Final Technical Report

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EXECUTIVE SUMMARY

My 2.5-yr Master's project accomplished the objectives of estimating lesser prairie-chicken (LPC) lek density and abundance in the Texas occupied range and modeling anthropogenic and landscape features associated with lek density by flying helicopter lek surveys for 2 field seasons and employing a line-transect distance sampling method. This project was important for several reasons. Firstly, wildlife managers and biologists have traditionally monitored LPC populations with road-based surveys that may result in biased estimates and do not provide access to privately-owned or remote property. From my aerial surveys and distance sampling, I was able to provide accurate density and abundance estimates, as well as new leks and I detected LPCs outside the occupied range. Secondly, recent research has indicated that energy development has the potential to impact LPCs through avoidance of tall structures, increased mortality from raptors perching on transmission lines, disturbance to nesting hens, and habitat loss/fragmentation. Given the potential wind energy development in the Texas Panhandle, spatial models of current anthropogenic and vegetative features (such as transmission lines, roads, and percent native grassland) influencing lek density were needed. This information provided wildlife managers and wind energy developers in Texas with guidelines for how change in landscape features could impact LPCs. Lastly, LPC populations have faced range-wide declines over the last century and they are currently listed as a candidate species under the Endangered Species Act. I was able to provide timely information on LPC populations in Texas that will be used during the listing process.

Line-transect distance sampling is a common technique used to estimate density and abundance of wildlife populations. Aerial surveys allow a larger area to be sampled in less time and access to remote or privately-owned land and helicopters in particular allow for reduced air speeds, sharper and safer turns between transects, and better vision directly below the aircraft as compared to fixed-wing aircraft. A recent Texas Tech graduate student evaluated the use of helicopters for surveying LPC leks and he found that lek detectability from an R-22 helicopter (2 observers) was 72.3% and there was minimal disturbance to the LPCs (McRoberts et al. 2011). He also found that the use of R-22 helicopters was a cost-effective technique for finding new leks as compared to driving roads and listening for leks. I followed the survey protocol of McRoberts et al. (2011) (i.e., transects spaced 400-m apart, flight altitude of 15 m above ground-level, target speed of 60 km/hr, survey between sunrise until ≈2.5 hr post-sunrise) and also concluded that the use of an R-22 helicopter is an efficient and effective method for monitoring LPC populations. My surveys cost $350/hr of flight time (for an average of 3hr of flight time per survey) plus gas mileage for the pilots, myself, and technicians. This may cost more than driving county roads for 3 hr listening for leks, but I found new leks that had not been previously detected by other graduate students or biologists and I was able to cover more area in less time with fewer personnel.

Spatial models relate landscape features, such as percent grassland and road density, with animal abundance, density, or occurrence. These models can identify suitable habitat and predict species occurrence or abundance. In particular, hierarchical distance sampling models rely on data collected by distance sampling methods and then relate spatial covariates to animal density or abundance through regression techniques. These methods model spatial variation associated with density or abundance and the

resulting estimates are often more precise. These methods also estimate a detection probability for the sampled population, which many other spatial techniques, such as occupancy modeling, do not.

INTRODUCTION

Wind power has increased greatly in the past 30 years, especially in the Great Plains. While it is considered a more environmentally-friendly source of energy, wind energy production still has the potential to negatively impact wildlife and wildlife habitat. West Texas has been identified as a major source for future wind power and 2 Competitive Renewable Energy Zones (CREZ) have been identified in the Texas Panhandle region. The Panhandle region is also an important stronghold for lesser prairie-chickens (LPC) and as with many other grassland birds, LPCs have experienced population declines in the Southern Great Plains. This loss is mostly due to conversion of native grassland to cropland, extensive grazing, invasion of woody plants, and disturbance from energy development. Thus, the main objectives of this study were to determine the current density and distribution of LPC leks within the Texas Panhandle in relation to potential high priority wind energy development areas and to model habitat and anthropogenic characteristics associated with lek density.

METHODS

To estimate lek density and abundance in the Texas Panhandle, I used a line transect-based distance sampling from a Robinson 22 helicopter (hereafter, R22) to locate LPC leks. I conducted flights in spring 2010 and 2011 from sunrise to ≈2.5 hr post-sunrise to coincide with peak LPC breeding activity. The surveys were flown at ≈15 m altitude and ≈60 km/hr, except when pilots had to adjust helicopter speed or height for safety concerns. The transects were flown from east to west in each survey block to take advantage of early morning sunlight. The surveys were occasionally shortened and completed transects on subsequent days in the event of unexpected inclement weather. When LPCs or leks were detected during a survey, the pilot flew over the detection to mark it with a waypoint and get an accurate count of the number of LPCs. I ground-truthed >50% of detections to verify breeding activity and obtain a more accurate LPC count and lek location.

I used the LPC range map developed by the interstate lesser prairie-chicken working group as our sampling frame. I divided the sampling frame into 285 survey blocks (5,184 ha each; Figure 1) and also divided the sampling frame into 2 portions for surveys during 2010 and 2011 (Figure 2). Each survey block was 7.2 × 7.2 km. These dimensions allowed for 18 400-m wide transects 7.2 km in length for each survey block. I divided the sampling frame into 4 separate strata in order to group similar sampling units and prioritize sampling areas. I ranked the 4 strata based on the greatest potential for wind energy development to impact LPC lek distribution.

The first stratum represented the portion of the study area which had the highest risk or greatest potential for wind energy development to impact LPC lek distribution (Table 1). This stratum included portions of the study area where leks were most likely to occur and where wind energy development was most likely to occur. This stratum included survey blocks that were within a Competitive Renewable Energy Zone (CREZ) and had >50% native grassland or Conservation Reserve Program (CRP)/idle cropland. The highest priority ranking of 1 was assigned to this stratum and as such, this stratum received more survey effort than each of the other strata. The second stratum included survey blocks that had >50% native grassland or CRP/idle cropland, but were not within a CREZ (Table 1). This stratum was issued a priority ranking of 2 and received slightly less survey effort than the first stratum, since the survey blocks were outside a CREZ and wind energy development was less likely. The third stratum included survey blocks that were not within a CREZ and composed of >50% shrubland. This stratum was issued a priority ranking of 3, since it was lower quality LPC habitat than the first 2 strata and not within a CREZ. The fourth received the least amount of survey effort with a priority ranking of 4. It included any survey blocks that were composed of >75% of a combination of native grassland-shrubland-grain field (30–50% native grassland, ≤50% shrubland, and >0% grainfield), regardless of CREZ association. This stratum had the least potential for wind energy development to impact LPC lek distribution, since it was comprised of lower quality LPC habitat.

I separated my data into 2 groups for analysis for each region: detections that were confirmed leks and all detections (i.e., lek and non-lek detections). To analyze the leks-only dataset, the individual lek was my sampling unit. For the all-detections dataset, each detection was a sampling unit and I analyzed my observations as groups of LPCs. I used the multiple covariate and conventional distance sampling engines in program DISTANCE 6.0 (Thomas et al. 2010) to analyze my data for both field seasons. For the leks-only dataset, my covariates included lek size, lek type, and survey date. We included lek size and lek type (i.e., man-made or natural) in the models because McRoberts et al. (2011*a*) determined that lek detectability was greater for man-made leks and larger leks. I included a quadratic term for survey date among my covariates because lek attendance peaks in the middle of the spring and the birds are less likely to flush during this period (McRoberts et al. 2011). For the all-detections dataset, my covariates included lek confirmation, detection type, and survey date. Detections that were confirmed leks were assigned a 1 and non-lek detections were assigned a 0. For detection type, detections observed in a manipulated landscape (e.g., oil pad, grain field, or next to a stock tank) were assigned a 1 and detections observed in a natural landscape (e.g., grassland or shrubland) were assigned a 0. I examined several key function and series expansion combinations as recommended by Buckland et al. (2001) to determine which model(s) best described detectability. I model averaged as needed among the competing models ($\Delta \mathrm{AIC}_c \leq 2$) to account for model selection uncertainty and estimate lek density and abundance for the sampling frame.

To model landscape characteristics and lek density, I selected11 vegetative and anthropogenic covariates that could influence lek density based on previous literature and my research objectives. I divided each survey block into 4, 12.96-km^2 quadrats and calculated landscape covariates for each quadrat. I developed 3 a priori model sets (Table 4). My vegetation model set included percent grassland (i.e., composed of native grassland, CRP, or idle cropland and comprising >80% of the total vegetation in a patch), percent shrubland (i.e., shrubs <5 m tall and comprising ≥20% of the total vegetation in a patch), percent grain field (e.g., corn, winter wheat, or grain sorghum), average grassland patch size (km^2), average shrubland patch size (km^2), and edge density of all patches (km/km^2). I also included a quadratic term with percent grassland and percent shrubland because previous literature has suggested that optimum LPC habitat consists of native grassland interspersed with some shrubland. My road model set included paved road density (km/km2), unpaved road density (km/km^2), and all road density (km/km^2). My energy model set included density of transmission lines ≥69 kv (km/km^2) and active oil and gas well density (wells/km^2). I did not include variable(s) in the same model which had a pair-wise correlation ≥ 0.50 to avoid problems with multicollinearity.

I analyzed my data using the package "unmarked" (Fiske and Chandler 2011) in program R (R Development Core Team 2011) which implements the multinomial-Poisson mixture model (hierarchical distance sampling; Royle et al. 2004). I binned the distance data into 7 intervals (e.g., 0–35 m, 35–50 m, 50–70 m, 70–90 m, 90–120 m, 120–150 m, 150–179 m) and used the half-normal model to describe the detection function. The 3 a priori model sets (vegetative covariates, road covariates, and energy infrastructure covariates) were used to model the lek density relationships. For the vegetation model set, I did not allow percent grassland, percent shrubland, average grass patch size, or average shrub patch size to appear together in the same model to reduce the complexity and avoid multicollinearity among the covariates. I determined competitive models as a model with ΔAIC ≤ 2 and excluded models with uninformative parameters. I combined the top models from each set in a final model set along with a null model (Table 5). I evaluated goodness-of-fit of the best model(s) using a Freeman-Tukey chi-squared procedure with 1000 bootstrap replicates (Fiske and Chandler 2011). I created a lek density map in ArcGIS for each 12.96-km^2 quadrat covering the LPC range in Texas based on the model predictions. I estimated the total number of leks for the sampling frame and used the parametric procedure with 1,000 bootstrap replicates to estimate uncertainty in the lek abundance estimate (Fiske and Chandler 2011).

RESULTS

I surveyed 105 blocks during spring 2010 (northeast region) and 103 blocks during spring 2011(southwest region). I surveyed a total distance of 26,810.9 km and covered 88.6% of the sampling frame and 61.6% of the Texas LPC occupied range. I detected LPCs within 160.5 m of transect in the northeast and 178.3 m in the southwest. I detected 66 LPC groups in the northeast; 35 were confirmed as leks, 10 were known leks, 1 detection was outside of the current LPC range in Texas, and 13 detections were within a CREZ. In the southwest, I detected 109 LPC groups; 61 were confirmed as leks, 15 were known leks, 4 detections were outside of the current LPC range, and 10 detections were within a CREZ. The average number of LPCs observed attending leks was 4.5 (SE = 0.670) and 5.2 (SE = 0.525) LPCs in the northeast and southwest, respectively.

I found 1 model that was competitive for the leks-only dataset, the half-normal key function with lek size and lek type included as covariates (AIC$_c$ weight [w_i] = 0.235). Detectability was greater for natural leks and larger lek sizes. I found 2 competitive, parsimonious models for the all-detections dataset, the half-normal key function and cosine adjustment term (w_i = 0.211) and the hazard rate key function with no adjustment (w_i = 0.203). My lek and LPC density estimates for the sampling frame were 2.0 leks/100 km² (90% CI = 1.4–2.7 leks/100 km²) and 12.3 LPCs/100 km² (90% CI = 8.5–

17.9 LPCs/100 km²), respectively (Table 2). I estimated 1.0 leks/100 km² (90% CI = 0.6–1.7 leks/100 km²) for the first stratum and 2.4 leks/100 km² (90% CI = 1.5–3.8 leks/100 km²), 2.7 leks/100 km² (90% CI = 1.6–4.3 leks/100 km²), and 2.7 leks/100 km² (90% CI = 1.3–5.7 leks/100 km²) for the second, third, and fourth strata, respectively. My lek and LPC abundance estimates for the sampling frame were 293.6 leks (90% CI = 213.9–403.0 leks) and 1,822.4 LPCs (90% CI = 1,253.7–2,649.1 LPCs).

For the spatial modeling, I found 2 competitive models from the vegetation set: percent shrubland (AIC = 945.098, AIC weight [w_i] = 0.487) and percent shrubland + percent grain field (AIC = 946.558, w_i = 0.235; Table 4). There was a quadratic relationship between lek density and percent shrubland, in which lek density peaked when ≈50% of a quadrat was composed of shrubland patches (Fig. 3). The model containing percent grain field was ≤2 ΔAIC units of the top-ranked model and the parameter estimate did not differ from 0 for percent grain field (β = 0.689, SE = 0.917, P = 0.453); therefore, it was probably an uninformative parameter.

I found 2 competitive models from the road model set: paved road density + unpaved road density (AIC = 945.134, w_i = 0.716) and unpaved road density (AIC = 946.988, w_i = 0.284; Table 4). These 2 models were ≤2 ΔAIC units of each other; however both covariates were significant at α = 0.15 and therefore, both were informative. Unpaved road density was inversely related to lek density in the model with and without paved road density (β = –0.316, SE = 0.118, P = 0.008; β = –0.307, SE = 0.118, P = 0.010, respectively; Fig. 3) and paved road density was also inversely related to lek density (β = –1.228, SE = 0.641, P = 0.056).

I found 2 competitive models from the energy model set: transmission line density (AIC = 950.773, w_i = 0.636) and transmission line density + active oil and gas well density (AIC = 9552.558, w_i = 0.260; Table 4). However, the model that included active oil and gas well density was ≤2 ΔAIC units of the top- ranked model and the parameter estimate did not differ from 0 (β = 0.018, SE = 0.037, P = 0.633) indicating that model was likely spurious. The best model indicated an inverse relationship between lek density and transmission line density (β = –0.247, SE = 0.144, P = 0.086).

After combining top models from each model set, the most competitive model included percent shrubland + paved road density + unpaved road density (AIC= 938.926, w_i = 0.826; Table 5). Goodness of fit test indicated good model fit (χ^2 = 0.864; P = 0.477). Based on this model, I estimated 248.5 leks (*cv* = 0.136) in the sampling frame and predicted higher lek density in the northeast and southwest regions of the Panhandle and lower lek density in the central region of the Panhandle (Fig. 4).

DISCUSSION

I conducted the first randomized line-transect–based survey of the LPC range in Texas to provide lek density and population estimates. I detected 71 new leks, 5 LPC observations outside the occupied state range, and 23 observations within 1 of the 2 CREZs. These new leks and observations outside the occupied range probably would not have been detected by traditional road-based lek surveys. I also provided estimates of precision for the density estimates, which many previous population monitoring efforts have not done (McRoberts et al. 2011).

Lek size and lek type were the most influential covariates on lek detectability. McRoberts et al. (2011) also observed an increase in lek detectability with lek size, but they observed a higher detection probability for man-made leks, where my lek detectability was greater for natural leks. It seems intuitive that displaying LPCs would be easier to spot on manipulated landscapes void of vegetation, such as abandoned oil pads, and that windmills or stock tanks would provide a visual cue for observers looking for leks (McRoberts et al. 2011). However, Schroeder et al. (1992) did not detect 2 leks near a power line and windmill, and they concluded that lek detectability could be negatively influenced by landscape features that distract observers.

The abundance and density estimates from the literature differ from my estimates due to the techniques used to survey and estimate density and abundance. I accounted for incomplete detectability within my sampling frame and provided probabilistic sampling of potential habitat. In contrast, other estimates are derived from convenience-based sampling of higher-quality habitat that do not account for undetected individuals within the sampling frame. For example, Olawsky and Smith (1991) estimated LPC densities in the southwest Texas Panhandle and southeastern New Mexico that were >150 times more than my density estimates. They used a line-transect procedure to estimate density within their study area, but transects were restricted to roads and their surveys were conducted in some of the highest-quality LPC habitat. Davis et al. (2008) estimated an abundance estimate of 15,730 LPCs (range = 6,077–24,132 LPCs) for the Texas occupied range, but LPC density was assumed constant across the entire range for the state and their study areas were also higher-quality LPC habitat. In contrast, Hamilton and Manzer (2011) used point count surveys with distance sampling to estimate sharp-tailed grouse (*T. phasianellus*) lek density in east-central Alberta. Their regional density estimate was comparable to ours (2.6 leks/100 km^2; 95% CI=1.6–4.3 leks/100km^2).

The conservation status of several prairie grouse populations requires more effective population monitoring, such as aerial lek surveys, and McRoberts et al. (2011) and Timmer (2012) demonstrate the effectiveness of such surveys. Lek detectability from aerial surveys can be improved by using helicopters instead of fixed-winged aircraft and restricting surveys to clear sunny mornings when visibility is greatest. I further suggest not flying when wind speeds are >32 km/hr because it is more difficult to control aircraft speed along transect and navigating turns over tall structures is more dangerous. Schroeder et al. (1992) observed a decrease in lek detection with an increase in helicopter speed, so flying transects ≤60 km/hr should improve detectability. I observed LPCs flushing more frequently later in the morning in response to the helicopter, so restricting surveys to ≈2.5 hr post-sunrise should minimize this disturbance response.

I recommend a few suggestions to ensure quality data and accurate estimates when distance sampling and helicopter surveys are implemented to estimate lek density and abundance. Critical assumptions must be met, such as complete detectability on the transect (Buckland et al. 2001), which is possible with a helicopter. It is also important to mark where the birds flushed from and avoid re-counting flushed birds further on the transect (Buckland et al. 2001). Observers can use rangefinders to measure distances to detections and clinometers to measure sighting angles, so distances can be estimated with trigonometry (Buckland et al. 2001). However, I found that flying off-transect to a detected lek was more effective for obtaining an accurate location and count of LPCs at each detection. The distance data should be examined while the data are being collected so problems, such as heaping and spiking near the transect, can be corrected early on (Buckland et al. 2001). Lastly, I included covariates that could have affected lek detectability, such as lek size, in order to improve precision of our density estimates.

With the spatial models, I learned that percent of the landscape composed of shrubland patches (i.e., shrubs <5 m tall comprising ≥20% of the total vegetation) was a significant predictor of lek density. Lek density peaked when ≈50% of the landscape was composed of shrubland patches (Fig. 3). Low-growing shrubs are an important component of LPC habitat for nesting and brood cover, a seasonal source of insects and mast, and thermal cover (Applegate and Riley 1998, Pitman et al. 2005, Bell et al. 2010). For example, Applegate and Riley (1998) recommended 30–45% shrub composition for nesting, brood-rearing, and fall and winter foraging of LPCs. Woodward et al. (2001) found an association between declining LPC populations in New Mexico, Oklahoma, and Texas and less shrub composition and a greater rate in loss of shrubland. Radio-marked LPCs in a New Mexico and Oklahoma study occupied sites with a greater density of shrubs and had a higher survival rate for sites with >20% shrub cover (Patten et al. 2005). Bell et al. (2010) similarly observed broods selecting for sites with greater shrub canopy cover in New Mexico.

Both paved road density and unpaved road density were included in our top model and both indicated an inverse relationship to lek density (Fig. 3). According to Pruett et al. (2009), highways do not appear to impede LPC movement, but the noise and traffic associated with highways may cause LPCs to avoid surrounding habitat. Niche modeling of leks in Kansas showed an increase in habitat quality with increasing distance from a highway (Jarnevich and Laubhan 2011), while a different study in Kansas showed an avoidance of paved roads by marked hens (Hagen et al. 2011). Nests in Kansas were also located further than expected from paved and high-traffic graveled roads and distance to 2-track or ungraded service road was a significant predictor of nest success (Pitman et al. 2005). Lesser prairie-chickens may avoid unpaved roads due to disturbance from agricultural or oil and gas traffic. In a natural gas field development region in Wyoming, Holloran (2005) observed a decline in greater sage-grouse (*Centrocercus urophasianus*) lek attendance with increasing traffic volume on main haul roads. In a separate study, Lyon and Anderson (2003) found sage-grouse hens nested further from disturbed leks (i.e., leks within 3 km of a natural gas well pad or road) than undisturbed leks, possibly due to an avoidance of vehicular traffic associated with the gas wells. Several studies have documented an avoidance of prairie grouse to oil or gas wells (e.g., Pitman 2005, Hagen et al. 2011), but the activity associated with wells or roads may be the reason for avoidance behavior rather than the actual feature. Therefore, LPCs in my sampling frame may be responding to the vehicular traffic associated with oil or gas activity given that well density was not a significant predictor of lek density in this study.

Transmission line density was not included in my top model, but it was a significant predictor of lek density and indicated an inverse relationship to lek density. Other studies have documented an avoidance of transmission lines by prairie grouse. In an Oklahoma study, radio-marked LPCs avoided a power line by ≥100 m and few nests were found within 2 km of the power line (Pruett 2009). Hagen et al. (2011) examined the influence of anthropogenic features, such as transmission lines and oil or gas wells on hen habitat use and transmission lines were 1 of the most avoided anthropogenic features. Two separate studies in Kansas both documented avoidance of transmission lines and an increase in nesting or lek habitat quality with increasing distance from transmission line (Hagen et al. 2011, Jarnevich and Laubhan 2011).

Based on my spatial models, higher lek densities in Texas could be achieved by maintaining ≈50% of the landscape as shrubland patches. This can be achieved through habitat management techniques, such as prescribed burns or light grazing, which create a heterogeneous habitat of shrubs, grasses, and forbs. The greatest predicted lek density estimates occurred in Gray, Hemphill, and Lipscomb counties in the northeast Panhandle and Bailey, Cochran, and Yoakum counties in the southwest Panhandle (Fig. 4). Given that most of the leks were also detected in these counties, the construction or frequent use of roads for agriculture, oil or natural gas development, or other purposes, should be avoided in these areas to reduce negative impacts on LPCs. The construction of transmission lines for energy development should also be avoided in these areas. Regions in which predicted lek density is low (e.g., Carson county) may be better suited for energy development if it is imminent or habitat improvement projects to satisfy LPC management objectives. Wildlife managers and energy developers can also use these models to predict how lek density may change in response to habitat management strategies or activities promoting the construction or use of roads within the Texas occupied range. This information will be necessary if LPCs are federally-listed.

My study is unique in that I set up a formal study to provide spatial coverage of the entire sampling frame and used probabilistic sampling for the occupied LPC range in Texas. I accounted for incomplete detection of leks by modeling a detection function and was able to extrapolate the relationship between lek abundance and spatial covariates to the entire range in Texas (Buckland et al. 2001). In contrast, the niche models predicting lek occurrence in Kansas are not based on a formal statistical design which can introduce sampling biases (Jarnevich and Laubhan 2011). For example, most lek locations used were sampled from roads only. My study also highlights the need for similar modeling efforts of landscape features and lek density throughout the 5-state LPC range. My best model may not accurately predict LPC lek density in Colorado, Kansas, New Mexico, or Oklahoma because the type and intensity of anthropogenic activity and its impact on LPCs may vary greatly in other portions of the LPC range. Further, grazing intensity, fire frequency, soil types, local weather, and other factors can cause structural and compositional differences in vegetation throughout the LPC range. A regional habitat-priority map for LPCs throughout their range that is based on accurate models of lek density and landscape features is currently lacking. A consistent and detailed landcover layer for the entire LPC range is also lacking and would improve modeling efforts. Additionally, modeling lek density with change in habitat composition or anthropogenic features over time and examining spatially-explicit covariates at multiple scales could improve prediction of predict lek density in Texas and other regions (Woodward et al. 2001).

COMPUTER MODELING

I used the multiple covariate and conventional distance sampling engines in program DISTANCE 6.0 (Thomas et al. 2010) to estimate density and abundance for my sampling frame. Density estimates for a study area are derived by estimating detection functions, which account for animals not detected in the survey area. Detection is modeled as a function of distance from detected objects to randomly-positioned transects or points and other covariates. Critical assumptions of distance sampling that need to be met: objects are detected on the transect line with certainty, objects are detected at their initial location, detected objects are independent, and distance measurements are recorded without error. For a full description of the mathematical modeling and more detailed theory behind distance sampling, see Buckland et al. (2001). For more information regarding program DISTANCE, see Thomas et al. (2010).

I used the package "unmarked" in program R (Fiske and Chandler 2011, R Development Core Team 2011) to model hierarchical relationships between lek abundance and landscape features in my sampling frame. I analyzed my spatial data using the "distsamp" function of package "unmarked" in Program R, which implements the multinomial-Poisson mixture model. I evaluated goodness-of-fit of the best spatial model(s) using the "parboot" function, which implements a Freeman-Tukey chi-squared procedure with 1000 bootstrap replicates. This method is a form of distance sampling (hierarchical distance sampling) in which models incorporate a detection function to estimate density and then relate landscape features to density; the same assumptions need to be met as with regular distance sampling. For a full description of the mathematical modeling and more detailed theory behind hierarchical distance sampling, see Royle et al. (2004). For more detailed information on the package "unmarked" and related functions, see Fiske and Chandler (2011).

ACCOMPLISHMENTS

My initial objectives were to determine the current density and distribution of LPC leks within the Texas Panhandle and to model habitat and anthropogenic landscape characteristics associated with lek density. To accomplish these objectives, my principle investigators and I set the following goals, which were met and completed by June 30, 2012 (the end of the final quarter for this project):

1. Recruitment of MS student and arrangement of logistics
2. Set up study area and conduct LPC aerial surveys
3. Preliminary data analysis
4. Spatial data analysis
5. Continue aerial surveys
6. Complete aerial surveys and ground-truthing
7. Data analysis
8. Spatial analysis
9. Complete spatial analysis and final reporting

For project deliverables, I gave an informal presentation of project goals, objectives, and methodology to TPWD personnel on October 12, 2009 (group of 6), April 1, 2010 (conference call with group of 8), and May 9, 2010 (conference call with group of 7). I gave a presentation to Texas Parks and Wildlife Executives (group of 15) on June 8, 2010 discussing LPC research at Texas Tech University which includes this project. I gave a brief web presentation at a NWCC Grassland Shrub Steppe Species Collaborative phone conference on August 27, 2010. A short article on LPC aerial surveys at TTU was featured in the winter 2010 edition of The Wildlife Professional. I attended the Playa Lakes Joint Venture/Western Governors' Association meeting on LPCs and occupancy modeling in Wichita, Kansas January 18th and 19th, 2011. I attended the Texas Chapter for The Wildlife Society in San Antonio, Texas February 18th and 19th, 2011 and gave a formal presentation at this meeting. I attended the 29th meeting of the Prairie Grouse Technical Council in Hayes, Kansas October 4-6, 2011 and presented at this meeting. I attended the Texas Chapter for The Wildlife Society in Fort Worth, Texas and presented on my lek density and abundance estimates. I also defended my research on March 23, 2012 in Lubbock, Texas to committee members and other students and faculty in the Department of Natural Resource Management. Research for this project has also been highlighted in local news papers and local news broadcasts. I am currently finalizing two of my thesis chapters to submit to wildlife journals for publication.

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Table 1. Sampling stratification and survey effort allocation for lesser prairie-chicken lek surveys in the Texas Panhandle for spring 2010 and 2011.

Stratum [a]	CREZ [b]	Habitat Type	Weighting Factor [c] (f_i)	Allocation of Survey Blocks [c]	Actual Number of Blocks Surveyed [d]
Priority 1	Yes	≥50% Grassland	0.4	72	76
Priority 2	No	≥50% Grassland	0.3	54	73
Priority 3	No	>50% Shrubland	0.2	36	39
Priority 4	No	≥75% Grassland/ shrubland/grain field mix	0.1	18	20

[a] Lower numbers are a greater priority.

[b] Is the survey block in a Competitive Renewable Energy Zone (CREZ).

[c] N = 180 blocks for 2010 and 2011.

[d] N = 208 blocks for 2010 and 2011.

Table 2. Density and abundance estimates for 2 datasets from lesser prairie-chicken (LPC) aerial surveys in the Texas Panhandle in spring 2010 & 2011.

Dataset	D [a]	CI [b]	N [c]	CI
Leks-Only:				
Stratum1 [d]	1.0	0.6–1.7	51.3	30.0–87.9
Stratum 2 [e]	2.5	1.6–3.9	161.0	102.5–252.9
Stratum 3 [f]	2.7	1.6–4.5	55.1	33.6–90.3
Stratum 4 [g]	2.8	1.3–5.9	34.5	16.3–72.8
Range-wide [h]	2.0	1.5–2.8	301.9	219.4–415.4
All Detections:				
Stratum 1	7.0	4.1–12.0	352.6	205.5–604.8
Stratum 2	14.4	8.9–23.1	931.6	579.3–1,498.0
Stratum 3	17.1	9.6–30.5	346.2	194.1–617.6
Stratum 4	15.4	7.5–31.9	192.0	93.0–396.4
Range-wide	12.3	8.5–17.9	1,822.4	1,253.7–2,649.1

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[a] Density estimates (D) measured in leks/100 km² for the leks-only datasets and LPCs/100 km² for the all-detections datasets.

[b] Ninety percent confidence intervals for density and abundance estimates.

[c] Abundance estimates (N) measured in leks for the leks-only dataset and LPCs for the all-detections dataset.

[d] Stratum 1 includes survey blocks within a Competitive Renewable Energy Zone (CREZ) and composed of ≥50% grassland.

[e] Stratum 2 includes survey blocks not within a CREZ and composed of ≥50% grassland.

[f] Stratum 3 includes survey blocks not within a CREZ and composed of >50% shrubland.

[g] Stratum 4 includes survey blocks not within a CREZ and composed of ≥75% grassland/shrubland/grain field mix.

[h] Includes the estimated LPC range for Texas.

Table 3. Landscape covariates included in spatial models for predicting lesser prairie-chicken lek density in Texas and a description of each covariate.

Covariate [a]	Description
GRASS	Percent of the quadrat composed of grassland patches (native grassland, CRP, or idle cropland comprising >80% of the total vegetation) including a quadratic term.
SHRUB	Percent of the quadrat composed of shrubland patches (shrubs <5 m tall comprising ≥20% of the total vegetation) including a quadratic term.
AGP	Average grassland patch size (km^2).
ASP	Average shrubland patch size (km^2).
GRAIN	Percent of the quadrat composed of grain field patches (e.g., winter wheat, corn, or grain sorghum).
EDGE	Edge density for all landcover patches (km/km^2).
HWY	Paved road density (km/km^2).
DIRT	Unpaved road density (km/km^2).
ALL_ROADS	Paved and unpaved road density (km/km^2).
TRANSM	Transmission line (>69 kv) density (km/km^2).
WELL	Active oil and gas well density ($wells/km^2$).

[a] Each covariate estimated for a 12.96-km^2 quadrat.

Table 4. Three model sets of hierarchical distance sampling models predicting lesser prairie-chicken lek density in Texas. For each candidate model, I give –2×log-likelihood (–2LL), number of parameters (*K*), Akaike's Information Criterion (AIC), difference in AIC compared to lowest AIC of the model set (Δ_i), AIC weight (w_i), predicted lek abundance (N), and coefficient of variation for abundance (*cv*).

Model[a]	–2LL	*K*	AIC	Δ_i	w_i	N[b]	*cv*
Vegetation Model Set							
SHRUB	937.098	4	945.098	0.000	0.487	246.3	0.136
SHRUB + GRAIN	936.558	5	946.558	1.460	0.235	245.1	0.176
SHRUB + GRAIN + EDGE	936.026	6	948.026	2.927	0.113	245.3	0.137
GRASS	941.501	4	949.501	4.403	0.054	243.3	0.130
GRASS + EDGE	940.673	5	950.673	5.575	0.030	243.5	0.145
GRAIN + EDGE	944.137	4	952.137	7.039	0.014	148.5	0.104
AGP	946.475	3	952.475	7.377	0.012	248.9	0.132
AGP + EDGE	944.570	4	952.570	7.471	0.012	249.9	0.137
ASP + EDGE	945.029	4	953.029	7.931	0.009	251.0	0.134
AGP + GRAIN + EDGE	943.516	5	953.516	8.417	0.007	250.3	0.137
AGP + GRAIN	945.642	4	953.642	8.544	0.007	249.2	0.136
GRAIN	947.967	3	953.967	8.869	0.006	250.1	0.134
ASP	948.042	3	954.042	8.943	0.006	250.7	0.137
ASP + GRAIN + EDGE	944.108	5	954.108	9.009	0.005	251.2	0.132
ASP + GRAIN	947.489	4	955.489	10.391	0.003	251.1	0.134
SHRUB + EDGE	961.846	5	971.846	26.747	<0.001	145.9	0.118
GRASS + GRAIN	964.081	5	974.081	28.983	<0.001	244.4	0.136
GRASS + GRAIN + EDGE	963.872	6	975.872	30.774	<0.001	144.6	0.102
EDGE	969.874	3	975.874	30.775	<0.001	148.2	0.099

Table 4. Continued

Model[a]	–2LL	K	AIC	Δ_i	w_i	N[b]	*cv*
Road Model Set							
HWY + DIRT	937.134	4	945.134	0.000	0.716	249.5	0.135
DIRT	940.988	3	946.988	1.854	0.284	251.9	0.139
ROADS	961.990	3	967.990	22.855	<0.001	249.8	0.134
HWY	968.957	3	974.957	29.823	<0.001	246.6	0.137
Energy Model Set							
TRANSM	944.773	3	950.773	0.000	0.636	248.3	0.132
TRANSM + WELL	944.558	4	952.558	1.785	0.260	247.9	0.133
WELL	948.394	3	954.394	3.621	0.104	249.6	0.140

[a] Covariates described in Table 3.

[b] Predicted lek abundance for each model.

Table 5. Best overall hierarchical distance sampling models predicting lesser prairie-chicken lek density in Texas. For each candidate model, I give –2×log-likelihood (–2LL), number of parameters (*K*), Akaike's Information Criterion (AIC), difference in AIC compared to lowest AIC of the model set (Δ_i), AIC weight (w_i), predicted lek abundance (N), and coefficient of variation for abundance (*cv*).

Model[a]	–2LL	*K*	AIC	Δ_i	w_i	N[b]	*cv*
SHRUB + HWY + DIRT	926.926	6	938.926	0.000	0.826	248.5	0.136
TRANSM + HWY + DIRT	934.467	5	944.467	5.540	0.052	249.0	0.135
SHRUB	937.098	4	945.098	6.172	0.038	246.3	0.136
HWY + DIRT	937.150	4	945.150	6.224	0.037	249.5	0.135
DIRT + TRANSM	937.584	4	945.584	6.657	0.030	250.9	0.144
DIRT	940.988	3	946.988	8.062	0.015	251.9	0.139
TRANSM	944.773	3	950.773	11.846	0.002	248.3	0.132
NULL	948.407	2	952.407	13.480	0.001	249.7	0.136
SHRUB + HWY +DIRT+TRANSM	949.199	7	963.199	24.273	<0.001	146.5	0.101
SHRUB + DIRT +TRANSM	952.503	6	964.503	25.577	<0.001	248.9	0.144
SHRUB + DIRT	956.009	5	966.009	27.082	<0.001	148.1	0.102
SHRUB + TRANSM	956.967	5	966.967	28.040	<0.001	244.8	0.133

[a] Covariates described in Table 3.

[b] Predicted lek abundance for each model.

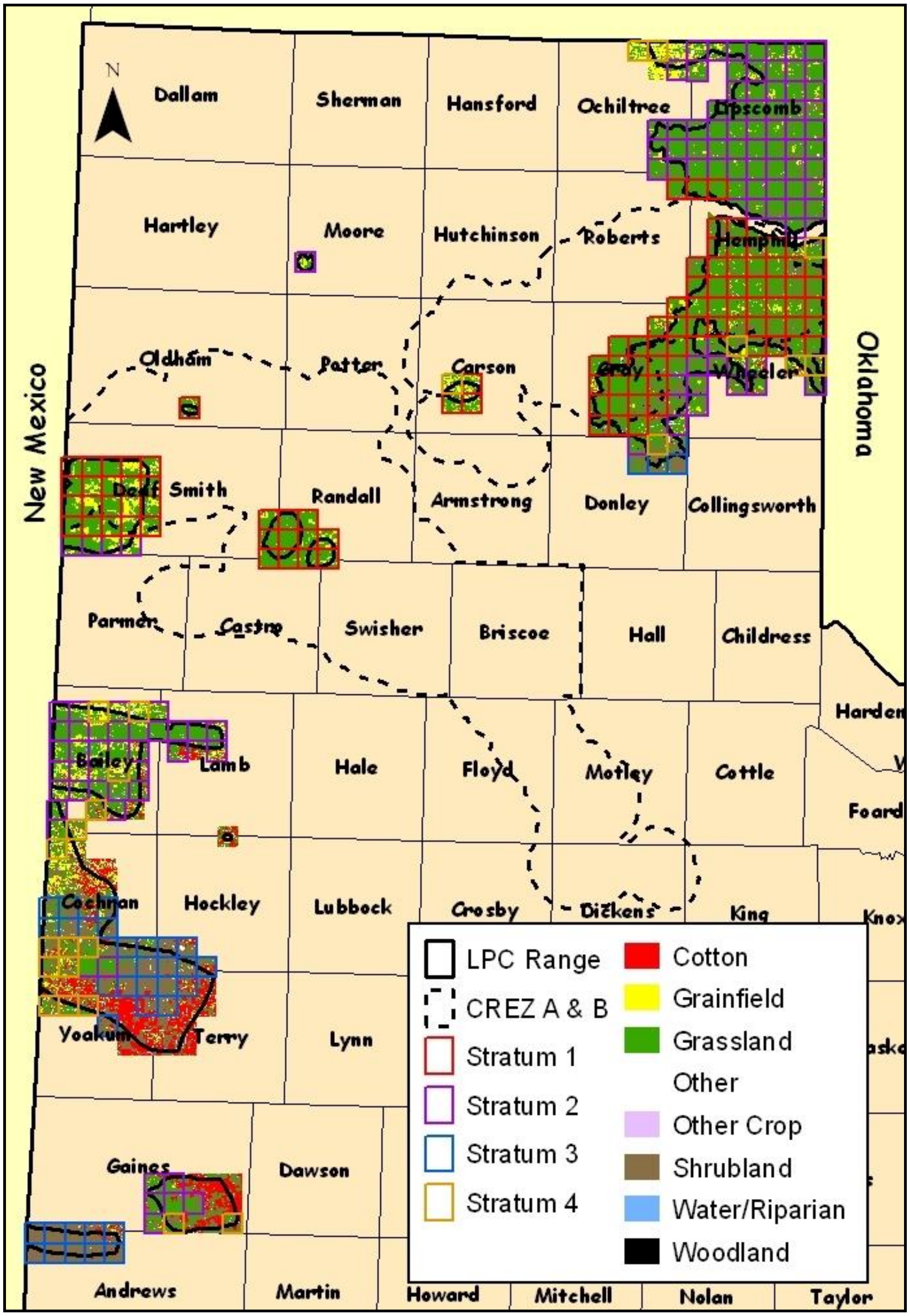

Figure 1. Sampling frame (285 survey blocks) covering the lesser-prairie chicken (LPC) range in the Texas Panhandle with vegetation classes, Competitive Renewable Energy Zone overlap, and priority rankings. Landcover data courtesy of USDA, National Agricultural Statistics Service, 2008 Texas Cropland Data Layer.

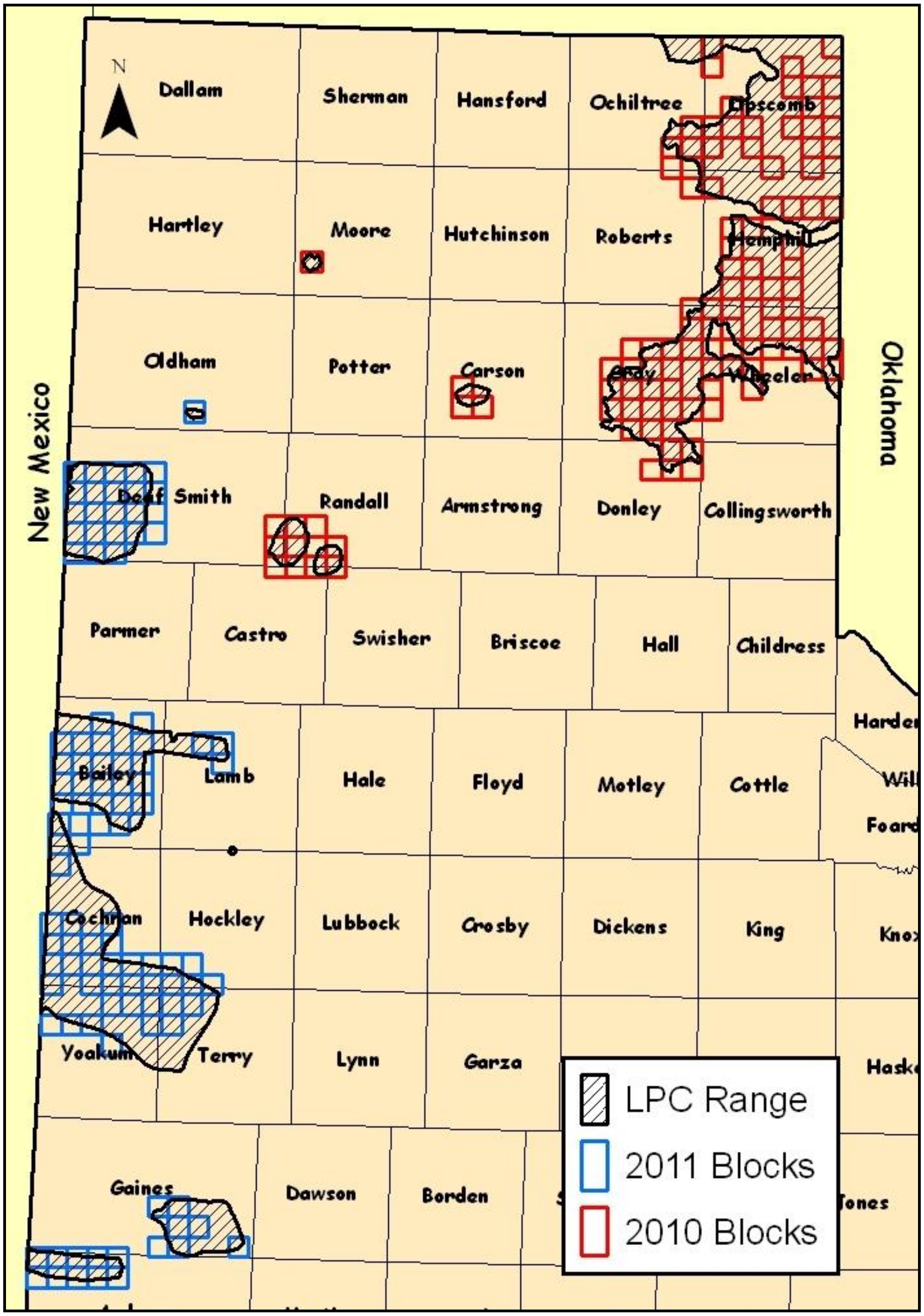

Figure 2. Map of the current estimated lesser prairie-chicken (LPC) range divided into 2 portions—105 blocks surveyed in the northeast region in spring 2010 (red blocks) and 103 blocks surveyed in the southwest region in spring 2011 (blue blocks).

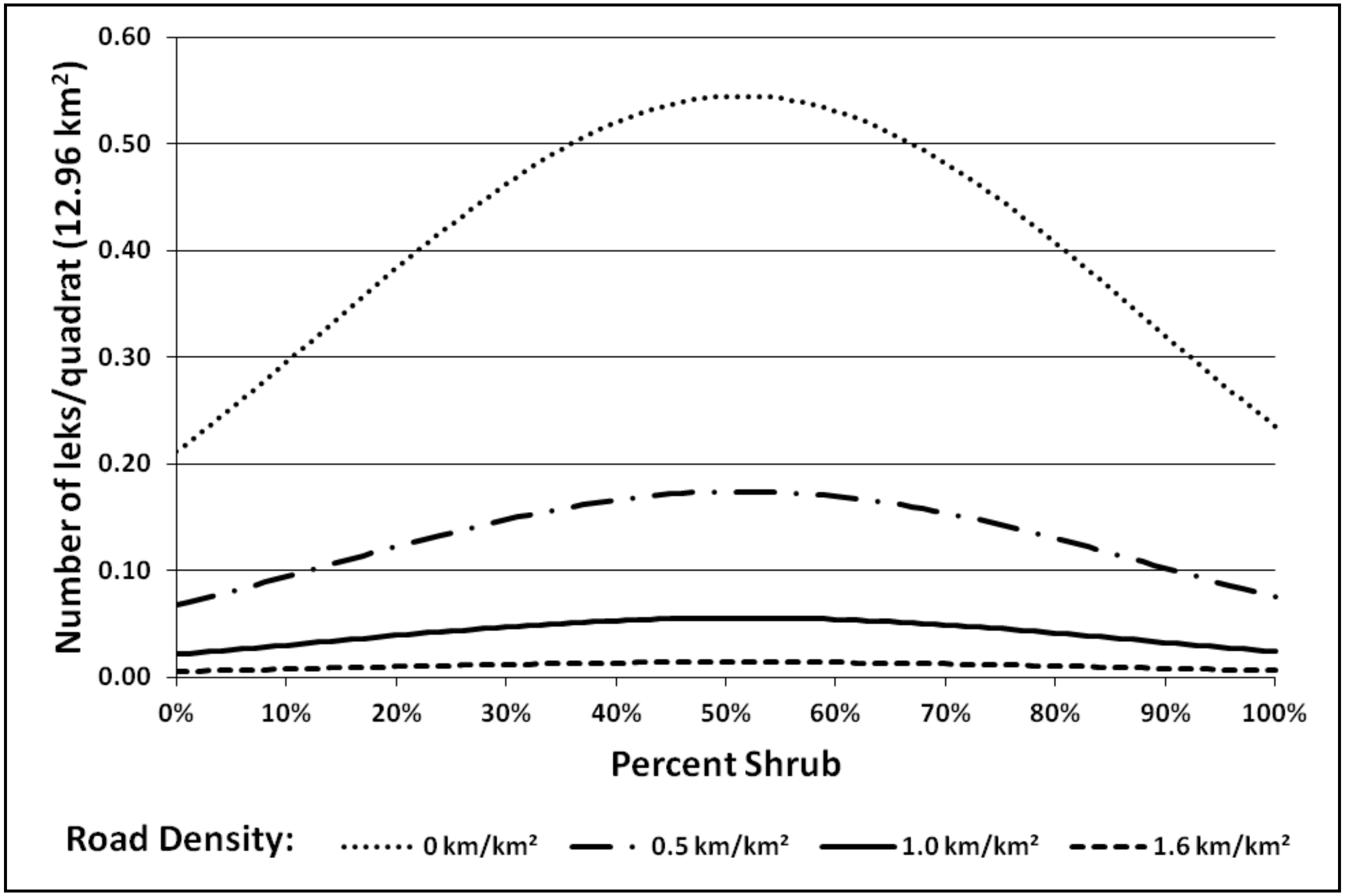

Figure 3. Predicted lesser prairie-chicken lek density in response to the percent of the landscape composed of shrubland patches and road density (km/km^2) in the Texas occupied range.

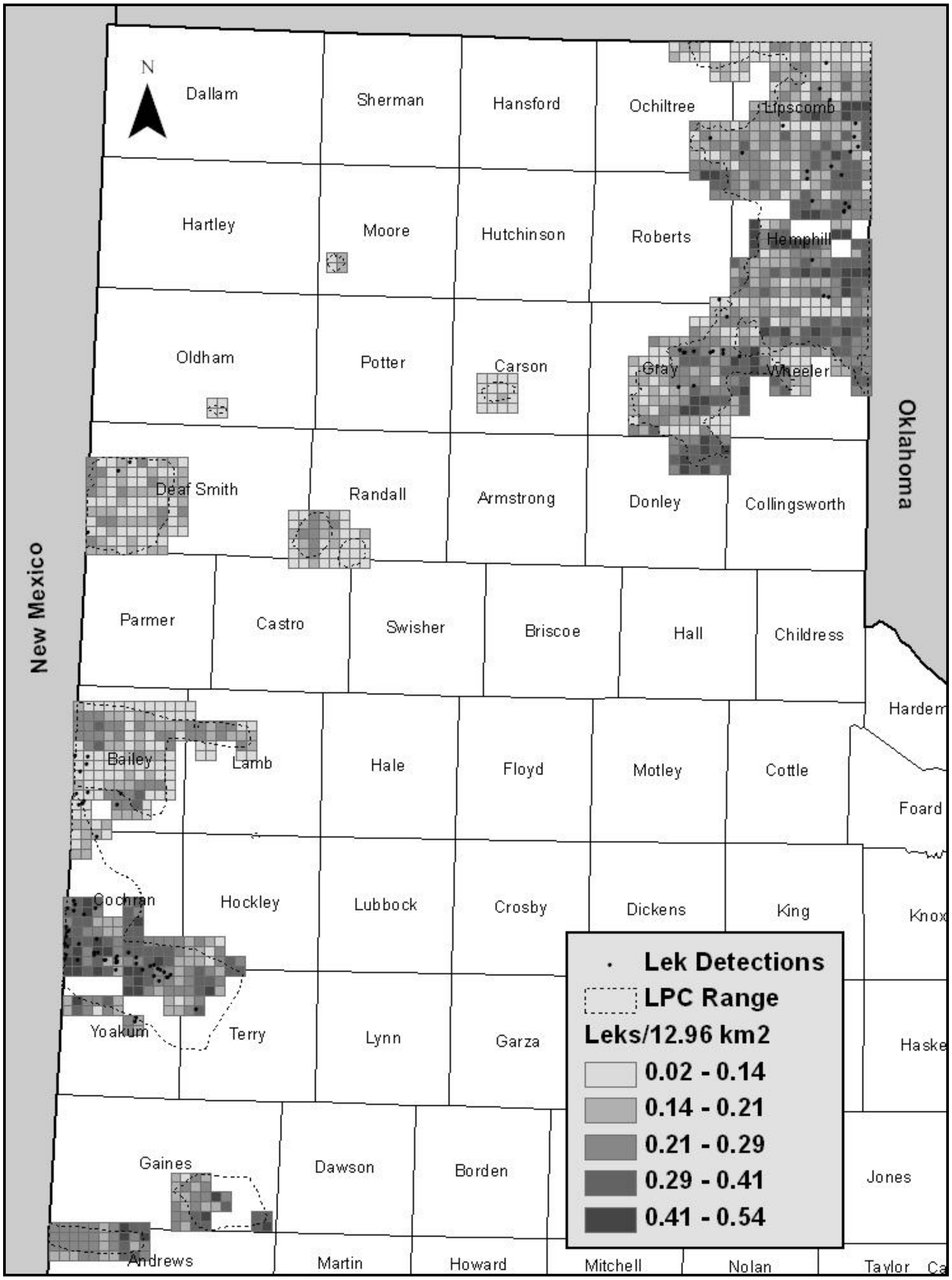

Figure 4. Predicted lesser prairie-chicken (LPC) lek density for 12.96 km^2 quadrats covering the Texas occupied LPC based on a hierarchical distance sampling model. Whites areas inside the occupied range were classified as non-LPC habitat and were not included in the sampling frame.