SURVIVAL, RESOURCE SELECTION, AND SEASONAL SPACE USE OF CONSERVATION RESERVE PROGRAM AND SHINNERY OAK HABITAT BY LESSER PRAIRIE-CHICKENS IN EASTERN NEW MEXICO

BY

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ABSTRACT

The lesser prairie-chicken (*Tympanuchus pallidicinctus*) has seen significant declines in its range and population since the early 1900s. Research in Kansas has shown that Conservation Reserve Program (CRP) grasslands are used by lesser prairie-chickens for breeding, nesting, and brood rearing. Lesser prairie-chicken use of CRP grasslands in New Mexico has not been well documented and there is disagreement as to its importance in their life history. In light of this, I set out with the following objectives: 1) estimate breeding season survival and determine cause specific mortality of lesser prairie-chickens, 2) characterize lesser prairie-chicken seasonal space use relative to the distribution of CRP and native shinnery oak habitat, and 3) determine resource selection of vegetation characteristics by lesser prairie-chickens in eastern New Mexico. I captured and radio collared lesser prairie-chickens in the springs of 2014 and 2015 and monitored their movements throughout the breeding and non-breeding seasons. Breeding season male survival was almost double that of females in both years. Lesser prairie-chickens selected shinnery oak habitat in much higher proportion was available for both broad scale and resource selection analyses. My results indicate that in New Mexico: 1) lesser prairie-chicken survival is consistent with other stable populations and 2) shinnery oak habitat is being selected for more than CRP/grassland habitat by lesser prairie-chickens. Further habitat improvement efforts for this species in eastern New Mexico should consider switching focus from CRP and concentrate on conservation of native shinnery oak prairie.

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INTRODUCTION

Lesser prairie-chickens (*Tympanuchus pallidicinctus*) were once an abundant species across the southern Great Plains of North America (Bent 1963). This landscape was drastically altered as Europeans expanded westward throughout the 20th century, and as a result, the lesser prairie-chicken has declined significantly in its population and range (Taylor and Guthery 1980, Van Pelt et al. 2013). Conversion of native prairie to row crop agriculture (Applegate and Riley 1998), shrub encroachment (Hunt and Best 2010), and energy development (Pitman et al. 2005, Pruett et al. 2009) have all been cited as causes for their decline.

The U.S. Fish and Wildlife Service (USFWS) listed the bird as threatened in March 2014 in an attempt to stop and possibly reverse their decline. As part of the listing decision, the USFWS attempted a new approach to recover this species by allowing the Western Association of Fish and Wildlife Agencies (WAFWA) to partially oversee the recovery effort. WAFWA, along with other state wildlife agencies, promoted state and federal assistance programs to encourage private landowners to conserve habitat. One of these programs was the Conservation Reserve Program (CRP). The CRP is a federal program, active since the mid-1980s, that encourages landowners to convert agricultural land to grassland habitat for soil conservation, although this program has had significant benefits to wildlife as well (Heard et al. 2000).

Previous studies have shown the benefit of CRP in stemming declines in many wildlife species, especially creating and conserving critical habitat for grassland birds

(Johnson and Schwartz 1993, Kantrud 1993, Reynolds et al. 2001). One grassland bird that has benefitted greatly from CRP is the lesser prairie-chicken. Several studies in the northernmost portion of the lesser prairie-chicken's range show high use of CRP fields (Rodgers and Hoffman 2005, Fields et al. 2006) and one study in particular attributed modest range expansions to lands enrolled in CRP (Rodgers and Hoffman 2005). In light of this documented use of CRP, agencies involved in lesser prairie-chicken recovery have begun to emphasize increased CRP enrollment by landowners across the bird's range.

While CRP seems to be effective in creating habitat for lesser prairie-chickens in the northern part of its range (Kansas, Colorado, and Oklahoma), the same benefit has not been demonstrated in New Mexico. In fact, at the inception of this project, there was disagreement among biologists in New Mexico as to if and when lesser prairie-chickens use CRP habitat in New Mexico. As a result, I undertook this project to assess CRP habitat use by lesser prairie-chickens in New Mexico and determine if it provides the same benefit in the southern portion of its range as has been documented in the northern portion of its range.

OBJECTIVES

1. Estimate breeding season survival and determine cause specific mortality of lesser prairie-chickens in eastern New Mexico.
2. Characterize lesser prairie-chicken seasonal space use relative to the distribution of CRP and native shinnery oak habitat in eastern New Mexico.

3. Determine resource selection of vegetation characteristics by lesser prairie-chickens in eastern New Mexico.

These objectives are presented in two chapters. My goal is to give managers current demographic rate information for lesser prairie-chickens in this portion of their range, and give insight into the validity of emphasizing CRP contract acquisition as a recovery tool for the lesser prairie-chicken in eastern New Mexico.

STUDY AREA

This study was conducted on public and privately owned lands near the town of Milnesand, NM in Lea and Roosevelt counties (Fig. 1). This area is part of the Llano Estacado plateau/ecoregion. The site is defined as semi-arid, receiving an average of 40.7 cm (15.8 – 91.6 cm) of precipitation per year (PRISM Climate Group 2016). Temperatures ranged from -14 to 39°C throughout the course of the study (PRISM Climate Group 2016). Elevation ranged from 1,200 to 1,300 m across the study area. Soils are a mix of the Brownfield, Amarillo, and Nutivoli series. The Brownfield and Amarillo series are characterized by very deep, well drained, moderately permeable soils occurring on nearly level to gently sloping plains (NRCS 2010). The Nutivoli series consists of very deep, excessively drained, and rapidly permeable soils on very gently sloping to moderately steep hills or dunes. Slopes for the Nutivoli series range from one to 20 percent (NRCS 2010).

This landscape is a patchwork of different land covers and land uses. Past and present land use has resulted in a mosaic of grassland, cropland, Conservation

Reserve Program (CRP), and shinnery oak prairie land cover types. Agriculture, energy development, and cattle ranching are the primary economic activities in the region today. Common crops cultivated in the area are corn, sorghum grain, and cotton.

Native grasslands in the region are dominated by shinnery oak (*Quercus havardii*) and sand sagebrush (*Artemisia filifolia*) with a mixture of perennial grass species. The most common of these species include sand dropseed (*Sporobolus cryptandrus*), hairy grama (*Bouteloua hirsuta*), little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), and side oats grama (*Bouteloua curtipendula*). In areas where cattle grazing has historically occurred, there is moderate to high encroachment of mesquite (*Prosopis glandulosa*). As early as the 1970s, chemical treatments were applied to this area to reduce the dominance of shinnery oak (Peterson and Boyd 1998). These chemical treatments, in addition to areas converted to CRP, have resulted in areas of grass-dominated prairie as opposed to a native shinnery oak dominated prairie. Additionally, non-native weeping lovegrass (*Eragrostis curvula*) was commonly used in early CRP plantings and has become established in many areas (Ripper et al. 2008).

The majority of trap sites were located on New Mexico Department of Game and Fish (NMDGF) owned Prairie Chicken Areas (PCA). These sites varied in vegetation cover, but in general were dominated by shinnery oak prairie and were not grazed at any point during the year. Evidence of abandoned infrastructure associated with oil and gas development was present on most of the PCAs. However, prior to

and during the study, restoration activities resulted in the removal of power poles and reclamation of many roads.

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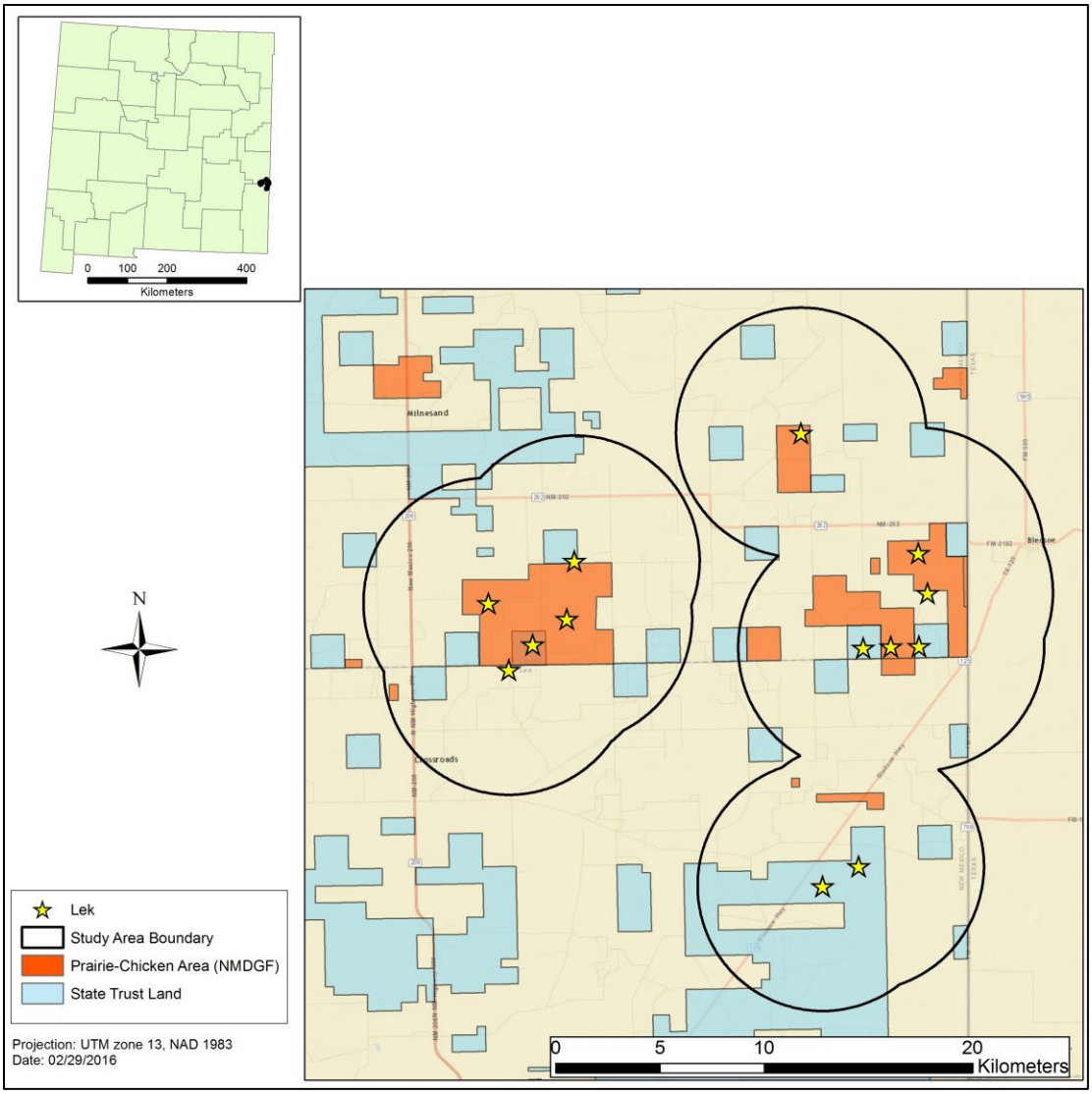

Figure 1. Study area in eastern New Mexico. State prairie-chicken areas (pink) and state trust lands (blue) are encompassed by 6 km buffers (black circles) that define my focal study areas where I trapped lesser prairie-chickens on leks (yellow stars) and tracked throughout the breeding and nonbreeding season.

CHAPTER I – BREEDING SEASON SURVIVAL OFMALE AND FEMALE LESSER PRAIRIE-CHICKENS IN A FRAGMENTED LANDSCAPE IN EASTERN NEW MEXICO

INTRODUCTION

Since European settlement the Great Plains prairie ecosystem in the heart of the North American continent has undergone significant change. Large tracts of relatively undisturbed native prairie were converted to row crop agriculture and it is estimated that 99.9% of native prairie has been lost to this and other forms of anthropogenic change (Samson and Knopf 1994). The decline and loss of the vegetation community associated with the prairie ecosystem has also been mirrored by its faunal communities. Of these, grassland birds have experienced perhaps the most precipitous decline of all (Brennan and Kuvlesky Jr. 2005). The most recent Breeding Bird Survey data show that many grassland bird species have been in decline for the last 30 years (Sauer et al. 1995).

The lesser prairie-chicken (*Tympanuchus pallidicinctus*), one of these declining grassland bird species, is currently a species of great conservation concern due to its rapidly declining populations and threats from future anthropogenic landscape change. The lesser prairie-chicken is a prairie grouse species that inhabits the southern Great Plains in the states of Kansas, Colorado, Oklahoma, Texas, and New Mexico. At the time of European settlement, anecdotal reports suggest that lesser prairie-chickens were very abundant in the High Plains region (Bent 1963). As

settlement continued into the 1900s, populations began to decrease and by the 1980s drastic declines in population size and occupied range became abundantly clear (Crawford and Bolen 1976, Taylor and Guthery 1980, Van Pelt et al. 2013).

There has been a long documented history of lesser prairie-chicken population fluctuations in the southern Great Plains. Hoffman (1963) noted large population declines after the droughts of the 1930s. Since this time, periodic droughts have also resulted in short term population declines (Brown 1978, Giesen 2000). Even in the face of these droughts, populations were able to rebound to recent highs in the late 1980s (Hagen et al. 2004). Recovery of lesser prairie-chicken populations after these declines was often attributed to large tracts of high quality habitat composed of undisturbed prairie and working rangelands that receive light grazing pressure (Hoffman 1963, Giesen 2000, Hagen et al. 2004). Following the 1980s, however, lesser prairie-chicken populations have shown poor and slow recovery following periodic and prolonged drought conditions (Hagen et al. 2004). Increasing loss of high quality habitat may be preventing lesser prairie-chicken populations from recovering because they cannot expand and seek out these higher quality patches of habitat during periods of drought.

Persistence and growth of lesser prairie-chicken populations is of great interest to state and federal wildlife managers. Nest success and brood survival are often cited as the most important vital rates when considering the persistence of gallinaceous birds (Moynahan et al. 2007). It is therefore critical that female gallinaceous birds survive to the age of reproduction if a population is to remain

stable. Hagen et al. (2009) found that female lesser prairie-chicken survival has the greatest effect on long-term population viability. In particular, survival during the breeding season seems to be highly important (Hagen et al. 2009). However, it is also critical not to discount male survival because low survival rates may impact genetic diversity in polygynous mating systems (Pruett et al. 2011, Grisham and Boal 2015).

Several studies have estimated the survival rates of lesser prairie-chickens in eastern New Mexico and west Texas (Leonard 2008, Pirius 2011, Grisham and Boal 2015). In the time between these studies and the listing decision of threatened by the U.S. Fish and Wildlife Service (USFWS; USFWS 2014), this region experienced an extended period of drought which caused even further declines to lesser prairie-chicken populations (Grisham and Boal 2015, McDonald et al. 2015). In response to these declines, the Western Association of Fish and Wildlife Agencies (WAFWA) began to conduct aerial surveys in 2012 to index and estimate lesser prairie-chicken populations across their range (McDonald et al. 2015).

Based on differences in land use and vegetation community, these surveys were split into four focal regions based on geography and vegetation type; (1) shinnery oak prairie region (SOPR) located in eastern New Mexico-southwest Texas Panhandle, (2) sand sagebrush prairie region (SSPR) located in southeastern Colorado southwestern Kansas-western Oklahoma Panhandle, (3) mixed-grass prairie region (MGPR) located in the northeast Texas Panhandle western Oklahoma-south central Kansas, and (4) short grass/Conservation Reserve Program (CRP) prairie region (SG/CRP) located in Northwestern Kansas. Of these regions, the SSPR, MGPR, and

SG/CRP are somewhat connected and geographically similar. The SOPR is geographically separated and distinct from these other regions in climate and vegetative community. WAFWA aerial surveys began to show modest increases in the northern populations in 2014 whereas the SOPR continued to show declines. In 2015 all northern populations showed net increases, while the SOPR fell to its lowest levels since the surveys began (McDonald et al. 2015).

Given our knowledge of the potential impact that survival may have on the continued population declines in the SOPR, I set out to 1) estimate contemporary breeding season survival of male and female lesser prairie-chickens and 2) determine causes and timing of lesser prairie-chicken mortality. Recent population declines and field observation led me to hypothesize that female survival rates would be below what is required for a stable population and female survival would be lower than that of male survival. I also hypothesized that improved habitat conditions in the final year of the study would lead to increased survival rates over those of the first year.

METHODS

Capture

Lesser prairie-chickens were captured using walk-in traps with drift fences (Haukos et al. 1990, Schroeder and Braun 1991) and whoosh nets (Davies 1981) during the spring lekking period (March – May) in 2014 and 2015. Upon capture, the gender and age of each bird was determined using pinnae length, presence of eye comb, and the barring pattern on primaries 9 and 10 (Copelin 1963). All captured

lesser prairie-chickens were banded with a uniquely numbered aluminum leg band. Each bird was then weighed and fitted with either a 13 g necklace style very-high-frequency radio transmitter (VHF; American Wildlife Enterprises, Monticello, FL) or a 22 g solar powered backpack style satellite platform transmitting terminal transmitter (hereafter referred to as GPS transmitter; Microwave Telemetry, Inc., Columbia, MD). VHF transmitters were equipped with a mortality switch that increased the pulse rate from 40 beats per minute to 80 after the transmitter remained stationary for 8 hours. Both transmitter types equated to <3% of the total body weight of each lesser prairie-chicken, which is sufficiently below the recommended 5% (Caccamise and Hedin 1985). All capture and handling procedures were approved by New Mexico State University IACUC (#2014-015).

Tracking and Monitoring

I located each lesser prairie-chicken 1-4 times per week during the focal period (March 15 – August 31). After a bird was located, a minimum of 3 locations and azimuths were taken using a hand held 3 element Yagi and R-1000 telemetry receiver (Communications Specialists, Orange, CA). Locations of fixes were recorded using an eTrex 30 handheld GPS unit (Garmin International Inc., Olathe, KS). I attempted to keep less than 20 minutes between all fixes to reduce disturbance and the probability that the bird moved. If a lesser prairie-chicken was flushed, its location was recorded using a GPS receiver. Location of a Signal software (LOAS; Ecological Software Solutions, Florida, USA) was used to generate maximum likelihood

estimates of lesser prairie-chicken locations based on the location and azimuth of fixes.

If a lesser prairie-chicken was lost at some point during the season for longer than a week, I made an exhaustive search effort radiating out 6 km from its lek of capture. If I did not re-acquire the bird's signal, I considered the bird to have emigrated from the study area or that its transmitter had failed and it was censored from that point forward. I continued to opportunistically monitor for lost birds throughout the season as I conducted other field work. Birds with GPS transmitters were tracked using GPS/Argos system. GPS locations were taken every 2 hours between 0400 – 2200 hours resulting in approximately 10 locations per day. This number was variable based on the daily solar charge of each individual transmitter. Locations were downloaded weekly.

Causes of Mortality

When a mortality signal from a VHF transmitter was received, I immediately homed to its location to determine cause of death. Birds equipped with GPS transmitters were determined to be dead when locations began to stack upon one another for several fixes and temperature sensors indicated a mortality. Birds with GPS transmitters were located using a hand held GPS unit as soon as a mortality was suspected. Kill sites for birds with GPS transmitters were often located >5 days after the mortality had occurred making it difficult to determine the exact cause of death.

When a kill site or carcass was located it was classified into one of four categories: mammal, avian, weather, or unknown. I also considered whether the transmitter had slipped or the harness had broken. I used remaining body parts, orientation of body parts, and the condition of the transmitter to determine cause of death. I also investigated the area immediately around the carcass to see if there were any predator tracks or scat. In addition to these measures, I also checked to see if there were any possible collision structures in the area, since these have been noted as a potential cause of death in lesser prairie-chickens (Hagen et al. 2007, Wolfe et al. 2007) and other grouse species (Connelly et al. 2000, Hovick et al. 2014).

I considered the cause of death to be mammalian if there were bite marks on the transmitter, chewed feathers or bands, or very few intact body parts. Potential mammalian predators observed in the study area were coyote (*Canis latrans*), American badger (*Taxidea taxus*), and bobcat (*Lynx rufus*). There have been reports of swift fox (*Vulpes velox*) in this area and I believe that I may have encountered some tracks during the 2014 field season. The mortality was considered to be avian predation if the carcass was decapitated, the breast muscle was the only body part eaten, or there was evidence of feather plucking. Additionally single crimps in the transmitter antenna were also considered evidence of an avian predator. Potential avian predators observed on the site were red-tailed hawk (*Buteo jamaicensis*), swainson's hawk (*Buteo swainsoni*), ferruginous hawk (*Buteo regalis*), northern harrier (*Circus cyaneus*), golden eagle (*Aquila chrysaetos*), prairie falcon (*Falco mexicanus*), and great horned owl (*Bubo viginianus*). The highest abundance of avian

predators tends to occur around lekking activities in this location (Grisham and Boal 2015).

Several strong weather events occurred throughout the study. These consisted of golf ball-sized hail, strong winds, and lightning. If I found a mortality immediately after one of these events and there did not appear to be evidence of mammal or avian predation I classified the mortality as weather caused. If I could not clearly classify the cause of death into one of the above categories then I classified it as unknown.

Weather Data

Rainfall data were gathered for 2013-2015 from Oregon State University's Parameter-Elevation Regressions on Independent Slopes Model (PRISM) climate data website (prism.oregonstate.edu). Daly et al. (2008) describe the methodology and modeling approach used to interpolate climate data from multiple climate monitoring stations across the United States and the reliability of these estimates. Monthly precipitation data were collected from the 4 km mesh layer for the focal area of my study (33.5876, -103.2620) for 2013, 2014, and 2015. In 2013 only data for September – December were collected and in 2015 only January – September data were collected. I included 2013 data to determine if precipitation from the fall and winter prior to the 2014 breeding season was potentially affecting growth of vegetation across the study area. Monthly 30-year average precipitation data were also collected to see if precipitation during the study was above or below normal.

Survival Analysis

I estimated survival for the breeding season using known-fate models in program MARK (White and Burnham 1999). I coded encounter histories as a weekly time step where each bird was coded as live, dead, or censored. I used March 15 as the beginning of the breeding season each year because this was the earliest date that I captured any lesser prairie-chickens and this was when territorial displays began in earnest. August 31 was used as the ending date because at this point broods are fully grown and begin to become independent from the mother (Fields et al. 2006). Lesser prairie-chickens begin to disperse from areas around leks to overwintering habitats at this time (Pirius 2011).

I developed 11 *a priori* models for lesser prairie-chicken survival based on a review of the literature and the objectives of my study. I intended to separate birds based on use or non-use of CRP habitat, but low use of CRP habitat by lesser prairie-chickens throughout the duration of the study prevented me from including this in the model set. The effects of gender, age, year, and biological period were examined.

Model development was driven by differential predation risk in male and female lesser prairie-chickens due to the difference in their respective life histories. Specifically, there is evidence that males and females experience different levels of mortality risk throughout the breeding season (Hagen et al. 2007, Grisham and Boal 2015, Plumb 2015). Hagen et al. (2007) found that females were highly susceptible to predation during nesting and brood rearing. Females actively tending nests had a higher risk of mortality than those that did not (Wolfe et al. 2007, Grisham and Boal

2015). Males are more susceptible to predation during the lekking period when they are highly visible and the post-lekking period when their body condition may be compromised from the stresses associated with breeding (Wolfe et al. 2007). In addition to survival differences due to gender, rainfall and vegetation growth between years led me to believe that there may be differences in survival between years. Finally, age was considered as an important covariate because previous research identified age as affecting lesser prairie-chicken survival (Fields et al. 2006, Wolfe et al. 2007).

I used Akaike's information criterion adjusted for small sample sizes (AIC_c; Akaike 1974) to determine model fit (Burnham and Anderson 2002). Changes in AIC_c (ΔAIC_c) and Akaike weights (AIC_w) were used to evaluate model performance and select the best approximating model (Burnham and Anderson 2002). If there was evidence of model uncertainty, I averaged across models that contained the top 95% of the AIC_c weight.

RESULTS

Probable Causes of Mortality

I captured and monitored 31 male and 8 female lesser prairie-chickens during the 2014 breeding season. In 2015 I captured 22 males and 18 females in addition to 17 males and 3 females that survived from the previous year. Of the 22 males I captured in 2015, 3 did not receive transmitters and were not included in my survival analysis. I eliminated 2 males and one female from analysis due to potential capture-

related myopathy. After accounting for non-collared birds and censored individuals, I used 30 male and 7 female unique encounter histories in 2014 and 35 male and 21 female unique encounter histories in 2015 for my survival analysis.

I recorded 29 deaths throughout the course of the study. Ten lesser prairie-chickens either lost their collars or emigrated from the study area. After the 2014 breeding season, one GPS transmitter failed and I was unable to determine the fate of that bird. The majority of deaths occurred in the months of April (7; 24%) and May (9; 31%). June (5; 17%) and July (6; 21%) accounted for all but 2 (7%) of the remaining deaths. I did not record any deaths in the final month of the breeding season (August).

The most deaths recorded were attributed to mammalian predators (14; 48%). Only 5 deaths (17%) were attributed to avian predators. I was unable to determine cause of death of 9 birds (31%). One female died on her nest presumably due to a severe hailstorm in 2014. Six transmitters slipped off of birds due to harness failure (3) or poor fitting during attachment (3). I did not find any evidence of death due to fence, powerline, or other structural collisions.

Survival

Gender-specific survival was the top ranked model of the 11 *a priori* models (Table 1.1). Gender was included in all of the top 5 models (Table 1.1). Additional models with support contained the interactive effects age, period, and year when combined with gender. Model-averaging yielded the probability that a sub-adult

female lesser prairie-chicken would survive the entire breeding season (March 15 – August 31) was 0.38 (SE= 0.14; 95% CI= 0.16 – 0.66) in 2014 and 0.39 (SE= 0.12; 95% CI= 0.19 – 0.62) in 2015 (Table 1.2). This was slightly lower than that of adult females which was 0.46 (SE= 0.18; 95% CI= 0.17 – 0.78) in 2014 and 0.44 (SE= 0.13; 95% CI= 0.21 – 0.69) in 2015 (Table 1.2). Survival probabilities for male lesser prairie-chickens were much higher. The probability that a sub-adult male lesser prairie-chicken would survive the entire breeding season was 0.78 (SE= 0.09; 95% CI= 0.56 – 0.91) in 2014 and 0.78 (SE= 0.10; 95% CI= 0.53 – 0.92) in 2015 (Table 1.2). Adult male survival was slightly higher than that of sub-adult males. In 2014 adult male survival was 0.80 (SE= 0.07; 95% CI= 0.63 – 0.90) and 0.81 (SE= 0.06; 95% CI= 0.66 – 0.90) in 2015 (Table 1.2).

DISSCUSSION

Survival estimates varied greatly between males and females. Male survival was relatively high (0.78 – 0.81; Table 1.2), consistent with the most recent study in the southern SOPR (Table 1.3; Grisham and Boal 2015). Very little information has been published on male survival in the SOPR (Grisham and Boal 2015), and other estimates of breeding season survival for male lesser prairie-chickens across their range have been variable and were often pooled with females due to low sample sizes (Toole 2005, Leonard 2008; Table 1.3). Although female survival and nest success are considered the most important vital rates affecting recruitment (Hagen et al. 2009), Grisham and Boal (2015) cautioned that male survival should not be

overlooked due to the implication it could have on genetic diversity. Lek mating systems already restrict genetic diversity because only a few males within a single lek often do almost all of the breeding (Pruett et al. 2011). This increases the chance of deleterious alleles becoming fixed in the population (Pruett et al. 2011). High survival estimates in this study are encouraging because they reduce the likelihood of this possibility.

Female survival rates ranged from 0.38 – 0.46 across age and year classes (Table 1.2), which is roughly half of the 0.76 breeding season survival reported by Grisham and Boal (2015). However, these results are consistent with estimates of female lesser prairie-chickens in studies conducted in the northern portion of their range (Fields 2004, Hagen et al. 2007, Plumb 2015; Table 1.3). Grisham and Boal (2015) hypothesized that the higher survival rates they observed might be caused by lower nest initiation rates, an inherently high time of predation for females (Hagen et al. 2009). Although the year prior to my study had low nest initiation rates (A. Lawrence and C. Strong, *unpublished data*), I observed almost all collared females attempting to nest in both 2014 and 2015. I observed that the majority of female mortalities occurred during the nesting and brood rearing period which lends support to the hypothesis that increased reproductive effort is likely the cause of lower observed survival rates. Although point estimates for female survival were on the low end of what has been observed elsewhere, 95% confidence interval estimates overlap with many of the other studies indicating that the female survival I observed is consistent with other stable populations (Table 1.3; Hagen et al. 2007, McDonald et

al. 2015, Plumb 2015). However, I do caution that continued monitoring is still warranted to ensure that this decrease in female survival is concurrent with increased recruitment, which has not occurred in the last two years (McDonald et al. 2015).

Interestingly, point estimates of adult survival were higher than those of sub-adults across year and gender (Table 1.2). This could be explained by the knowledge an individual bird gains over the course of a year about its surrounding environment. Birds that have resided in an area longer will know the location of food, water, and cover from predators and the elements. Additionally adult birds of both genders may exhibit different behaviors during periods of high mortality due to the knowledge of surviving these periods previously. For example, adult males will likely be more wary of predators on leks than sub-adults and adult females may choose better nest sites since they have had previous experience of choosing a nest site. These experiences potentially give adult birds a leg up on sub-adults. However, although point estimates indicated adult survival was slightly higher than sub-adult survival during the breeding season, these values are probably not biologically significant. Also 95% confidence intervals still indicate a relatively high degree of uncertainty and overlap in these estimates (Table 1.2).

Specific causes of mortality in my study contrasted with work by Wolfe et al. (2007) and Plumb (2015) that indicated avian predators accounted for more mortality events than mammals. However, my results were consistent with other studies conducted across the lesser prairie-chicken's range (Hagen et al. 2007, Grisham and Boal 2015). I had a higher number deaths attributable to mammalian predators (48%)

than to avian predators (17%). This may be due to differences in the amount of anthropogenic disturbance around leks. Avian predators are often associated with available perch sites (Preston 1990). In the area immediately surrounding leks (~3 km radius) within my study area there were very few power lines, tall trees, and other structures associated with human inhabitance. Leading up to and during my study, several habitat improvement activities resulted in the removal of powerlines no longer in use and of trees associated with old homesteads. This may be in contrast with other study areas in the northern ecoregions (Plumb 2015, Robinson 2015) and further east in the SOPR where landscapes are more heavily influenced by anthropogenic features (Grisham and Boal 2015).

Fence collisions have been noted as a potential major source of mortality for lesser prairie-chickens in Oklahoma and New Mexico (Wolfe et al. 2007). My findings of no mortalities attributable to fence collisions were consistent with those of Grisham and Boal (2015) and Strong (2016). This is likely due to a lower density of fences in my study area and fence marking mitigation activities that have occurred since Wolfe et al. (2007). Removal and deterioration of fences on the interior of the Milnesand and Sandhills Prairie Chicken Areas (PCA) create a low risk of collision near leks. Death from structural collision within my study area is likely not a factor affecting survival of lesser prairie-chickens.

The hypothesis that survival would vary between the first and second year of my study was not supported by my data (Table 1.2). This hypothesis was driven by differences I observed in vegetation and rainfall. Shinnery oak leafed out

approximately 2 weeks earlier in 2015 than in 2014. Although this likely produced better nesting cover, it appears that earlier leaf-out did not have much of an impact on survival. Additionally, there were only subtle differences in rainfall between years (Fig. 1.1). The winter of 2013 had almost no rainfall, but early rainfall in 2014 may have compensated for this (Fig. 1.1). Rainfall across the High Plains often comes from monsoon season thundershowers. These are sporadic in nature and can dump large amounts of rainfall in one area while leaving another with none. Accordingly, it makes sense that actual point estimates of survival between 2014 and 2015 were slightly different, but confidence intervals around these estimates showed a high degree of overlap between years (Table 1.2).

MANAGEMENT IMPLICATIONS

My results indicate that male lesser prairie-chicken survival rates were nearly double that of females during the breeding season. This is likely explained by the increased predation risk females experience during nesting and brooding periods. With recent lesser prairie-chicken population declines in the region it is important that the landscape is managed in such a way that female survival can be maximized. Conserving and maintaining intact areas with shinnery oak and grass cover at an adequate height for nesting will be the best way maximize female survival during this period. New Mexico Department of Game and Fish owned PCAs already have ideal species composition and cover available. In this case the best management strategy may be to preserve these areas as they are so that in years of high precipitation good

nesting cover will be readily available. Continued reduction and removal of anthropogenic structures may reduce the risk of mortality due to collision and avian predators that often use these structures for perches and nest sites. Monitoring of vital rates should continue to ensure that populations improve when weather conditions provide optimal vegetation cover for nesting.

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Table 1.1. Output from 11 a priori models used to assess the breeding season survival of lesser prairie-chickens in the area around Milnesand, NM, USA from 2014 – 2015. Darker font denotes models that contain 95% of the AIC_c weight.

Model	ΔAIC_c[a]	AIC_c Weight	Model Likelihood	K	Deviance
S(gender)	-	0.56	1.00	2	94.02
S(age*gender)[b]	2.24	0.18	0.33	4	92.24
S(year*gender)	3.73	0.09	0.15	4	93.73
S(period*gender)	4.00	0.08	0.14	6	89.96
S(age*gender*year)	5.28	0.04	0.07	8	87.21
S(age)	5.41	0.04	0.07	2	99.43
S(period)	8.60	0.01	0.01	3	100.61
S(constant)	8.68	0.00	0.01	1	104.71
S(year*age)	9.26	0.00	0.01	4	99.25
S(year)	10.64	0.00	0.00	2	104.66
S(week)	28.18	0.00	0.00	24	77.34

Gender – Survival is a function of gender (male, female)
Age – Survival is a function of age (sub-adult, adult)
Year – Survival is a function of year (2014, 2015)
Period – Survival is a function of breeding season period [lekking (March – April), nesting (May – June), post-nesting (July – August)]
Week – Survival is a function of each week during the breeding season
Constant – Survival is constant across all other variables and weeks during the breeding season
[a]AIC_c for the top model was 228.50
[b]* represents an interactive effect between the named variables

Table 1.2. Model averaged results of survival analysis for lesser prairie-chickens near Milnesand, New Mexico.

Year	Age	Gender	Estimate	SE[a]	95% CI	
					Lower	Upper
2014	Adult	Female	0.46	0.180	0.17	0.78
2014	Sub-adult	Female	0.38	0.138	0.16	0.66
2014	Adult	Male	0.80	0.068	0.63	0.90
2014	Sub-adult	Male	0.78	0.091	0.56	0.91
2015	Adult	Female	0.44	0.134	0.21	0.69
2015	Sub-adult	Female	0.39	0.116	0.19	0.62
2015	Adult	Male	0.81	0.062	0.66	0.90
2015	Sub-adult	Male	0.78	0.099	0.53	0.92

[a]All reported standard errors are unconditional

Table 1.3. Published survival estimates of male and female lesser prairie-chickens during the breeding season (approx. March – August) across their range.

Region	Gender	Survival	95% CI	Study
Kansas	Female	0.62 - 0.66	0.48 - 0.77	Fields 2004
Kansas	Female	0.57 - 0.86	0.38 - 0.96	Hagen et al. 2007
Kansas	Female	0.46	0.38 - 0.53	Plumb 2015
Texas Panhandle	Both[a]	0.66	-[b]	Toole 2005
Texas Panhandle	Both	0.61	0.41 - 0.80	Leonard 2008
West Texas/New Mexico	Female	0.76	0.61 - 0.87	Grisham Boal 2015
West Texas/New Mexico	Male	0.82 - 0.98	0.73 - 0.99	Grisham Boal 2015
New Mexico	Female	0.32 - 0.56	-	Merchant 1982
Oklahoma and New Mexico	Both	~0.78	-	Wolfe et al. 2007

[a]in studies with "both" for gender, male and female survival were pooled together

[b]- indicates that no 95% confidence interval was given for estimates

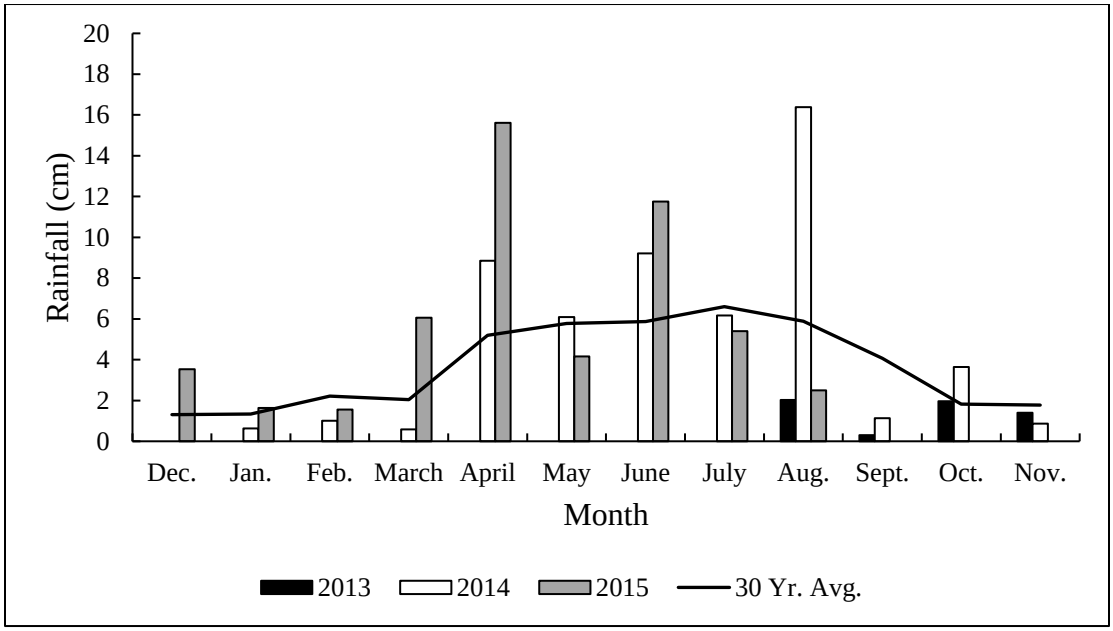

Figure 1.1. Rainfall by month in centimeters for the study area (33.5876, -103.2620) for 2013, 2014, and 2015. In 2013 only September – December are reported and in 2015 only January – September are reported. The 30 year average is indicated by the black line. All data were gathered from PRISM Climate Group at Oregon State University.

CHAPTER II – SEASONAL SPACE USE AND RESOURCE SELECTION OF GRASSLAND AND NATIVE SHINNERY OAK PRAIRIE BY LESSER PAIRIE-CHICKENS IN EASTERN NEW MEXICO

INTRODUCTION

Since European settlement, the heart of the North American continent, the prairie ecosystem, has undergone significant change. Settlers converted relatively undisturbed prairie to row-crop agriculture, rangelands for cattle grazing, and urban areas throughout the 19th and 20th centuries (Deering and Pettit 1972). The loss of native prairie to various forms of anthropogenic change is estimated at 99.9% (Samson and Knopf 1994). One of the unforeseen consequences of prairie conversion to row-crop agriculture was soil erosion. This became especially clear during the Dust Bowl era of the 1930s (Worster 1979). Although conditions improved by the 1960s, soil loss due to bare agricultural fields in the spring was still high (OTA 1982). By the 1980s the federal government estimated that soil erosion across agricultural lands was 18 tons per hectare per year (OTA 1982). Of particular importance was the finding that of this erosion, 45 percent of water erosion was occurring most rapidly on 6.5 percent of the United States' cropland (OTA 1982).

Consequently in 1985 the Natural Resource Conservation Service (NRCS) created the Conservation Reserve Program (CRP) to reduce the soil erosion. The CRP

was first implemented in 1986 with the goal of preventing soil erosion by targeting areas with highly erodible soils. The CRP works by offering farmers financial incentives to plant agricultural land back into permanent cover to prevent wind and water erosion that occurs on bare agricultural fields. Soon after its inception, wildlife managers began to realize CRP benefits to wildlife in areas where expanses of agriculture dominated the landscape (Johnson and Schwartz 1993, Kantrud 1993, Reynolds et al. 2001). As the CRP model expanded through time, it was seen as a mechanism to stop the decline of a rapidly disappearing group of wildlife, grassland birds (Ryan et al. 1998).

The lesser prairie-chicken (*Tympanuchus pallidicinctus*) is one such grassland bird species that has seen precipitous declines. At the time of initial settlement in the southern Great Plains region, anecdotal reports suggest that lesser prairie-chickens were abundant in the area (Bent 1963). As settlement continued into the 1900s, lesser prairie-chicken populations began to decrease and had declined dramatically by the 1980s (Crawford and Bolen 1976a, Taylor and Guthery 1980a).

One of the most likely causes of the lesser prairie-chicken's decline is conversion of native grasslands to crop production (Applegate and Riley 1998, Jackson and DeArment 1963). In the early 2000s, several studies noted the potential importance that CRP could play in recovering the lesser prairie-chicken. In Kansas, Fields et al. (2006) stated that CRP habitat provided preferable nesting habitat for lesser prairie-chickens. Rodgers and Hoffman (2005) also stressed the importance of CRP habitat to lesser prairie-chickens and noted range and population expansions in

areas of west-central Kansas which they attributed to CRP plantings of native grasses intermixed with forbs. Most recently, the Western Association of Fish and Wildlife Agencies (WAFWA) in its range wide conservation plan noted the CRP as a key government program, already in place, that creates high quality habitat for lesser prairie-chickens (Van Pelt et al. 2013).

Although CRP habitat appears to be important to lesser prairie-chickens in Kansas, to date no study has documented whether or not CRP habitat has the same benefits in the southern portion of their range. CRP habitat in New Mexico differs in several ways from CRP habitat in Kansas. The vegetation composition and structure within CRP fields in New Mexico, as well as the arrangement of those fields in relation to other native habitats is quite different. Weeping lovegrass (*Eragrostis curvula*), a non-native grass species, comprises a significant proportion of CRP plantings in eastern New Mexico and west Texas (Ripper et al. 2008). In addition to these non-native CRP plantings, Ripper et al. (2008) found that CRP plantings in general had low species diversity in New Mexico. In contrast CRP plantings in Kansas consist almost entirely of native species and have been intermixed with forbs in some cases (Fields et al. 2006).

Another important difference in lesser prairie-chicken habitat in New Mexico and west Texas is that it contains a significant shrub component comprised primarily of shinnery oak (*Quercus havardii*). Shinnery oak is a long-lived plant that typically grows to a height of less than one meter (Haukos 2011). It has deep and complex root systems and, once removed, is difficult if not impossible to reestablish (Peterson and

Boyd 1998). In contrast, lesser prairie-chicken habitat in Kansas is predominantly grasslands, with some areas containing a sand sage (*Artemisia filifolia*) component (Taylor and Guthery 1980a, Van Pelt et al. 2013).

In light of the emphasis on CRP for the recovery of the lesser prairie-chicken (Van Pelt et al. 2013, USFWS 2014) and CRP's unknown benefit in the southern portion of the bird's range, I set out to evaluate its role with the following objectives: 1) assess the seasonal use of grass dominated habitat (CRP) by lesser prairie-chickens in relation to the availability of it and other land cover types within the study area and 2) use resource selection probability functions to determine the effect that vegetation characteristics have on the probability of use of lesser prairie-chickens in New Mexico.

METHODS

Capture

Lesser prairie-chickens were captured using walk-in traps with drift fences (Haukos et al. 1990, Schroeder and Braun 1991) and whoosh nets (Davies 1981) during the spring lekking period (March – May) of 2014 and 2015. Upon capture, the gender and age of each bird was determined using pinnae length, presence of eye comb, and the barring pattern on primaries 9 and 10 (Copelin 1963). All captured lesser prairie-chickens were banded with a uniquely numbered aluminum leg band (National Band and Tag, Newport, KY). Each bird was then weighed and fitted with either a 13 g necklace style very-high-frequency radio transmitter (VHF; American

Wildlife Enterprises, Monticello, FL) or a 22 g solar powered backpack style satellite platform transmitting terminal transmitter (hereafter referred to a GPS transmitter; Microwave Telemetry, Inc., Columbia, MD). VHF transmitters were equipped with a mortality switch that increased the pulse rate from 40 beats per minute to 80 after the transmitter remained stationary for 8 hours. Both transmitter types equated to <3% of the total body weight of each bird, sufficiently below recommended 5% (Caccamise and Hedin 1985).

Tracking and Monitoring

VHF collared lesser prairie-chickens were located 1-4 times per week during the focal period (March 15 – August 31) for both 2014 and 2015. During the non-breeding or winter season (September 1 – March 14), I gathered only locations from GPS collared birds. However, in 2014-15 a concurrent study provided the personnel to collect locations on a subset of my VHF collared individuals, which I included in my analysis.

After a VHF collared bird was located, a minimum of 3 locations and azimuths were taken using a hand held 3 element Yagi and R-1000 telemetry receiver (Communications Specialists, Orange, CA). Locations of fixes were recorded using an eTrex 30 handheld GPS unit (Garmin International Inc., Olathe, KS). I attempted to limit time between fixes to 20 minutes to reduce disturbance and the probability that the bird moved between fixes. Location of a Signal software (LOAS; Ecological Software Solutions, Florida, USA) was used to generate maximum likelihood

estimates of lesser prairie-chicken locations based on the location and azimuth of fixes. If a lesser prairie-chicken was flushed, its location was recorded using a GPS receiver.

If a lesser prairie-chicken was lost at some point during the season for longer than a week, I made an exhaustive search for it radiating out 6 km from its lek of capture. If the bird's signal was not re-acquire, it was considered to have emigrated from the study area or that its transmitter had failed. I continued to opportunistically monitor for lost birds throughout the season as I conducted other field work.

GPS collared birds were tracked using GPS/Argos system. GPS locations were taken every 2 hours between 0400 – 2200 hours resulting in approximately 10 locations per day. This number was variable based on the daily solar charge of each individual transmitter. Locations were downloaded weekly.

Focal Area

For this study I developed a focal area to define "available" habitat for lesser prairie-chickens. The focal area was created by buffering each lek of capture by 6 km. Pruit (2011) found that 97.2% of all bird locations were ≤ 4.8 km from the lek of capture. In 2013, one year prior to the beginning of this project, a sister study in eastern New Mexico observed that a buffer of 6 km from the lek of capture encompassed > 95% of all bird locations (Strong 2016). Given this prior information of lesser prairie-chicken movements, I used a 6 km buffer to define what was "available" to these birds after they ended breeding activities associated with their lek

of capture. I used this focal area to define “available” habitat for broad scale habitat use and resource selection analysis.

Vegetation Sampling

Vegetation sampling was conducted at bird-used and random locations to assess resource selection. This sampling was carried out between July 1 and August 31 in both years. This time period was chosen because at this point breeding and nesting activities were mostly complete and birds began to disperse from the areas immediately around the lek. Locations of bird-used vegetation surveys were determined from VHF or GPS telemetry locations. Available locations were created by generating random points within the focal area (6 km leks). Surveys were conducted at a bird-used and available locations once per week for each bird during the sampling period. Surveys were conducted within 5-10 days from when the telemetry location was collected.

Vegetation surveys consisted of 3 parts. The first was a measure of visual obstruction at the center of the survey. I used a modification of the sampling protocol described by Robel et al. (1970). Readings of 100% obstruction were taken at each of the 4 cardinal directions at a distance of 4 m from the pole with the observer’s eye one meter above the ground. The second part of the survey was an ocular estimate of ground cover. I used a 60×60 cm frame and estimated the percent coverage of shrubs, gasses, forbs, litter, and bare ground to the nearest 5% (Daubenmire 1959). I repeated this 4 times at 4 m from the center of the survey in each of the 4 cardinal directions.

The final part of the survey was an estimate of species composition, vegetation density, and vegetation height. The point-centered quarter method was used to estimate the density of shrubs, forbs, and grasses at each survey location (Mitchell 2007). In each quadrant (NE, SE, SW, NW) I measured the distance and height of the nearest shrub, forb and grass. Density was calculated using equation one from Mitchell (2007). I also identified each shrub, forb, and grass to species in each quadrant.

Remote Sensing

I used remotely sensed satellite images to map the location and extent of land cover types throughout the focal area of the study. Inspection of the study area revealed 6 distinct cover types. These cover types were labeled as: shinnery oak prairie, mesquite (*Prosopis glandulosa*) shrub-land, grassland, dune/well-pad, agricultural land, and developed land. These cover types were defined using the following criteria: shinnery oak prairie if there was >50% shinnery oak coverage within a 15 m radius, mesquite shrub-land if there were >3 mesquite bushes over one meter tall within a 15 m radius, grassland if there was >50% grass coverage within a 15 m radius, dune/well-pad if >50% of the area within a 15 m radius was bare soil or on a well-pad, and agricultural land if >50% of the area within a 15 m radius was plowed or planted with an agricultural crop.

Sample locations were collected from across the study area for spectral training of the classifier. At each location the exact land cover type was determined

by an on the ground visit. The majority of these points were collected opportunistically at locations sampled for vegetation surveys related to the resource selection portion of the study. To ensure that an adequate number of samples was obtained across the entire study area, an additional spatially balanced random sample was generated within the focal area (Jensen 2005). Congalton (1991) suggested that collecting a minimum of 50 samples per cover type was a balance between statistical soundness and logistic feasibility. This was used as a guideline, with additional samples being collected for classes that were of interest for this study (particularly shinnery oak prairie and grassland).

After training samples were obtained, 4 Landsat-8 Operational Land Imager (OLI) scenes were acquired from the U.S. Geological Surveys' (USGS) earth explorer website. All scenes were georectified by the USGS to Standard Terrain Correction Level T1. The dates of these scenes were April 8 (leaf-off) and October 1 (leaf-on) 2014 as well as February 6 (leaf-off) and May 29 (leaf-on) 2015. Using images from multiple scenes is a common technique in remote sensing and usually helps improve the accuracy of supervised classifications (Jensen 2005). I used ENVI (Exelis Visual Information Solutions, Boulder, CO) to radiometrically correct all scenes and conduct all analysis. After each scene was radiometrically corrected, I stacked all 4 scenes and subset them to the study area. I tested using principal components analysis and adding additional textural bands to the 4-month stacked image to improve classification accuracy (Shaban and Dikshit 2001, Hestir 2011). Additional textural bands consisted of entropy, contrast, and homogeneity metrics of

the red (RED) and near infrared (NIR) bands for the 2 growing season (leaf-on) scenes.

Prior to applying any classifiers, all human developed areas were hand digitized from high resolution aerial imagery and excluded. This included ranch houses, corrals, out-buildings, and paved roads. This was done to avoid potential confusion between other cover types because corrals and small out-buildings had spectral signatures similar to that of grassland and mesquite shrub-land. I experimented using 3 supervised classifiers: maximum likelihood (ML), neural network (NN), and support vector machines (SVM). ML classifiers are widely used in land cover classification (Lu and Weng 2007) and have produced highly accurate classifications in other arid regions (Shupe and Marsh 2004). SVM and NN classifiers have the advantage that spectral histograms need not be normally distributed (Candade and Dixon 2004) and can produce better results when non-spectral data are integrated into the classification, such as structural layers (Lu and Weng 2007). I tested these classifiers on different combinations of the principal component image, the 4-month stacked image, and the additional textural bands.

After pre-processing was complete, I ran a preliminary classification using a SVM classifier with only the 4-month stacked image. I used this preliminary classification to generate a separate sample of 200 points to be used for assessing the accuracy of this and any further classifications. The dune/well-pad class took up a very small portion of the focal area which allowed for the approximately 50 points (Congalton 1991) for the remaining 4 classes. These points were split according to the

proportion of the study area that encompassed each cover type. Points were visited on the ground if possible and were assessed from a high resolution 2014 National Agricultural Inventory Program (NAIP) image if a ground visit was not possible (Jensen 2005). Accuracy was measured using error matrices that produced estimates of overall accuracy in addition to user's and producer's accuracy.

Broad Scale Space Use Analysis

Using the land cover map, I conducted an analysis of lesser prairie-chicken use of available cover types in 4 of the 6 categories: shinnery oak prairie, mesquite shrub-land, grassland, and agricultural land. Dune/well-pad and developed land were excluded from this analysis because lesser prairie-chickens show a pattern of avoidance of anthropogenic structures (Pitman et al. 2005, Pruett et al. 2009) and these categories constituted a relatively small portion of the overall study area. I created selection ratios using methods outlined by Manly et al. (2002:46-81). Use was measured at the individual level and habitat availability was measured at the population level (design II; Manly et al. 2002). Selection ratios were calculated for breeding and non-breeding periods for each of the 2 years during the study, resulting in 4 separate seasons for comparison. Selection ratios were calculated individually for each bird and then averaged to create a population level selection ratio with an associated standard error and 95% confidence interval for each season. For each population level selection ratio, Bonferroni simultaneous confidence intervals were calculated for each season using an experiment-wise alpha (α_e) of 0.05 (Manly et al.

2002). Selection ratios greater than one in a given category indicate selection in higher proportion than availability and those less than one indicate selection in lower proportion than was available on the landscape. Categories that have selection ratios with confidence intervals that overlap one are considered to be selected in proportion to their availability.

Resource Selection Analysis

I estimated use and availability of vegetation characteristics for lesser prairie-chickens within the study area. Each week I randomly selected one telemetry location during daylight hours (0600 – 2000) for a subset of my captured birds that I characterized as use locations. Available locations were randomly generated for each bird within a 6 km radius of the lek it was captured on (2nd order selection; Johnson 1980). This produced one use and one available location per week for each of the 6 weeks of the sampling period.

I evaluated vegetation characteristics contributing to habitat selection within my study area. First I tested all vegetation characteristic variables for collinearity. Any variables that had a variance inflation factor (VIF) ≥ 3 in any model were considered to be potentially collinear (Graham 2003). If a variable was flagged as being potentially collinear, I investigated the effects of removing this variable to determine if it was masking the effects of other potentially important variables. If there was an effect, I chose the measure that I felt was most biologically important to lesser prairie-chickens and most accurately represented the vegetation community.

I used a model selection approach by creating an *a priori* set of candidate models (Burnham and Anderson 2002) based on my knowledge of CRP importance in Kansas (Rodgers and Hoffman 2005, Fields et al. 2006, Van pelt et al. 2013) and prior studies conducted in the southern portion of the bird's range (Haukos and Smith 1989, Johnson et al. 2004, Bell et al. 2010). I predicted that grass density, forb density, percentage shrub cover, visual obstruction, grass height, shrub height, forb height, and percentage bare ground would be important variables. Haukos and Smith (1989) found that lesser prairie-chicken hens in Texas selected un-treated shinnery oak that received less grazing pressure. Bell et al. (2010) found that lesser prairie-chickens in New Mexico selected locations based on shinnery oak dominance and overhead cover during high summer temperatures. In Kansas, CRP fields that had forbs interseeded into them had increased use by lesser prairie-chickens (Rodgers and Hoffman 2005, Fields et al. 2006). Hunt and Best (2010) found that lesser prairie-chicken leks that had encroachment of taller shrubs, particularly mesquite, had increased levels of abandonment. Based on these prior studies, I hypothesized that bird use would be positively associated with visual obstruction, percent shrub cover, grass height, and forb density, while shrub height and bare ground would be negatively associated with bird use.

I used a generalized linear mixed-effects model to generate a population level resource selection function to predict relative probability of use of vegetation characteristics within my study area (Manly et al. 2002, Gilles et al. 2006). Models were fit with the software R, v3.2.1 (R Development Core Team 2015) using the

package lme4 (Bates and Maechler 2016). Individual birds were categorized as random intercept effects. This accounts for issues associated with uneven sample sizes, temporal autocorrelation, and variation in selection among individuals (Gilles et al. 2006). I used parametric bootstrapping to create 95% confidence intervals with 10,000 simulations to determine if parameter estimates differed from zero. Bootstrapped confidence intervals are a more conservative approach than traditional confidence estimates (Efron and Tibshirani 1986) and account for potential misspecification of the variance-covariance structure in mixed-effects models (Bolker et al. 2009). I used Akaike's Information Criterion corrected for small sample sizes (AIC_c; Akaike 1974) to evaluate models (Burnham and Anderson 2002). This is appropriate because I was interested in making inferences at the population level and not the individual bird level (Vaida and Blanchard 2005).

RESULTS

Capture

I captured and monitored 31 male and 8 female lesser prairie-chickens during the 2014 breeding season. In 2015 I captured 22 males and 18 females in addition to 16 males and 3 females (38 males and 25 females total monitored for 2015) that survived from the previous year. A total of 18 and 5 birds were monitored in the winters of 2014-15 and 2015-16 respectively.

Remote Sensing

The results from the land cover map estimated that grassland (33,087 ha, 50.2%) and shinnery oak prairie (18,636 ha, 30.0%) covered the majority of the focal area. Mesquite shrub-land (5,208 ha, 8.4%), agricultural land (2,232 ha, 3.6%), dune/well pad (1,826 ha, 2.9%), and developed land (1,215 ha, 2.0%) accounted for a much smaller portion of the focal area. Between the vegetation surveys and the spatially balanced random sample, I collected a total of 848 reference points to train my classifier. I tried 10 different combinations of features and classifiers. The classification that produced the highest overall accuracy was one using a SVM classifier on a 4 time period stacked image with two additional texture layers— a 3×3 moving window contrast layer (RED) and a 7×7 moving window Entropy layer (NIR).

I used a total of 198 points for accuracy assessment. The overall accuracy of this image was 80.3%. Shinnery oak prairie, mesquite shrub-land, and grassland all showed some level of confusion between each other. Shinnery oak prairie and mesquite shrub-land both had several points that were misidentified as grassland. Additionally, grassland also had some points that were classified into the shinnery oak prairie and mesquite shrub-land classes. The producer's accuracy was 86%, 53%, 77%, and 97% for for shinnery oak prairie, mesquite shrub-land, grassland, and agriculture land, respectively. The user's accuracy was 68%, 73%, 81%, and 97% for shinnery oak prairie, mesquite shrub-land, grassland, and agriculture land, respectively.

Broad Scale Selection Analysis

One bird was censored from my broad-scale selection analysis in the breeding season of 2015 because it emigrated out of the study area for a significant portion of the summer. This resulted in a total of 2,135 VHF locations and 20,712 GPS locations for my breeding-season analysis. I censored one other bird from my broad scale selection analysis in the non-breeding seasons of 2014-15 and 2015-16 because it emigrated out of the study area (~10 km from lek of capture) for the majority of the non-breeding season. This resulted in a total of 214 VHF locations and 11,786 GPS locations for my non-breeding season analysis. Of the 6 land cover categories, only shinnery oak prairie had a selection ratio significantly greater than one ($\alpha_e > 0.05$) in all of the four time periods (Fig. 2.2). All other categories were used in lower proportion than they were available on the landscape. The only exception was during the breeding season of 2014 in which the agricultural land was used in proportion to availability (Fig. 2.2c).

Resource Selection Analysis

Used and available vegetation characteristics were collected for 23 different birds in 2014 (20 males, 3 females) and 21 different birds in 2015 (19 males, 2 females). This resulted in a total of 209 use points and 224 available for 2014-2015. Of the 11 *a priori* models, a model that included the additive effects of shrub height, percent bare ground cover, grass density, and percent shrub cover best described lesser prairie-chicken habitat selection (Tables 2.1 & 2.2). Relative probability of bird

use was negatively associated with shrub height, grass density, and percent bare ground cover (Table 2.2, Fig. 2.3a-c), while shrub cover was positively associated with relative probability of bird use (Table 2.2, Fig. 2.3d). None of the 95% bootstrapped confidence levels overlapped zero except for grass density (-0.417, 95% CI= -0.806 – 0.048; Table 2.2).

DISCUSSION

Several studies have shown that CRP can provide seasonally valuable habitat in northern portions of the lesser prairie-chickens range (Rodgers and Hoffman 2005, Fields et al. 2006). The same has not been confirmed in southern portions of the lesser prairie-chicken's range where shrubs, particularly shinnery oak, are a more substantial component of lesser prairie-chicken habitat (Taylor and Guthery 1980a). In Kansas, for example, conversion of native prairie to agriculture and then to CRP results in grassland habitat similar in structure and composition to the vegetation community present pre-settlement. In contrast, conversion of shinnery oak prairie in in eastern New Mexico and western Texas to agriculture for multiple years results in a complete loss of its shinnery oak component (McIlvain 1954, Boyd and Bidwell 2002). Since shinnery oak is difficult to reestablish once eliminated, conversion of agricultural lands into CRP results in a prairie lacking the shrub component that was originally present in the prior vegetation community (Peterson and Boyd 1998).

My analysis of lesser prairie-chicken habitat use revealed that shinnery oak prairie was used in much higher proportion than was available within the study area (Fig. 2.2). This was despite shinnery oak prairie comprising only 30% of the study area. All other cover types were selected for less than or equal to their proportional availability. Of particular interest were selection ratios of less than one in all seasons for the grassland cover type even though it represented 53.2% of the study area. Consequently, throughout the course of this study I observed very few bird locations within current CRP contracts. Several other studies in New Mexico (Johnson et al. 2004, Patten et al. 2005, Bell et al. 2010) and adjacent counties in Texas (Haukos and Smith 1989) also found a strong association between lesser prairie-chickens and shinnery oak cover.

I did observe one season in which lesser prairie-chickens used agricultural land in proportion to its availability (Fig. 2.2a). This was driven by a few individuals in the southeastern portion of the study area that made frequent use of active and fallow agricultural fields for several months during the summer. Some studies have documented the potential positive effect of grain crops to lesser prairie-chickens during the winter (Crawford and Bolen 1976b, Applegate and Riley 1998), but due to the broad-scale effects of habitat fragmentation (Fuhlendorf et al. 2002) and degradation of nesting habitat (Taylor and Guthery 1980a), agriculture has had an overall negative effect on lesser prairie-chicken populations.

I did see a slight but non-significant increase in use of the grassland cover type during the non-breeding season (Fig. 2.2c-d). Davis et al. (1979) and Taylor and

Guthery (1980b) made similar observations, which indicates that areas with higher grass densities may be more important during the winter months. Shinnery oak, like many other oak species, is deciduous (Mayes et al. 1998). The lack of cover after shinnery oak drops its leaves might make areas with higher grass densities more appealing to lesser prairie-chickens since grasses retain their ability to provide escape and thermal cover throughout the non-breeding season.

Selection for shinnery oak prairie during the breeding season was confirmed by my vegetation resource selection analysis. Relative probability of use increased as percent shrub cover increased (Figure 2.3). Not surprisingly, shrub cover at bird-selected locations was driven primarily by shinnery oak (Table 2.3). Patten et al. (2005) had similar results when they compared microsite selection in New Mexico and Bell et al. (2010) found that hens with broods selected shinnery oak cover at fine scales during periods of high temperatures. Resource selection analysis for this study was conducted during the two hottest months of the summer which may indicate that lesser prairie-chickens were selecting shinnery oak shrub cover for thermal refuge.

Shrub height, however, had a negative relationship with selection. Shrub heights in the grassland cover type were higher than those in shinnery oak prairie (Fig. 2.4b). Shrub heights measured at random locations and those that I surveyed within CRP fields were primarily driven by an abundance of soapweed yucca (*Yucca glauca*) which grows to heights of 1-2 m (Table 2.3). Other tall shrubs like mesquite, present at random sites, have a negative association with lesser prairie-chicken use (Hunt and Best 2010, Strong 2016). Shinnery oak was the primary driver of shrub

heights in shinnery oak prairie (Table 2.3) and typically grows no higher than 30-60 cm (Peterson and Boyd 1998).

Grass density and percent bare ground were both negatively associated with relative probability of use. Grass densities were typically higher in grassland than in the shinnery oak prairie cover type on my study area (Fig. 2.4d). Grass cover provides less thermal refuge during periods of high temperature than shinnery oak (Bell et al. 2010) and many CRP fields in my study area had dense stands of weeping lovegrass (Table 2.3; Ripper et al. 2008). Weeping lovegrass is generally recognized as undesirable habitat for lesser prairie-chickens because it does not allow birds to conveniently move across the landscape at ground level. In contrast, grass densities were lower in shinnery oak prairie (Fig 2.4d). A combination of grasses at lower densities and shinnery oak at higher densities can provide overhead cover from predators and solar radiation while still providing spaces for birds to move underneath a vegetative canopy.

The results of my broad scale habitat use and resource selection analysis highlight the important differences in habitat use and selection between the northern and southern portions of the lesser prairie-chicken's range. It is well known that shinnery oak prairie is a key component of lesser prairie-chicken habitat in New Mexico (Hagen et al. 2004). The irreversible effects of converting shinnery oak prairie to agriculture underscores the fundamental differences between conversion of agricultural lands to CRP in Kansas versus New Mexico to create lesser prairie-chicken habitat. In the northern portion of the lesser prairie-chicken's range, CRP

provides a return to a relatively native vegetation state. In New Mexico, CRP along with chemical shrub treatments, convert a shinnery oak prairie into a grass monoculture that does not include a shinnery oak component or resemble a native shinnery oak prairie (Peterson and Boyd 1998). The findings of my study that shinnery oak dominated habitat is used at a much higher proportion to its availability than grassland habitat suggest that emphasizing CRP for lesser prairie-chicken habitat in New Mexico may not be the best road to recovery and conservation of this species in this region.

MANAGEMENT IMPLICATIONS

My research indicates that shinnery oak prairie is a key component of lesser prairie-chicken habitat in New Mexico. Contrary to other parts of the bird's range, New Mexico still contains a relatively large amount of undeveloped rangeland. Management in this region should focus on the preservation and enhancement of existing native shinnery oak prairie since this fragile habitat is difficult to recover once lost. The policy of emphasizing CRP in this region as a tool for lesser prairie-chicken recovery should perhaps be targeted to areas where large expanses of agriculture dominate the landscape and native rangeland no longer exists. Texas, in general, has a much higher density of agriculture than New Mexico. Accordingly, Texas may be a better area to focus efforts to increase CRP contracts in this southern portion of the lesser prairie-chicken's range as this area has lost most of its shinnery oak prairie and is dominated by agricultural development. If CRP contracts are

acquired in the southern portion of the lesser prairie-chicken's range, plantings need to be managed for structure and species composition that promote lesser prairie-chicken occupancy. Plantings that consist of native grass species and a proper mix of forbs should be preferred for any new CRP contracts. Conversion of non-native CRP contracts to a heterogeneous mix of native grasses and forbs may also increase the value of this habitat for lesser prairie-chickens.

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Table 2.1. Results of model selection for generalized linear mixed-effects models predicting habitat selection of lesser prairie-chickens within study area during the post-lekking period 2014-2015 near Milnesand, NM, USA.

Model	K[b]	ΔAIC_c[c]	w_i
shrub height + bare ground cover + grass density + shrub cover	6	0.00	0.89
GLOBAL[a]	11	4.28	0.10
shrub height + shrub cover + grass density	5	11.21	0.00
shrub height + shrub cover + grass density + shrub height*shrub cover	6	11.37	0.00
grass density + shrub cover + grass density*shrub cover	5	18.84	0.00
bare ground cover + grass density + bare ground cover*grass density	5	36.67	0.00
grass density + grass height + forb density + bare ground cover	6	37.44	0.00
grass density	3	72.31	0.00
shrub height	3	74.79	0.00
grass density + forb density + grass density*forb density + VOR[e]	6	76.72	0.00
INTERCEPT ONLY[d]	2	86.00	0.00

[a]Global model included: shrub height + grass density + grass height + forb density + forb height + VOR + bare ground cover + shrub cover + grass density*shrub cover
[b]K = number of parameters in the model
[c]AICc for the top model was 517.77
[d]model including only a fixed and random intercept for a benchmark comparison
[e]Visual obstruction reading

Table 2.2. Estimated coefficients for the top model of a generalized linear mixed-effects resource selection model predicting habitat selection by lesser prairie-chickens in eastern New Mexico, USA.

		95% Confidence Interval[a]	
Variable	Estimate	Lower	Upper
Intercept	-0.194	-0.412	0.051
shrub height	-0.946	-1.528	-0.297
bare ground cover	-0.471	-0.732	-0.186
grass density	-0.417	-0.806	0.048
shrub cover	0.572	0.296	0.822

[a]Confidence intervals were calculated using parametric bootstrapping with 10,000 simulations

Table 2.3. Composition of shrub and graminoid species by percent in vegetation surveys within shinnery oak prairie and grassland cover types in eastern New Mexico, USA.

Species		Shinnery Oak Prairie[a]	Grassland[b]
Shrubs			
	Yellow sundrops (*Calylophus serrulatus*)	1	25
	Broom snakeweed (*Gutierrezia sarothrae*)	6	33
	Shinnery oak (*Quercus havardii*)	89	8
	Soapweed yucca (*Yucca glauca*)	2	29
	Other[c]	1	4
	Total	**100**	**100**
Graminoids			
	Big bluestem (*Andropogon gerardii*)	7	-
	Pruple threeawn (*Aristida purpurea*)	4	11
	Hairy grama (*Bouteloua hirsuta*)	10	-
	Oneflower flatsedge (*Cyperus retroflexus*)	3	5
	Fall witchgrass (*Digitaria pubiflora*)	10	-
	Weeping lovegrass (*Eragrostis curvula*)	2	43
	Thin paspalum (*Paspalum setaceum*)	13	5
	Little bluestem (*Schizachyrium scoparium*)	13	6
	Sand dropseed (*Sporobolus cryptandrus*)	24	4
	Other[d]	14	25
	Total	**100**	**100**

[a]209 total surveys were conducted in shinnery oak prairie

[b]119 total surveys were conducted in the grassland cover type. Only fields within 3 km of active leks were surveyed

[c]7 different shrub species. All comprised less than 5% of the total in either set of surveys

[d]20 different graminoid species. Each of the 20 species comprised less than 5% of the total in either set of surveys

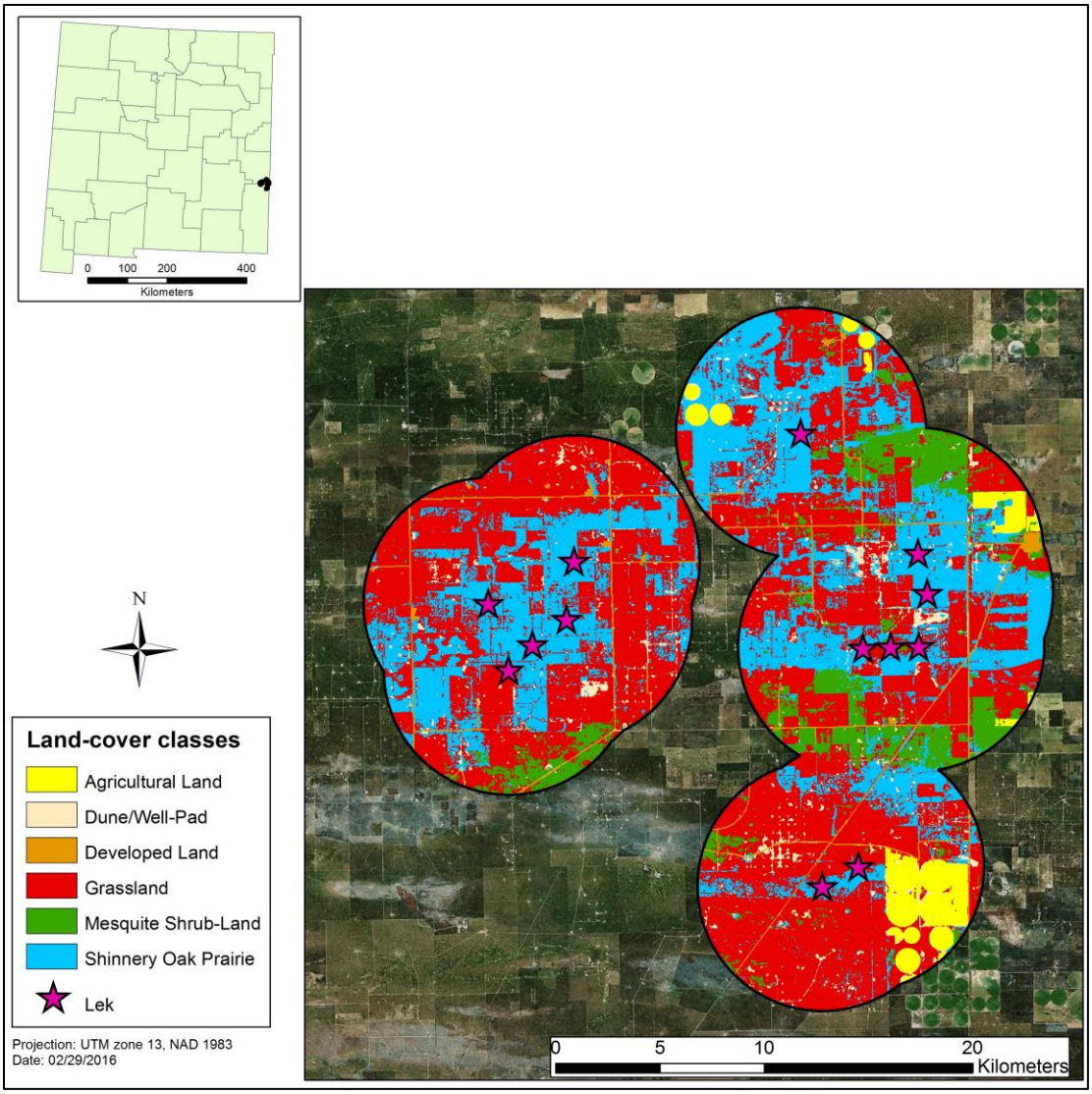

Figure 2.1 Study area map showing the results of a supervised classification and lesser prairie-chicken lek locations in eastern New Mexico, USA.

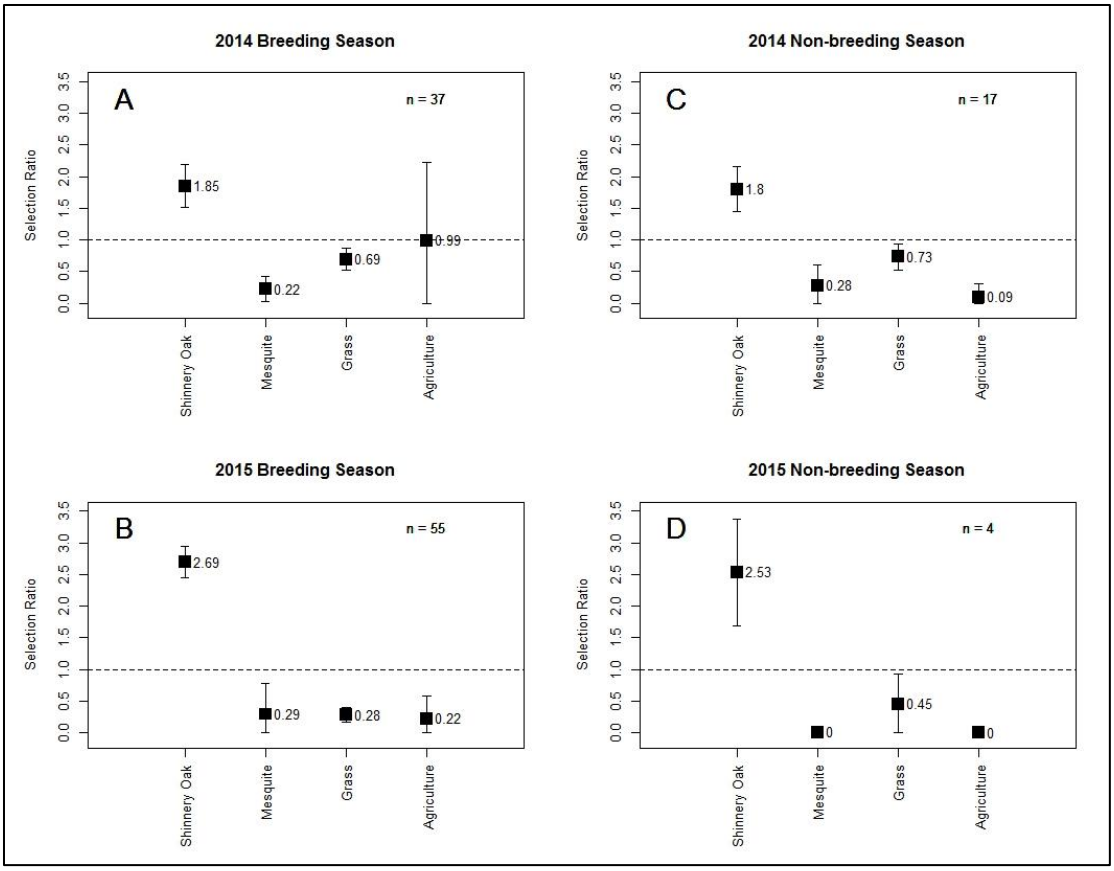

Figure 2.2. Selection ratios and confidence intervals ($\alpha_e = 0.05$) of lesser prairie-chickens for 4 cover types identified within the study area in eastern New Mexico, USA. Selection ratios >1 indicate a cover type was selected in higher proportion than available while those <1 indicate a cover type was selected in lower proportion than available. Shinnery oak was selected in higher proportion than available in all seasons.

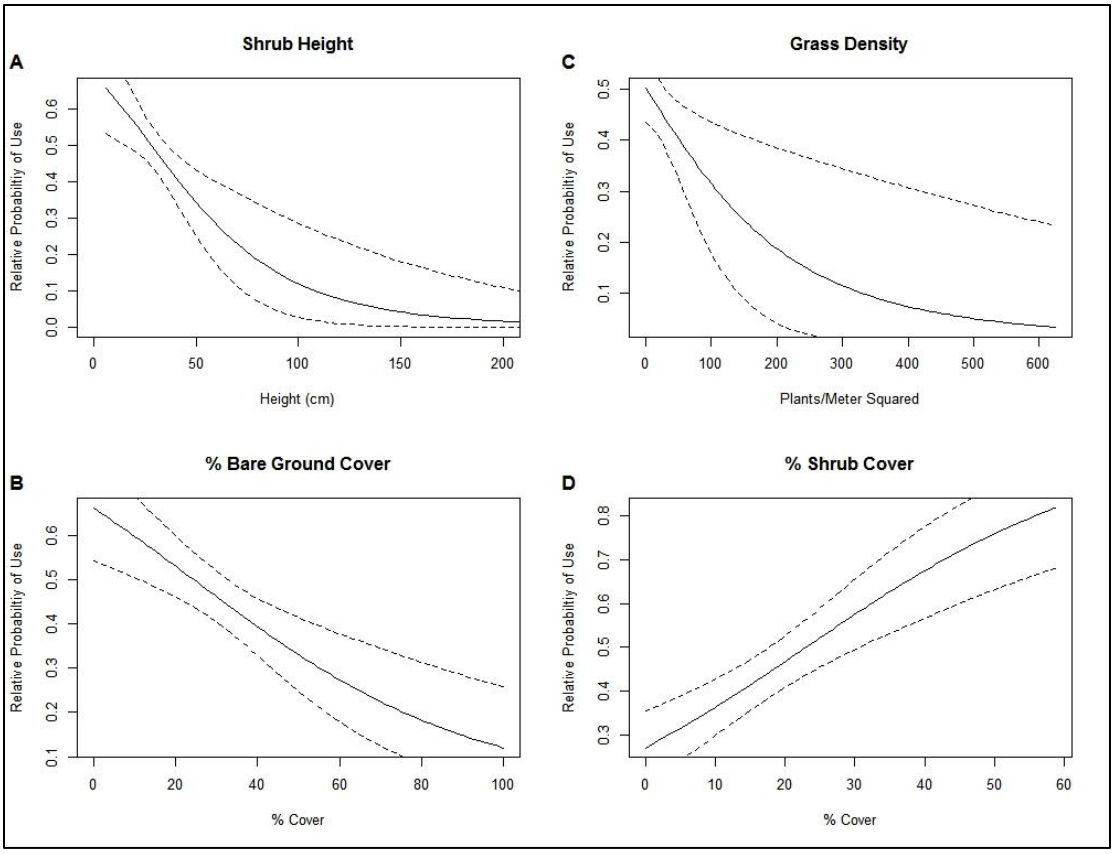

Figure 2.3. Relative probability of use (solid line) with 95% bootstrapped confidence intervals (dashed lines) as a function of four modeled covariates predicting resource selection by lesser prairie-chickens in eastern New Mexico, USA. Shrub height (A), grass density (B), and % bare ground (C) all show decreasing relative probability of use with increasing height, density, and % bare ground, respectively. As shrub cover (D) increases, relative probability of use increases.

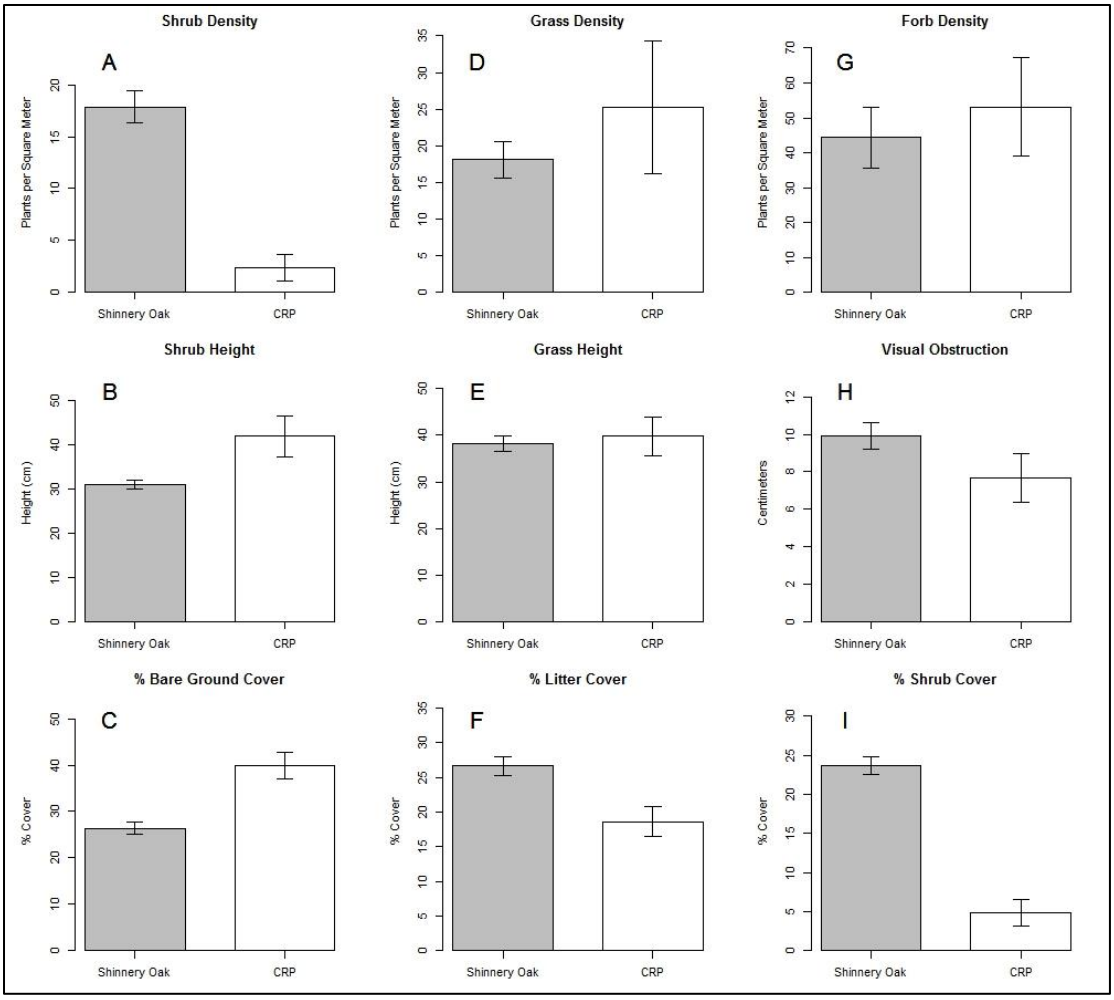

Figure 2.4. Vegetation metrics measured between CRP/grasslands and native shinnery oak prairie in eastern New Mexico, USA. Shrub density (A), visual obstruction (H), % litter cover (F), and % shrub cover (I) were all higher on shiner oak prairie than on CRP/grassland dominated sites. Shrub height (B) and % bare ground (C) were all higher on CRP/grassland dominated than shinnery oak prairie dominated sites. Forb densities (G), grass densities (D), and grass height (E) did not differ between sites. Data are presented as mean with a 95% confidence interval.