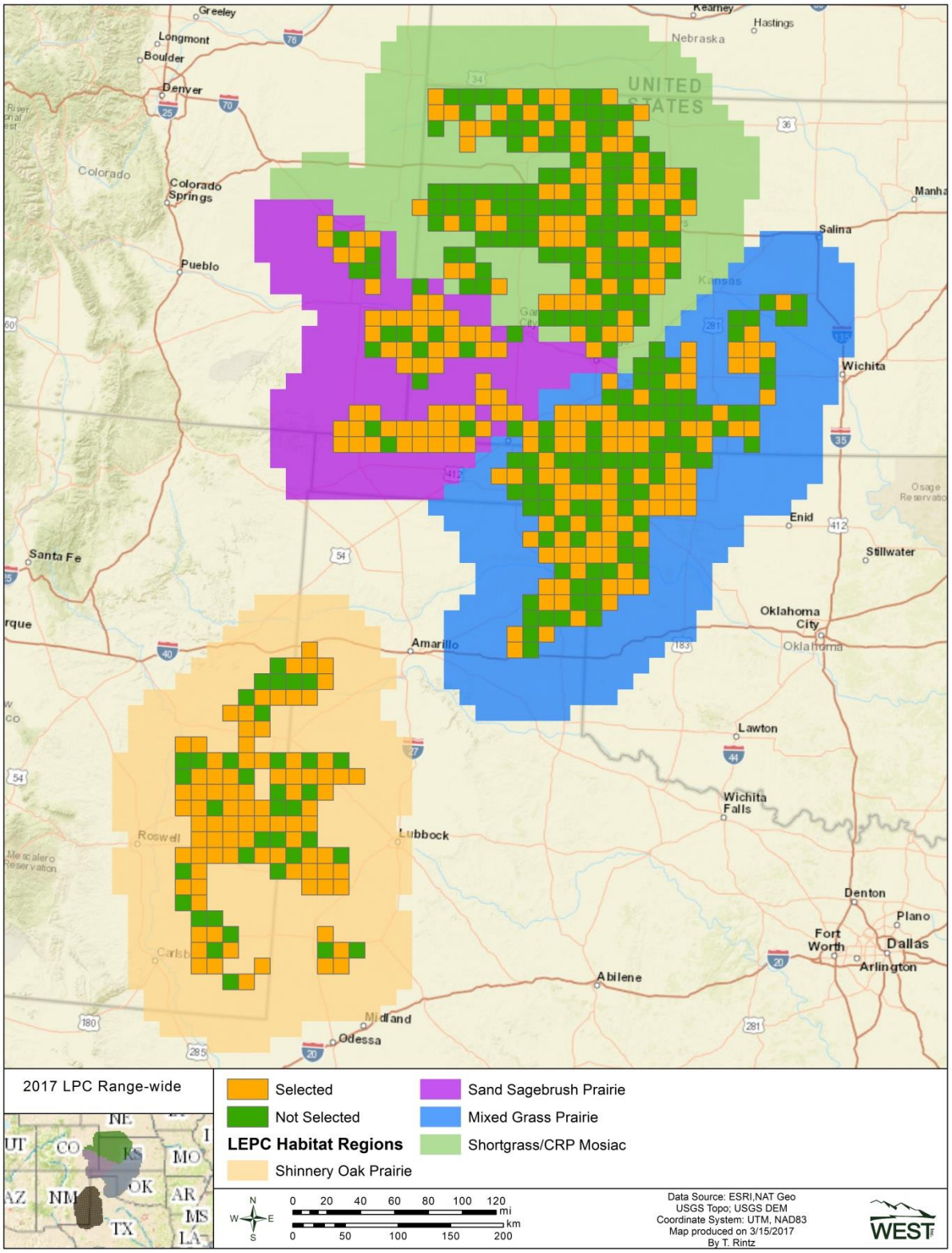

Figure 1. Study area for 2012, 2013, 2014, 2015, 2016, and 2017 lesser prairie-chicken surveys illustrated with grid cells selected for survey in 2017. The colored areas surrounding the study sub-areas indicated an approximate 77.7-km (30-mi) buffer into which the survey may be expanded in the future.

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.

In 2012, 256 grid cells were selected for survey. The SOPR and SGPR were individual strata with equal probability sampling: 75 of 123 cells were surveyed in the SOPR and 80 of 165 cells were surveyed in the SGPR (Table 1). 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. A total of 283 grid cells were surveyed from 2013 to 2016; two-hundred and five grid cells were resurveyed from 2012 and 38 new cells were selected from the GRTS list.

In 2017, a rotating panel design was implemented in each ecoregion. A panel of approximately 20% of the top ranked grid cells on the GRTS list was dropped and a panel of equal size was added from the grid cells next on the GRTS list in each ecoregion. Funds became available for survey of additional cells in two regions in 2017; ten additional cells were surveyed in the SOPR and 10 additional cells were surveyed in the MGPR for a total sample size of 303 probabilistically selected cells.

Table 1. Total number of grid cells surveyed by year and region

	Region				
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

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).

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 (300 m, 7,200 m [984 ft, 23,622 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 was 300 meters on each side of the transect lines. Area surveyed in each grid cell was 8% of the total 225 square km.

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

Statistical Methods

Probability of Detection

We pooled data collected from 2012 to 2017 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 2017 and adjusted estimates of population sizes for 2012, 2013, 2014, 2015, and 2016. Estimates for 2012, 2013, 2014, 2015, and 2016 were expected to differ slightly from results reported in McDonald et al. (2012, 2014a, 2014b, 2015, 2016).

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 confidence intervals (CIs) for density and population totals of LPC, HPC, and GPC individuals and leks by year for each ecoregions. From each bootstrapped sample we generated new estimates of densities, population totals, and differences. We calculated CIs based on the central 80% and/or 90% 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. The random error terms followed a first-order autoregressive process to account for autocorrelation in the population between years (Kutner et al. 2005).

RESULTS

Data collected from surveys in 2012 (256 grid cells), 2013 to 2016 (283 grid cells), and 2017 (303 grid cells) were used to estimate the trends in population sizes. Estimates of population size and density were calculated for 2017 based on the 303 grid cells surveyed and estimates of population size and density were updated for 2012, 2013, 2014, 2015, and 2016. The data collected from 2012 to 2017 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).

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, 134 in 2016, and 172 in 2017 while surveying on transects (i.e., within 300 m [984 ft] of the transect line) for a total of 748 detections of prairie-chickens in the combined data set (Table 2). Note that fewer cells were in the survey in 2012 (256 cells) while survey effort was increased to 283 cells from 2013 to 2016, and to 303 cells in 2017.

Of the 748 prairie-chicken clusters detected from 2012 to 2017, 60.0% were in short-grass grassland, 21.1% were in crop land, 10.4% were in tall-grass grassland including CRP grassland (with little or no shrubs), 5.7% were in sand-sage prairie, and 2.3% were in shinnery oak (including other shrub dominated land; Table 2).

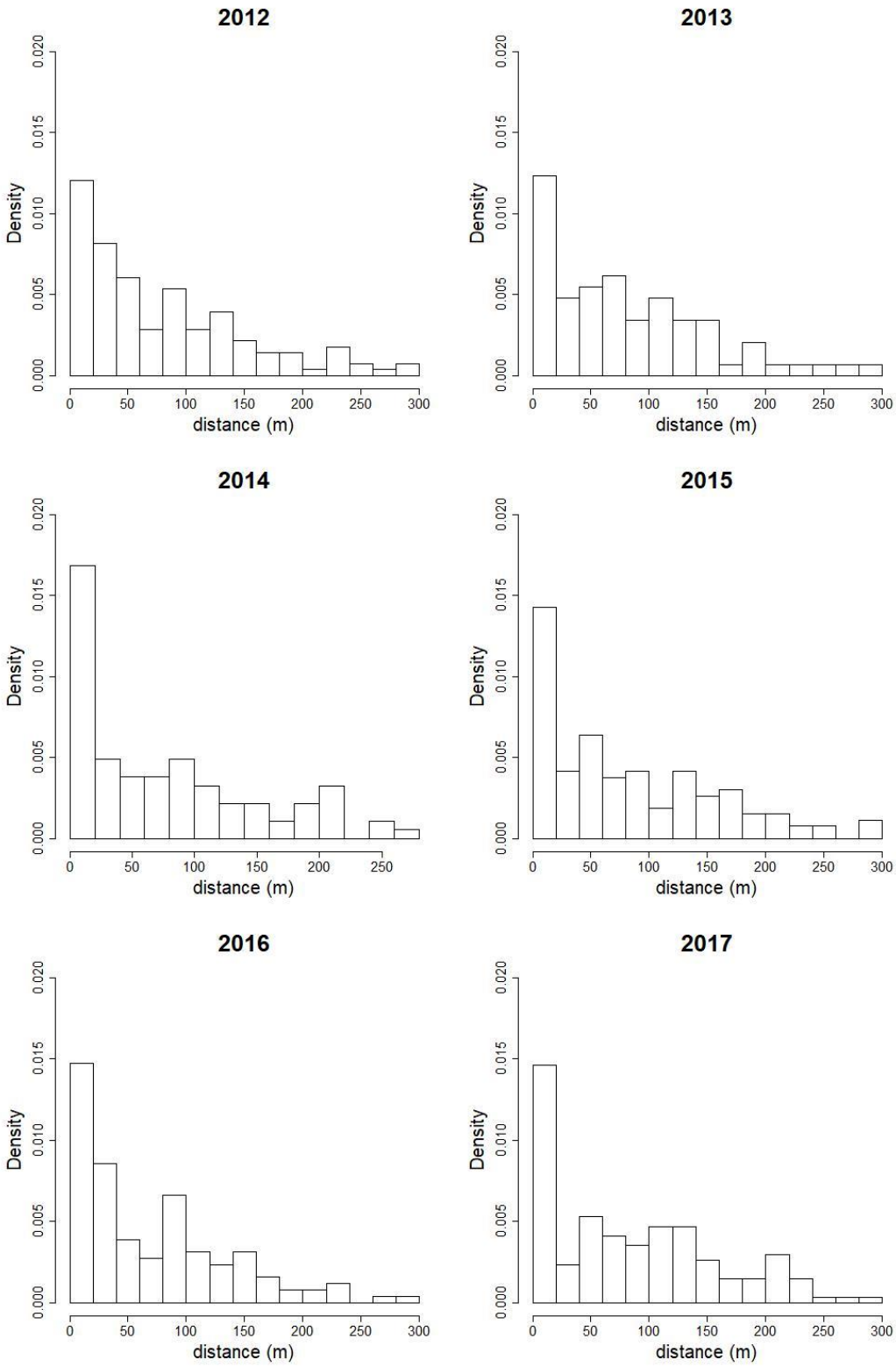

Figure 2. Histograms of the perpendicular distance (m) from the transect line to the center of detected clusters of prairie-chickens: 2012, 2013, 2014, 2015, 2016, and 2017.

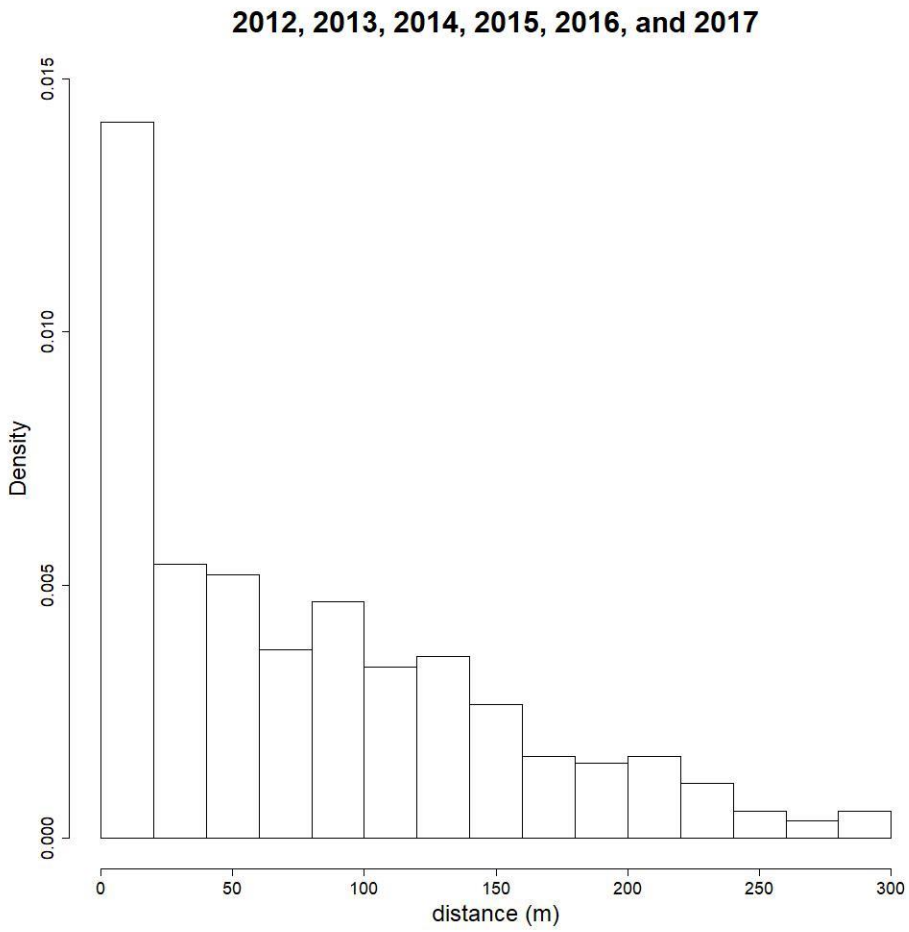

Figure 3. Histogram of the perpendicular distance (m) from the transect line to the center of detected clusters of prairie-chickens pooled from 2012, 2013, 2014, 2015, 2016, and 2017.

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 2012, 2013, 2014, 2015, 2016, and 2017.

	Habitat						
Year	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)	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%)	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
2017	2 (0.7%)	49 (25.4%)	92 (49.3%)	5 (0.7%)	4 (12.7%)	20 (11.2%)	172
Total	**3 (0.4%)**	**158 (21.1%)**	**449 (60.0%)**	**17 (2.3%)**	**43 (5.7%)**	**78 (10.4%)**	**748**

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 2017 increases the sample sizes of the datasets to 279 and 259 for the front left and back left observers, respectively (Table 3). 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 3. 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
2017	63	50
Total	**279**	**259**

We dropped 13 observations over the period 2012 through 2017 that were 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 4 and 5). 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 clusters of prairie-chickens using model averaging with the corrected Akaike Information Criterion (AICc; Akaike 1973).

Table 4. 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		
Model Covariates	AICc	Model Weight	Model Covariates	AICc	Model Weight
distance + size	338.54	0.57	distance + size + habitat	360.46	0.53
Size	340.47	0.22	distance + size	360.76	0.45
distance + size + habitat	341.55	0.13	size + habitat	367.78	0.01
size + habitat	343.11	0.06	Size	368.96	0.01
distance	345.31	0.02	distance + habitat	375.50	<0.01
None	346.56	0.01	Distance	377.27	<0.01
distance + habitat	349.04	<0.01	Habitat	380.54	<0.01
Habitat	350.02	<0.01	None	382.74	<0.01

Table 5. 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 (748 clusters) from 2012, 2013, 2014, 2015, 2016, and 2017 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
Unadjusted negative exponential	Ne	3117.39	~1.00
size + habitat	Hn	3154.83	< 0.001
Habitat	Hn	3158.18	< 0.001
Size	Hn	3150.17	< 0.001
None	Hn	3153.74	< 0.001
size + habitat	Hr	3138.48	< 0.001
Habitat	Hr	3138.19	< 0.001
Size	Hr	3132.84	< 0.001
None	Hr	3132.71	< 0.001

Trends in Number of LPC Detected and Average Cluster Size

There were 368 LPC detected in 2012, 203 in 2013, 224 in 2014, 276 in 2015, 251 in 2016, and 336 in 2017 (Table 6). Note that fewer cells were in the survey in 2012 (256 cells) while survey effort was increased to 283 cells from 2013 to 2016, and to 303 cells in 2017. The average cluster size of LPC detected was similar in 2016 and 2017, with 3.4 and 3.3 LPC per cluster, respectively (Table 7). An increase in average cluster size was observed from 2016 to 2017 in the SSPR and a slight decrease was observed in the MGPR and SGPR.

Table 6. Trends in numbers of lesser prairie-chickens detected by ecoregion (estimated number detected in SGPR) and overall in 2012, 2013, 2014, 2015, 2016, and 2017. "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, 283 cells were flown in 2013, 2014, 2015, and 2016, and 303 cells were flown in 2017

	Region									
	SOPR		SSPR		MGPR		SGPR (estimated)		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**

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 7. Average trends in cluster sizes of lesser prairie-chicken detected by ecoregion and overall in 2012, 2013, 2014, 2015, 2016, and 2017.

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	3.8	**3.3**
2016	2.5	2.8	3.8	3.6	**3.4**
2017	2.7	3.3	3.5	3.3	**3.3**

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

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 and 9, and Figures 4, 5a, and 5b). We estimated the total population size of LPC to be:

- 37,108 (90% Confidence Interval [CI]: 27854, 52280) birds in 2012;
- 19,471 (90% CI: 13036, 28184) in 2013;
- 23,064 (90% CI: 16200, 30563) in 2014;
- 28,875 (90% CI: 20256, 38974) in 2015;
- 24,779 (90% CI: 18580, 31193) in 2016; and
- 33,269 (90% CI: 23619, 44325) in 2017.

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 2017. The estimated average rate of increase of 2,931 LPC in the total LPC population size from 2013 to 2017 was statistically significant (p-value = 0.06).

The estimated total population increase of 8,490 lesser prairie-chicken from 2016 to 2017 (34% increase) was statistically significant at the 80% confidence level (147, 18306; Table 10a). The estimated increase in LPC in the SGPR ecoregion of 7,893 was marginally significant at the 80% confidence lever (80% CI: -24, 15915).

Table 8. Trends in estimated densities of lesser prairie-chickens per 100 km^2 (39 mi^2) by ecoregion and overall in 2012, 2013, 2014, 2015, 2016, and 2017. Bootstrapped 90% confidence intervals were reported on the densities of lesser prairie-chicken per 100 km^2.

	Region				
Year	SOPR	SSPR	MGPR	SGPR	Overall
2012	14.43 (8.52, 21.52)	15.77 (9.17, 22.58)	25.04 (14.34, 37.99)	55.37 (33.55, 75.39)	30.77 (23.1, 43.35)
2013	7.73 (5.02, 12.74)	13.06 (8.21, 17.59)	10.48 (6.94, 13.53)	29.71 (13.87, 50.17)	16.14 (10.81, 23.37)
2014	5.27 (3.06, 9.14)	3.12 (2.66, 3.51)	18.58 (9.33, 28.96)	36.81 (21.77, 51.27)	19.12 (13.43, 25.34)
2015	3.24 (1.96, 5.06)	5.49 (2.73, 9.66)	24.5 (19.52, 31.16)	46.58 (25.61, 70.29)	23.94 (16.8, 32.32)
2016	11.41 (7.31, 17.98)	8.87 (3.97, 13.23)	16.84 (11.43, 22.51)	36.24 (22.36, 51.08)	20.55 (15.41, 25.87)
2017	9.38 (5.17, 22.09)	9.19 (4.33, 13.91)	19.64 (12.23, 26.86)	57.37 (33.82, 82.47)	27.59 (19.58, 36.75)

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 9. Trends in estimated population sizes of lesser prairie-chickens by ecoregion and overall for 2012, 2013, 2014, 2015, 2016, and 2017. Bootstrapped 90% confidence intervals were reported on the population sizes of lesser prairie-chicken.

	Region				
Year	SOPR	SSPR	MGPR	SGPR	Overall
2012	3993 (2358, 5955)	2520 (1465, 3608)	9915 (5677, 15044)	20681 (12531, 28159)	37,108 (27854, 52280)
2013	2140 (1391, 3527)	2086 (1312, 2810)	4149 (2750, 5358)	11096 (5181, 18738)	19,471 (13036, 28184)
2014	1458 (848, 2531)	498 (424, 560)	7359 (3696, 11469)	13749 (8132, 19149)	23,064 (16200, 30563)
2015	897 (541, 1401)	878 (436, 1543)	9701 (7730, 12341)	17399 (9567, 26252)	28,875 (20256, 38974)
2016	3159 (2023, 4975)	1417 (634, 2113)	6670 (4527, 8916)	13534 (8352, 19079)	24,779 (18580, 31193)
2017	2596 (1430, 6112)	1469 (692, 2222)	7778 (4845, 10638)	21427 (12633, 30804)	33,269 (23619, 44325)

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 10a. Estimated differences in population estimates for lesser prairie-chickens between years with bootstrapped 80% confidence intervals on the differences.

Δ Year	Region				Total
	SOPR	SSPR	MGPR	SGPR	
2013 minus 2012	-1853 (-6178, -512)	-434 (-1470, 585)	-5767 (-9734, -2246)	-9585 (-16457, -984)	**-17637 (-28417, -8586)**
2014 minus 2013	-682 (-1711, 242)	-1588 (-2130, -997)	3211 (118, 6402)	2653 (-4335, 8792)	**3593 (-4573, 11119)**
2015 minus 2014	-561 (-1439, 26)	380 (-20, 812)	2342 (-1053, 6192)	3650 (-3850, 10949)	**5811 (-2733, 14766)**
2016 minus 2015	2261 (1230, 3578)	539 (-208, 1186)	-3031 (-5484, -938)	-3865 (-11248, 3169)	**-4096 (-12464, 3314)**
2017 minus 2016	-563 (-2079, 1722)	52 (-714, 874)	1108 (-1715, 3894)	7893 (-24, 15915)	**8490 (147, 18306)**

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 10b. 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	-1853 (-12454, -258)	-434 (-1746, 880)	-5767 (-10975, -1515)	-9585 (-19200, 1393)	**-17637 (-34042, -5882)**
2014 minus 2013	-682 (-2045, 487)	-1588 (-2310, -850)	3211 (-391, 7431)	2653 (-5957, 10718)	**3593 (-7028, 13023)**
2015 minus 2014	-561 (-1735, 174)	380 (-41, 1071)	2342 (-2264, 7145)	3650 (-5639, 13874)	**5811 (-4441, 17261)**
2016 minus 2015	2261 (1012, 4147)	539 (-388, 1413)	-3031 (-6253, -371)	-3865 (-13743, 4855)	**-4096 (-15148, 5714)**
2017 minus 2016	-563 (-2525, 2961)	52 (-919, 1112)	1108 (-2540, 4585)	7893 (-1858, 18289)	**8490 (-1779, 20891)**

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).

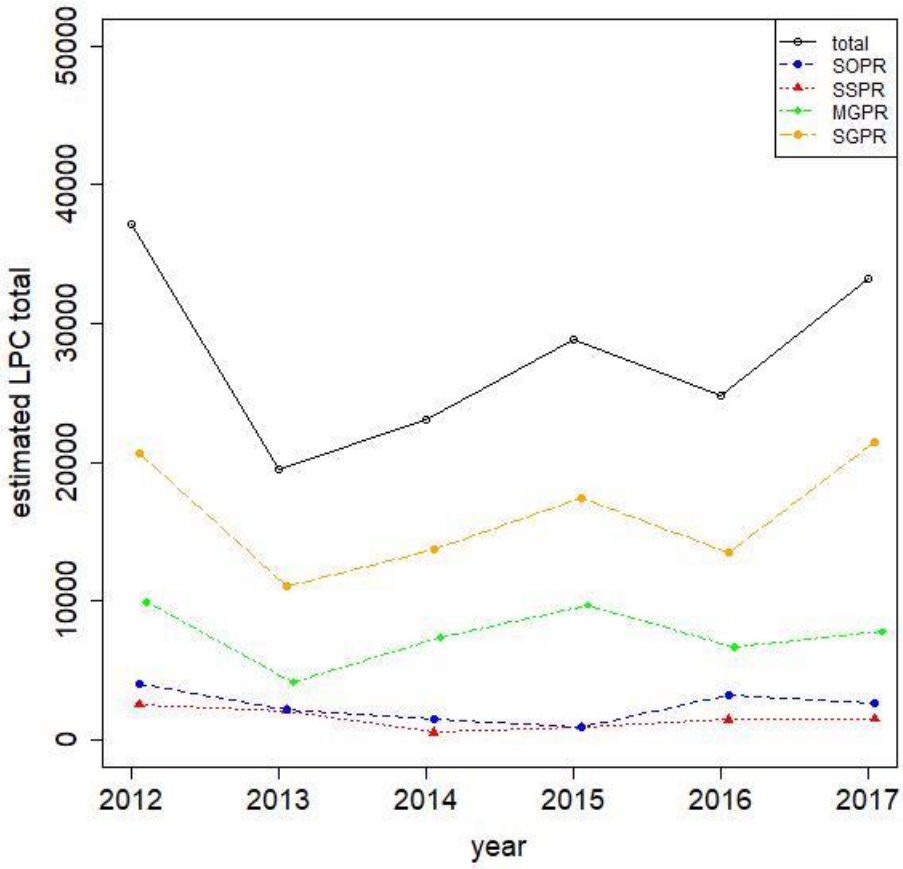

Figure 4. Trends in estimated total population sizes of lesser prairie-chicken in 2012, 2013, 2014, 2015, 2016, and 2017. SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas), SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle), MGPR = Mixed-Grass Prairie Region (northeastern Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass CRP Prairie Region (northwest Kansas).

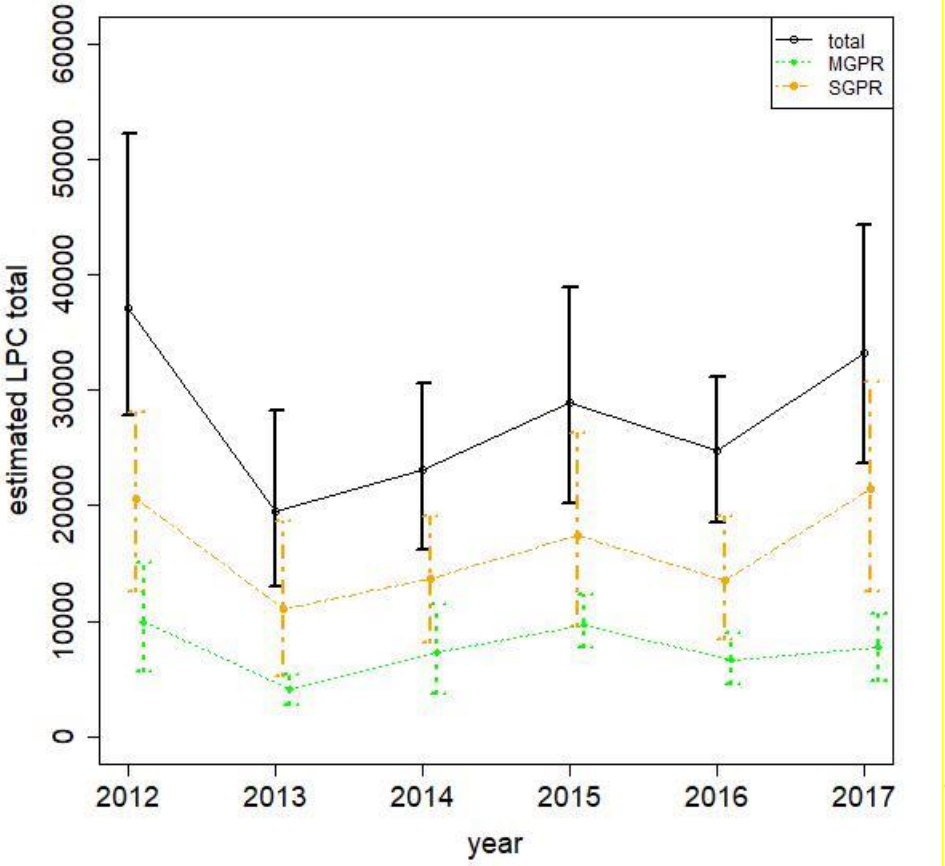

Figure 5a. Trends in estimated total population sizes of lesser prairie-chickens in 2012, 2013, 2014, 2015, 2016, and 2017 with 90% confidence intervals for the original study area, MGPR = Mixed-Grass Prairie Region (northeast Texas, northwestern Oklahoma, south-central Kansas), and SGPR = Short Grass CRP Prairie Region (northwestern Kansas).

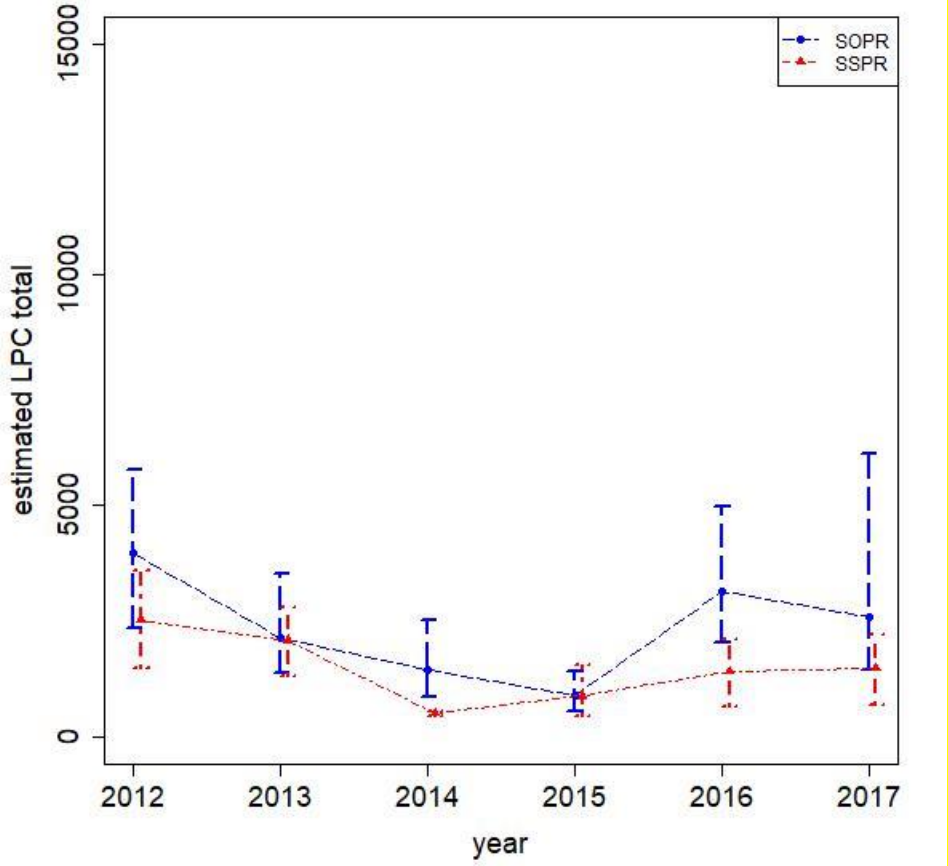

Figure 5b. Trends in estimated total population sizes of lesser prairie-chickens (LPC) in 2012, 2013, 2014, 2015, 2016, and 2017 with 90% confidence intervals in the SOPR = Shinnery Oak Prairie Region (eastern New Mexico, western Texas) and SSPR = Sand Sagebrush Prairie Region (southeastern Colorado, southwestern Kansas, Oklahoma Panhandle).

Estimated Trends in LPC Leks

We estimated a 55% increases in the density and abundance of LPC leks in 2017 relative to 2016 (Tables 11 and 12). The abundance of LPC leks was estimated to be:

3,470 (90% CI: 2248, 5393) in 2012;
2,228 (90% CI: 1425, 3195) in 2013;
2,719 (90% CI: 1824, 3951) in 2014;
1,713 (90% CI: 1066, 2391) in 2015;
2,053 (90% CI: 1159, 3090) in 2016; and
3,186 (90% CI: 2194, 4614) in 2017.

Table 11. 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, 2016, and 2017. Bootstrapped 90% confidence intervals were reported on the densities of lesser prairie-chicken leks per 100 km^2.

	Region				
Year	SOPR	SSPR	MGPR	SGPR	Overall
2012	1.58 (0.80, 5.28)	1.43 (0.56, 2.32)	2.51 (1.49, 3.64)	4.85 (1.79, 8.17)	**2.88 (1.86, 4.47)**
2013	0.79 (0.00, 1.75)	2.35 (2.03, 2.67)	1.08 (0.50, 1.57)	3.22 (1.18, 5.78)	**1.85 (1.18, 2.65)**
2014	0.97 (0.30, 2.39)	0.41 (0.00, 0.85)	2.19 (1.25, 3.19)	4.06 (2.08, 6.28)	**2.25 (1.51, 3.28)**
2015	0.29 (0.00, 0.77)	0.37 (0.00, 1.07)	2.15 (1.18, 3.04)	1.94 (0.76, 3.38)	**1.42 (0.88, 1.98)**
2016	0.80 (0.24, 1.51)	0.40 (0.00, 1.09)	1.65 (0.80, 2.45)	2.99 (0.89, 5.59)	**1.70 (0.96, 2.56)**
2017	1.11 (0.23, 3.79)	1.17 (0.38, 1.86)	2.35 (1.44, 3.27)	4.71 (2.47, 7.07)	**2.64 (1.82, 3.83)**

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 12. Estimated trends in abundances of lesser prairie-chicken leks by ecoregion and overall for 2012, 2013, 2014, 2015, 2016, and 2017. Bootstrapped 90% confidence intervals were reported on the abundances of lesser prairie-chicken leks.

	Region				
Year	SOPR	SSPR	MGPR	SGPR	Overall
2012	438 (223, 1462)	228 (89, 371)	993 (591, 1442)	1811 (667, 3051)	**3470 (2248, 5393)**
2013	219 (0, 485)	376 (324, 426)	429 (199, 623)	1204 (442, 2159)	**2228 (1425, 3195)**
2014	268 (82, 662)	65 (0, 136)	868 (493, 1264)	1518 (776, 2345)	**2719 (1824, 3951)**
2015	79 (0, 214)	58 (0, 171)	851 (469, 1203)	724 (284, 1261)	**1713 (1066, 2391)**
2016	221 (67, 419)	63 (0, 174)	652 (318, 969)	1117 (333, 2089)	**2053 (1159, 3090)**
2017	308 (65, 1049)	187 (60, 296)	931 (570, 1296)	1760 (923, 2640)	**3186 (2194, 4614)**

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)

ACKNOWLEDGEMENTS

The 2012 survey and reports were accomplished by the financial support of the Great Plains Landscape Conservation Cooperative, the Bureau of Land Management, and the National Fish and Wildlife Foundation through grants to the Western Association of Fish and Wildlife Agencies. Financial support for the 2013, 2014, 2015, 2016, and 2017 surveys and this report were provided by grants to the Western Association of Fish and Wildlife Agencies from the wildlife agencies of the states of Colorado, Kansas, New Mexico, Oklahoma, and Texas, the Bureau of Land Management, the National Fish and Wildlife Foundation, and various oil and gas companies and associations.

The recommended study design and methods were developed with the assistance of the following members of the Lesser Prairie-chicken Interstate Working Group: Bill Van Pelt, WAFWA Grassland Coordinator, Arizona Game and Fish Department; Jim Pitman, WAFWA; Sean Kyle, WAFWA, David Klute, Colorado Division of Parks and Wildlife*;* Grant Beauprez, New Mexico Department of Game and Fish; and Doug Schoeling, Oklahoma Department of Wildlife Conservation.

We wish to acknowledge our use of the ground survey data collected by the Kansas Department of Wildlife, Parks and Tourism and the initial analysis of these data provided by Michael Houts, WAFWA. We also wish to acknowledge the assistance of the aerial survey crew members and pilots.

LITERATURE CITED

Akaike, H. 1973. Information Theory as an Extension of the Maximum Likelihood Principle. Presented at the Second International Symposium on Information Theory. B. N. Petrov and F. Csaki, eds. Pp. 267-281.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. J. Thomas. 2001. An Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford, United Kingdom. 432 pp.

Johnson, D. H. 2002. The Importance of Replication in Wildlife Research. Journal of Wildlife Management 66: 919-932.

Kansas Applied Remote Sensing (KARS). 2015. Southern Great Plains Chat: A Decision Support System for Lesser Prairie-Chicken. Southern Great Plains Crucial Habitat Assessment Tool (SGP CHAT). KARS, Kansas Biological Survey, University of Kansas.

Kutner, M.H., Nachtsheim, C., Neter, J. and Li, W. 2005. Applied Linear Statistical Models. New York: Mc Graw-Hill.

Lesser Prairie-Chicken Interstate Working Group (LPCIWG). 2011. Estimated Occupied Range of the Lesser Prairie-Chicken. Updated January 2011. Available online at: https://catalog.data.gov/dataset/ estimated-occupied-range-of-the-lesser-prairie-chicken

Manly, B. F. J. 2006. Randomization, Bootstrap and Monte Carlo Methods in Biology. Third Edition. Chapman and Hall/CRC, Boca Raton, Florida.

McDonald, L., J. Griswold, T. Rintz, and G. Gardner. 2012. Results of the 2012 Range-Wide Survey of Lesser Prairie-Chickens (*Tympanuchus pallidicinctus*). Prepared for the Western Association of Fish and Wildlife Agencies (WAFWA), c/o. W. van Pelt, WAFWA Grassland Coordinator, Phoenix, Arizona. Prepared by Western EcoSystems Technology, Inc. (WEST), Laramie, Wyoming. September 14, 2012.

McDonald, L., G. Beauprez, G. Gardner, J. Griswold, C. Hagen, F. Hornsby, D. Klute, S. Kyle, J. Pitman, T. Rintz, D. Schoeling, and B. van Pelt. 2014a. Range-Wide Population Size of the Lesser Prairie-Chicken: 2012 and 2013. Wildlife Society Bulletin 38: 536-546.

McDonald, L., K. Adachi, T. Rintz, G. Gardner, and F. Hornsby. 2014b. Range-Wide Population Size of the Lesser Prairie-Chicken: 2012, 2013, and 2014. Prepared for the Western Association of Fish and Wildlife Agencies (WAFWA), c/o. B. van Pelt, WAFWA Grassland Coordinator, Phoenix, Arizona. Prepared by Western EcoSystems Technology, Inc. (WEST), Laramie, Wyoming. July 31, 2014.

McDonald, L., K. Nasman, T. Rintz, F. Hornsby, and G. Gardner. 2016. Range-Wide Population Size of the Lesser Prairie-Chicken: 2012, 2013, 2014, 2015 and 2016. Prepared for the Western Association of Fish and Wildlife Agencies (WAFWA), c/o. B. van Pelt, WAFWA Grassland Coordinator, Phoenix, Arizona. Prepared by Western EcoSystems Technology, Inc. (WEST), Laramie, Wyoming. July 21, 2016.

McKelvey, K. S., Pearson, D.E. 2001. Population Estimation with Sparse Data: The Role of Estimators Versus Indices Revisited. Canadian Journal of Zoology 79: 1754-1765.

R Development Core Team. 2012. The R Project for Statistical Computing. R version 2.14.2. Institute for Statistics and Mathematics Resources Web Page, Institute for Statistics and Mathematics, Wein, Austria. https://www.r-project.org/

Rabe, M. J., S. S. Rosenstock, and J.C. deVos, Jr. 2002. Review of Big-Game Survey Methods Used by Wildlife Agencies of the Western United States. Wildlife Society Bulletin 30: 46-52.

Stevens, J., Don L. and A. R. Olsen. 2004. Spatially Balanced Sampling of Natural Resources. Journal of the American Statistical Association 99(465): 262-278. doi: 10.1198/016214504000000250.

Appendix A. Estimated Densities and Abundances of GPC and HPC

Densities (Table A-1 and A-2) 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:

33,723 (90% CI: 23786, 47165) in 2012;
15,762 (90% CI: 10574, 20773) in 2013;
17,113 (90% CI: 11318, 22810) in 2014;
23,649 (90% CI: 16522, 30120) in 2015;
28,978 (90% CI: 19940, 39867) in 2016; and
36,279 (90% CI: 26720, 46543) in 2017.

An increase of 7,301 GPC was observed from 2016 to 2017; however, this increase was not statistically significant (80% CI: -3413, 17272; Table A-4).

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

339 (90% CI: 213, 478) in 2012;
126 (90% CI: 52, 210) in 2013;
96 (90% CI: 57, 137) in 2014;
254 (90% CI: 147, 375) in 2015;
298 (90% CI: 166, 437) in 2016; and
432 (90% CI: 262, 624) in 2017.

Table A-1. Estimates of greater prairie-chicken (GPC) and hybrid prairie chicken (HPC) densities per 100 km^2 (39 mi^2) for 2012, 2013, 2014, 2015, 2016, and 2017 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.

Year	GPC	HPC
2012	90.29 (63.68, 126.28)	0.91 (0.57, 1.28)
2013	42.20 (28.31, 55.62)	0.34 (0.14, 0.56)
2014	45.82 (30.30, 61.07)	0.26 (0.15, 0.37)
2015	63.32 (44.24, 80.64)	0.68 (0.39, 1.00)
2016	77.59 (53.39, 106.74)	0.80 (0.44, 1.17)
2017	97.13 (71.54, 124.61)	1.16 (0.70, 1.67)

Table A-2. Estimates of greater prairie-chicken (GPC) and hybrid prairie-chicken (HPC) population sizes for 2012, 2013, 2014, 2015, 2016, and 2017 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	33723 (23786, 47165)	339 (213, 478)
2013	15762 (10574, 20773)	126 (52, 210)
2014	17113 (11318, 22810)	96 (57, 137)
2015	23649 (16522, 30120)	254 (147, 375)
2016	28978 (19940, 39867)	298 (166, 437)
2017	36279 (26720, 46543)	432 (262, 624)

Table A-3. 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, 2016, and 2017 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.

Year	Density	Abundance
2012	5.83 (3.84, 8.72)	2175.65 (1434.31, 3255.83)
2013	4.45 (2.75, 6.10)	1660.31 (1026.08, 2276.81)
2014	5.18 (3.3, 7.12)	1934.00 (1232.23, 2661.09)
2015	4.01 (2.24, 5.93)	1498.15 (835.92, 2213.03)
2016	7.88 (5.00, 10.99)	2944.05 (1866.09, 4106.38)
2017	6.59 (4.43, 8.77)	2460.35 (1655.87, 3277.02)

Table A-4. Estimated differences in population estimates for greater prairie-chickens between years with bootstrapped 80% and 90% confidence intervals on the differences.

Δ Year	Estimate	80% Confidence Interval	90% Confidence Interval
2013 minus 2012	-17961	-29688, -9805	-32661, -7758
2014 minus 2013	1351	-4060, 7454	-5815, 9020
2015 minus 2014	6536	-516, 13045	-2633, 14923
2016 minus 2015	5329	-3465, 15323	-5551, 18314
2017 minus 2016	7301	-3413, 17272	-6297, 19858

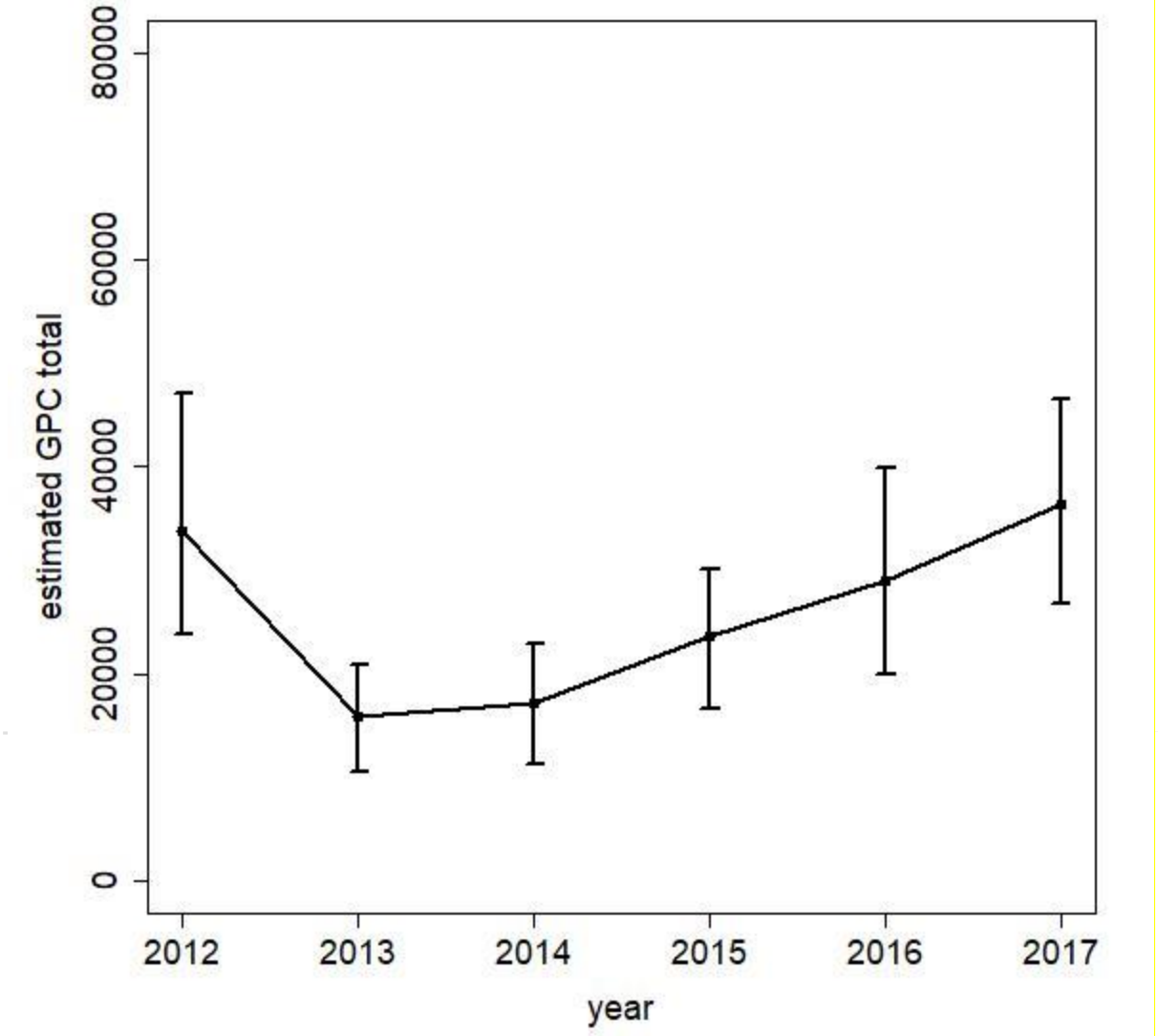

Figure A-1. Estimated population sizes of greater prairie-chickens (GPC) with 90% confidence intervals in 2012, 2013, 2014, 2015, 2016, and 2017 in the Short Grass CRP Prairie Region (northwestern Kansas).

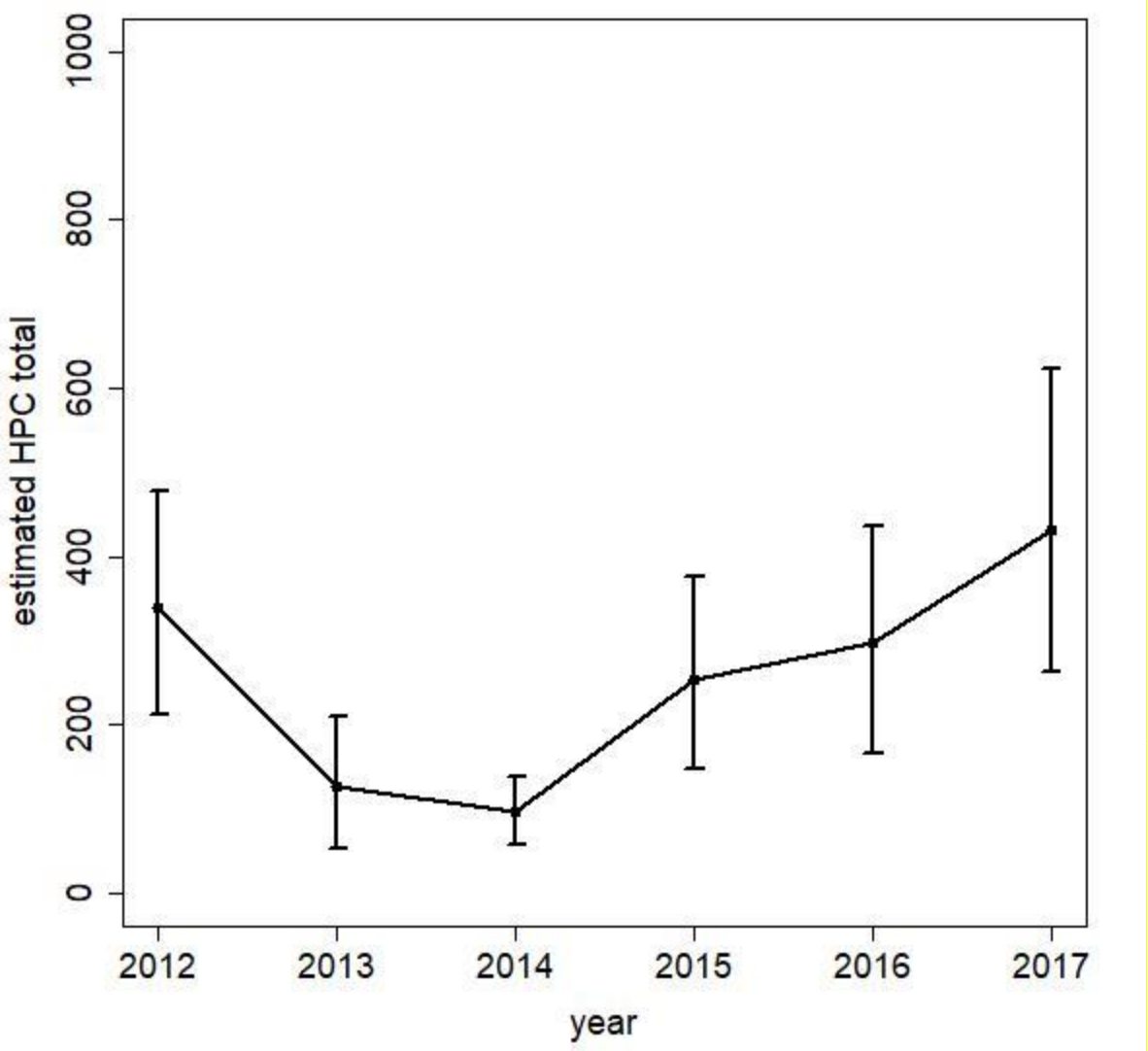

Figure A-2. Estimated population sizes of hybrid prairie-chickens (HPC) with 90% confidence intervals in 2012, 2013, 2014, 2015, 2016, and 2017 in the Short Grass CRP Prairie Region (northwestern Kansas).