Understanding the Ecology of Lesser Prairie-Chickens in Conservation Reserve Program-Dominated Landscapes, With Implications Towards Lesser Prairie-Chicken Management in Texas

by

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ABSTRACT

Lesser prairie-chickens (*Tympanuchus pallidicinctus*) occur in mixed-grass prairies in the Southern Great Plains of North America. Conversion of native prairie to agriculture, energy development, unmanaged grazing, and recurrent drought have substantively reduced the lesser prairie chicken's geographic range and abundance, and the species has become a significant conservation priority in recent years. Grasslands enrolled in the federal Conservation Reserve Program (CRP) provide cover for lesser prairie-chickens during the nesting and brood-rearing seasons in the Shortgrass Prairie/CRP ecoregion of their range, which has led to population increases. Lesser prairie-chicken males are known to boom and display in CRP fields in the High Plains of Texas, but little is known about the species' ecology within CRP in the Sand Shinnery Oak Prairie ecoregion of its range. I investigated lesser prairie-chicken habitat selection, nest survival and ecology, and male and female survival in order to assess the effectiveness of CRP as a tool for prairie-chicken conservation in Texas. I captured 19 male and 6 female lesser prairie-chickens within CRP fields in Bailey and Cochran Counties, Texas during the years 2015-2017. I equipped each individual with a GPS platform transmitter terminal (PTT), which recorded 4 GPS locations per day at ± 18 m accuracy. I used selection ratios to assess lesser prairie-chicken selection between different CRP enrollments, native grassland, and agricultural fields for the breeding and non-breeding seasons, at the second and third orders of selection. At the second order of selection, lesser prairie-chickens selected Conservation Reserve Program fields seeded in non-native grasses (w_i = 4.16, 95% CI=1.92 – 6.39) and native grasses and forbs (w_i = 3.57, 95% CI=2.41 – 4.73) year-round. Cropland (w_i = 0.17, 95% CI=0.07 – 0.27) and

native grassland (w_i = 0.27, 95% CI=0.05 – 0.49) were avoided, and native grass Conservation Reserve Program fields were used in proportion to their availability (w_i = 1.24, 95% CI=0.80 – 1.68) year-round. Only Conservation Reserve Program fields seeded in native grasses and forbs were selected at the third order of selection (w_i = 1.33, 95% CI=1.18 – 1.49). I monitored 8 lesser prairie-chicken nests during the course of the study, and all but one were located within CRP fields. I used the nest survival model within Program MARK to estimate nest survival within my study area. Apparent nest success was 50%, and the probability of a nest surviving the incubation period was 0.49 (95% CI = 0.16-0.77). I recorded 16 mortalities during the course of my study, and the majority were attributed to mammalian depredation (63%). Most mortality events (63%) occurred during the second half of the breeding season (June – August). I used known-fate models within Program MARK to estimate lesser prairie-chicken survival for the breeding and non-breeding seasons. The probability of a lesser prairie-chicken surviving the breeding season was 0.61 (SE = 0.08, 95% CI = 0.44-0.78), and the probability of an individual surviving the non-breeding season was 0.82 (SE = 0.11, 95% CI = 0.50-0.95). Survival increased as the proportion of native grass and forb CRP within the home range increased. Based on my results, CRP fields benefit lesser prairie-chickens in the High Plains of Texas. Lesser prairie-chicken home ranges included CRP fields, and my estimates of nest survival and adult survival are consistent with previous studies. Despite the benefits of CRP fields, lesser prairie-chicken abundance within CRP in Texas is currently low. Populations are still recovering from the severe drought of 2011. Also, CRP fields constitute approximately 17% of the study area, and they are often isolated and too small to individually support prairie-chickens. Adding new CRP fields adjacent

to existing fields and targeting large agricultural fields for enrollment will increase CRP patch size and serve to connect the lesser prairie-chicken population across the High Plains of Texas. Based on my results, an aggregation of CRP fields totaling 2,500 ha will support multiple LEPC leks. Also, maintaining CRP fields in grasses after contract expiration and actively managing expired fields for prairie-chickens will benefit the species in the distant future.

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CHAPTER I
INTRODUCTION

LITERATURE REVIEW

Geographic Distribution

The lesser prairie-chicken (*Tympanuchus pallidicinctus*, hereafter LEPC) is a lekking prairie grouse of the southern Great Plains of North America. The species' geographic range has been significantly reduced over the last century, and it now inhabits portions of Colorado, Kansas, Oklahoma, Texas, and New Mexico (Crawford 1980, Bailey and Williams 2000, Sullivan et al. 2000, Van Pelt et al. 2013). The reduction in LEPC range has been attributed primarily to habitat loss and fragmentation through conversion of native prairie to agriculture, unmanaged grazing, recurrent drought, woody plant encroachment, and energy development (Henika 1940, Woodward et al. 2001, Hagen and Giesen 2005). The current LEPC occupied range is approximately 80,000 km^2 in area (Van Pelt et al. 2013).

Lesser prairie-chickens inhabit four habitat ecoregions throughout their geographic range (Van Pelt et al. 2013, McDonald et al. 2016). The different ecoregions include: 1) sand shinnery oak (*Quercus havardii*) prairie in eastern New Mexico and the Southern High Plains of Texas, 2) sand sagebrush (*Artemisia filifolia*) prairie in southeastern Colorado, southwestern Kansas, and the western Panhandle of Oklahoma, 3) mixed-grass prairie in south central Kansas, northwest Oklahoma, and northeast Texas, and 4) shortgrass prairie/Conservation Reserve Program (CRP) mosaic in northwestern Kansas. Individuals in the shinnery oak prairie ecoregion have been found to be both geographically and genetically isolated from individuals in the other three ecoregions (Hagen et al. 2010).

Habitat

Lesser prairie-chicken habitat is characterized by prairies composed of mid- and tall grass species and short statured shrubs. Often these prairies are found in areas with sandy soils, which support taller and more structured vegetation compared to shortgrass prairie (Haukos and Zavaleta 2016). The sand shinnery oak prairie ecoregion constitutes the southwest portion of the LEPC range. The plant community within shinnery oak prairie is comprised of sand shinnery oak and sand sagebrush, as well as various mid- to tall grasses. Common grass species include sand and big bluestem (*Andropogon hallii*, *A. gerardii*), little bluestem (*Schizachyrium scoparium*), dropseeds (*Sporobolus* spp.), and purple three-awn (*Aristida pururea*, Grisham et al. 2016). The sand sagebrush prairie ecoregion constitutes the northwestern portion of the LEPC range, and the plant community is comprised of sand sagebrush, as well as sand and little bluestem, switchgrass (*Panicum virgatum*), and prairie sandreed (*Calamovilfa longifolia*, Haukos et al. 2016). Shrubs are more important in LEPC ecology in the western portion of the species' range, due to reduced amount and reliability of precipitation progressing east to west across the Great Plains (Haukos and Zavaleta 2016).

The mixed-grass prairie and shortgrass prairie/CRP ecoregions constitute the northeastern portion of the LEPC range. The mixed-grass prairie is comprised mainly of perennial grasses with mixed sand sagebrush, shinnery oak, sand plum (*Prunus* spp.), sumac (*Rhus* spp.), and yucca (*Yucca* spp., Hagen et al. 2004). Native prairie within the shortgrass/CRP ecoregion is comprised of buffalo-grass (*Buchloe dactyloides*), blue grama (*Bouteloua gracilis*), sideoats grama (*B. curtipendula*), little bluestem, sand dropseed (*Sporobolus cryptandrus*), and western wheatgrass (*Pascopyrum smithii*,

Dahlgren et al. 2016). Conservation Reserve Program fields in this region and throughout Kansas are comprised of native grass species such as big and little bluestem, Indian grass (*Sorghastrum nutans*, switchgrass, and sideoats grama, as well as numerous native forbs (Dahlgren et al. 2016). Fields enrolled in CRP provide necessary nesting habitat within the shortgrass/CRP ecoregion, while native rangeland is used more for brood-rearing (Fields 2004).

Much of the current LEPC occupied range is fragmented and composed of a matrix of native rangeland, cropland, and land enrolled in CRP. Several studies have examined LEPC habitat selection within landscapes with various land uses and vegetation cover types (Jamison 2000, Fields 2004, Toole 2005, Kukal 2010, Pirius et al. 2013, Borsdorf 2013). Male LEPCs showed selection for native sand sagebrush prairie and selection against cropland, CRP land, and native grassland in southwestern Kansas (Jamison 2000). Wintering LEPCs in northeastern Texas selected grasslands with less than 15% canopy cover of shrubs (Kukal 2010). Toole (2005), also working in northeast Texas, found that LEPCs selected native rangeland over cropland and CRP land, with over 85% of the area used by LEPCs being rangeland.

Population Status

Lesser prairie-chicken populations have declined significantly over the last 100 years due to habitat loss and recurrent drought. One estimate of the population decline is 97% range-wide since the late 1800s (Crawford 1980). Within Texas, past estimates of LEPC abundance include up to two million individuals before 1900, 12,000 in 1937, and between 11,000 – 18,000 in 1979 (Litton 1978, Texas Game, Fish, and Oyster Commission 1945, and Crawford 1980 respectively). However, Timmer et al. (2013)

calculated a population estimate of 1,822 LEPCs throughout Texas, with a density of only 0.12 birds/ha. The 19th century estimate of two million LEPCs throughout Texas is improbable, but it still shows the marked decline of LEPCs across the state (Davis et al. 2008).

Based on aerial surveys, the range-wide LEPC population dropped to approximately 19,000 individuals in 2013 after two years of drought across the southern Great Plains and increased to approximately 26,000 individuals in 2016 (McDonald et al. 2016). Due to significant range and population declines, LEPCs were listed as threatened under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service 2014) in May of 2014. However, the listing ruling was vacated by judicial decision in September of 2015, and the species was removed from the Endangered Species List in July of 2016.

Movements and Home Ranges

Daily movement distances and space use of LEPCs differ seasonally and by ecoregion. Varying space use is attributed to behavioral activities (e.g. nest searching vs. incubation, Riley et al. 1994) and resource variability within seasons (Sell 1979). Home range size and daily movements are also influenced by drought conditions, with larger home ranges and longer daily movements occurring during drought periods (Merchant 1982). In Kansas and Colorado, Plumb (2015) recorded LEPC females moved on average 2074 m/day during the nest searching period and only 780 m/day during brooding. For the cumulative breeding season, females moved on average 1352 m/day and had an average home range size of 340 ha. In the Southern High Plains of Texas, LEPC females had an average home range size of 671 ha for the cumulative breeding season, almost double the estimate from the northeast portion of the LEPC range (Borsdorf 2013).

Male LEPCs generally have smaller home ranges and move less than females during the breeding season. More space use by females is attributed to nest site searching and dispersal after failed nest attempts (Borsdorf 2013). In southwest Kansas, male LEPC daily movements were longest during March (range between 435 and 786 m/day) and shortest during May through September (range between 140 and 365 m/day). Male home range size ranged from 12 to 140 ha during April and May, when males were displaying on leks, and remained small throughout the summer, with a range of 77-144 ha (Jamison 2000). Average breeding season home range size was 306 ha for LEPC males in the Southern High Plains of Texas (Borsdorf 2013).

Space use by LEPCs increases during the non-breeding season and is often similar between sexes. Male home ranges increased to 229-409 ha during the winter in southwest Kansas (Jamison 2000). Average home range size was 503.5 ha for females and 489.1 ha for males during the non-breeding season in Sand Shinnery Oak Prairie in Texas (Pirius et al. 2013). In Kansas, Colorado, and New Mexico, female home ranges averaged 986 ha for the non-breeding season, and male home ranges averaged 904 ha (Robinson 2015).

Nest Ecology and Survival

The persistence of LEPC populations is influenced directly by nest survival (Pitman et al. 2006, Hagen et al. 2009). Nests are usually located near leks (Giesen 1994, Applegate and Riley 1998, Hagen et al. 2004) and are placed in areas with moderate visual obstruction averaging 2-3 dm (Lautenbach 2015). Residual grasses often characterize nest sites (Riley et al. 1992, Giesen 1994, Fields 2004, Davis 2009, Lyons et al. 2011). Within native prairies, grasses such as purple three-awn (*Aristida purpurea*), bluestems (*Schizachyrium scoparium* and *Andropogon* spp.) and dropseeds (*Sporobolus*

spp.) are most often used for nest substrates (Suminski 1977, Haukos and Smith 1989, Riley et al. 1992, Fields 2004, Jones 2009). Shrubs are also utilized when grass cover is reduced due to unmanaged grazing, fire suppression, and drought (Giesen 1994, Johnson et al. 2004, Davis 2009, Grisham et al. 2014). Although the type of nest substrate is important, vegetation structure is likely the most important predictor of nest site selection (Hagen et al. 2013). A lack of visual obstruction in prairies dominated by sand shinnery oak has been attributed to limiting nest survival in the Southern High Plains of Texas (Grisham et al. 2014). However, light herbicide applications that reduce shinnery oak cover and promote native grass growth negate the limitation of visual obstruction on nest survival (Fritts et al. 2016).

Overall grass cover is greatest at nests in native prairie with interspersed CRP (Hagen et al. 2013). Fields (2004) found that nests placed in CRP fields had a higher grass percentage than nests placed in native rangeland. Nests within CRP also had taller vegetation than surrounding native rangeland. Overall, both grass and grass/forb CRP fields had a greater abundance of bunchgrasses than native rangeland and cropland, and these two cover types were the only types used in greater proportion to their availability for nesting (Fields 2004).

Adult and Sub-adult Survival

Lesser prairie-chicken adult and sub-adult survival is generally lower during the breeding season compared to the non-breeding season (Hagen et al. 2007, Wolfe et al. 2007, Jones 2009, Lyons et al. 2009). Increased male mortality during the breeding season is attributed to conspicuousness on the lek and increased energy costs associated with breeding (Hagen et al. 2005, Wolfe et al. 2007). Male survival was found to be

lower during the latter part of the breeding season in the Texas Southern High Plains (Grisham and Boal 2015). Lower survival in the later months of the breeding season was a result of intense breeding activities as well as drought (Grisham and Boal 2015). Higher female mortality during the breeding season is associated with searching for suitable nest sites, incubation, and brooding chicks (Haukos et al. 1988, Hagen et al. 2007, Wolfe et al. 2007, Grisham 2012).

Conservation Reserve Program

Due to substantial range and population declines, much effort has been put into finding conservation practices that will increase both habitat quantity and quality for LEPCs. One such practice is CRP, which was initiated under the Federal Food Security Act of 1985 and resulted in 14 million ha of marginal croplands being seeded to grasses and other permanent vegetation (Rodgers and Hoffman 2005). Although the main goal of the program was to prevent soil erosion, many wildlife species have benefitted from the conversion of cropland back to grasses.

The implementation of CRP had varying effects on LEPC populations. In Kansas, there was a strong population increase and range expansion after CRP was implemented (Rodgers 1999, Rodgers and Hoffman 2005). Grassland area within the LEPC range in Kansas increased by 11.9% from 1985 to present, and Kansas grasslands are now more connected and less fragmented due to CRP (Spencer et al. 2017). Initial fields in Kansas were planted in native, warm season grasses and later interseeded with native forbs, which differed from CRP fields in many other areas of the LEPC range (Fields 2004, Rodgers and Hoffman 2005, Davis et al. 2008, Ripper et al. 2008). Early CRP fields in Colorado were also seeded in native grasses, but sideoats grama (*Bouteloua curtipendula*)

eventually dominated the stands, creating a monoculture (Rodgers and Hoffman 2005, Davis et al. 2008).

Most of the early CRP fields in New Mexico, Oklahoma, and Texas were planted in monocultures of non-native grasses such as weeping lovegrass (*Eragrostis curvala*), Caucasian bluestem (*Bothriochloa bladhii*), yellow bluestem (*B. ischaemum*), and klinegrass (*Panicum coloratum*) (Sullivan et al. 2000, Rodgers and Hoffman 2005, Davis et al 2008). LEPCs in general did not experience population growth or range expansion as a result of initial CRP plantings in New Mexico, Oklahoma, and Texas (Rodgers and Hoffman 2005, Davis et al. 2008). Only until recently, almost 30 years after the implementation of CRP, have LEPCs been believed to utilize CRP lands in the Southern High Plains of Texas. This is likely a result of CRP fields aging and becoming more populated with native species, as well as new fields being initially seeded in native grasses and forbs (Applegate and Riley 1998, Sullivan et al. 2000, Davis et al. 2008).

Lesser prairie-chicken leks have been documented within CRP fields in Bailey County and the northern portion of Cochran County in the High Plains of Texas. However, nothing is known about LEPC space use, nesting ecology, survival, and selection between different CRP types in this portion of the species' range. The goal of my study was to fill in knowledge gaps regarding LEPC ecology in CRP in Texas and to assess how CRP can complement management efforts within sand shinnery oak prairie in Texas.

THESIS FORMATTING

Each chapter in this thesis is an independent manuscript and meant to facilitate future publication of results. Chapters contain redundancies in introduction, study area,

and methods since they are meant to be stand-alone documents. The chapters are formatted to meet the guidelines for The Journal of Wildlife Management. All methods were approved under Texas Tech University Animal Care and Use protocol #14073-10.

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CHAPTER II

MULTISCALE HABITAT SELECTION OF LESSER PRAIRIE-CHICKENS IN AN AGRICULTURE/CONSERVATION RESERVE PROGRAM LAND MATRIX

ABSTRACT The lesser prairie-chicken (*Tympanuchus pallidicinctus*) has received considerable attention in recent years, due to population declines and the uncertainty of its status on the U.S. Endangered Species Act. Substantial effort is being put into studying the life history of the species and the effects of management practices on its ecology. However, there is still a lack of information addressing 1) if lesser prairie-chickens select Conservation Reserve Program fields for their daily activities and 2) how the species selects these areas considering their availability on the landscape. The goal of this chapter was to assess if Conservation Reserve Program lands are lesser prairie-chicken habitat via habitat selection analyses, and if so, guide future management to create and/or connect these areas for the species' benefit. I assessed habitat selection of lesser prairie-chickens within Conservation Reserve Program fields in Texas using selection ratios after quantifying the amount and arrangement of different cover types (including Conservation Reserve Program fields) across the study area. I assessed habitat selection using a Type II design at the second order of selection and a Type III design at the third order. My landscape analysis found Conservation Reserve Program fields constituted 17% of the study area and all fields enrolled in the program were smaller than the species' traditional suggested minimum patch size requirement (4,900 ha). At the second order of selection, lesser prairie-chickens selected Conservation Reserve Program fields seeded in non-native grasses (w_i = 4.16, 95% CI=1.92 – 6.39) and native grasses and forbs (w_i = 3.57, 95% CI=2.41 – 4.73) year-round. Cropland (w_i = 0.17, 95% CI=0.07 – 0.27) and native grassland (w_i = 0.27, 95% CI=0.05 – 0.49) were avoided, and

native grass Conservation Reserve Program fields were used in proportion to their availability (w_i = 1.24, 95% CI=0.80 – 1.68) year-round. Only Conservation Reserve Program fields seeded in native grasses and forbs were selected at the third order of selection (w_i = 1.33, 95% CI=1.18 – 1.49). Based on my results, Conservation Reserve Program fields smaller than the recommended 4,900 ha patch size requirement were habitat for lesser prairie-chickens, and as such, may be beneficial to the species on the High Plains of Texas.

KEY WORDS Conservation Reserve Program, habitat selection, lesser prairie-chicken, Texas, *Tympanuchus pallidicinctus*

The lesser prairie-chicken (*Tympanuchus pallidicinctus*, hereafter LEPC) occupies portions of Colorado, Kansas, New Mexico, Oklahoma, and Texas, in the southern Great Plains of North America. The species' occupied range has declined by an estimated 90% since 1900, due to substantial habitat loss and degradation (Hagen et al. 2004). The factors contributing to habitat loss include conversion of native prairie to agriculture, energy development, woody plant encroachment, and unmanaged grazing (Woodward et al. 2001, Hagen and Giesen 2005). Much of the habitat converted to agriculture was lost prior to the 1950s, but the development of center pivot irrigation in the 1960s allowed for the conversion of areas previously unsuitable for crop production (Spencer et al. 2017). Lesser prairie-chickens are now found in 2 geographically isolated populations in 4 habitat ecoregions. One population is located within the shinnery oak (*Quercus havardii*) prairie ecoregion on the Southern High Plains of New Mexico and Texas. The other population is located in the sand sagebrush (*Artemesia filifolia*) prairie ecoregion in southeastern Colorado, southwestern Kansas, and the western Panhandle of

Oklahoma, the mixed-grass prairie ecoregion in south central Kansas, northwest Oklahoma, and northeast Texas, and shortgrass prairie/Conservation Reserve Program ecoregion in northwestern Kansas (Van Pelt et al. 2013).

Loss of habitat and recurrent drought have resulted in significant LEPC population declines (Hagen and Giesen 2005). Prominent droughts across the southern Great Plains occurred during the 1930s, ‘50s, and early ‘90s, and all contributed to LEPC declines (Sullivan et al. 2000). More recently, the drought of 2011 had significant effects on LEPC populations, particularly in the shinnery oak prairie ecoregion (McDonald et al. 2014). Less than 2,000 LEPCs were estimated to remain within both portions of the species’ range in Texas (Timmer et al. 2013). Range-wide, the estimated LEPC population was approximately 26,000 individuals in 2016, with the majority of individuals occurring in the shortgrass prairie/CRP ecoregion in Kansas (McDonald et al. 2016). Due to significant range and population declines, LEPCs were listed as threatened under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service 2014) in May of 2014, but the listing ruling was vacated by judicial decision in September of 2015.

Lesser prairie-chickens are found in prairies characterized by tall and mid-grasses and small shrubs, which are often supported by sandy soils (Haukos and Zavaleta 2016). The traditional thought is LEPCs require large, unfragmented patches of prairie (4,900 – 20,236 ha) to sustain a population, mostly due to seasonal habitat needs (Applegate and Riley 1998, Davis 2005). Habitat requirements for LEPCs include open areas for male display, areas with a mixture of tall grasses and shrubs for nesting, grass and forb-dominated areas with overhead cover for brood rearing, and grass and shrub-dominated areas close to grain fields for fall and winter (Taylor and Guthery 1980, Applegate and

Riley 1998, Hagen et al. 2004). Much of the current LEPC occupied range is fragmented and composed of intensive agriculture, native grasslands, and lands enrolled in CRP (Rodgers 2016).

The CRP was initiated under the Federal Food Security Act of 1985, in an effort to reduce soil erosion. Numerous wildlife species, including LEPCs, have benefitted from the conversion of marginal croplands back to grasslands through CRP. The LEPC range within Kansas has expanded north of the Arkansas River due to the implementation of CRP (Rodgers and Hoffman 2005), and CRP fields in northwest Kansas provide nesting habitat in a matrix of shortgrass prairie and cropland (Fields 2004). Lesser prairie-chicken use of CRP is typically greater during drought years and in the drier, western portions of the species' range (Fields 2004, Sullins 2017).

Lesser prairie-chickens are known to inhabit CRP fields in the shinnery oak prairie ecoregion of the LEPC range and are part of a genetic metapopulation of LEPCs across the Southern High Plains of Texas and eastern New Mexico (Oyler-McCance et al. 2016). However, few studies have examined how lesser prairie-chickens select CRP fields in context of their availability on the landscape in this ecoregion. The objectives of my study were to 1) calculate the proportion of agricultural land, CRP land, and native grassland across the study area, 2) quantify average CRP field size, and 3) examine LEPC selection among agricultural land, native grassland, and different CRP enrollment types. I hypothesized that intensive agriculture would comprise the majority of the landscape and that most CRP fields would be smaller than the recommended patch size requirement for LEPCs (4,900 – 20,236 ha; Haukos and Zavaleta 2016). I also hypothesized LEPCs

would select CRP fields seeded in native grasses and forbs over CRP fields seeded in non-native grasses and agricultural fields (Fields 2004, Rodgers and Hoffman 2005).

STUDY AREA

This study took place on private lands in Bailey and Cochran Counties within the Southern High Plains of Texas (33º52'N, 102º58'W; Figure 2.1). The landscape within the study area was highly fragmented due to extensive conversion of native prairie to intensive agriculture. Cotton (*Gossypium* spp.) and grain sorghum (*Sorghum bicolor*) were the primary crops produced, and both center pivot irrigation and dryland farming techniques were common. Beef cattle production was also present in the area but to a lesser extent than crop production. Native prairie within the study area was characterized by shrub/shortgrass vegetation communities that were bisected by shinnery oak prairie. Mesquite (*Prosopis glandulosa*), buffalo grass (*Bouteloua dactyloides*), blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), sand dropseed (*Sporobolus cryptandrus*), narrow-leaf yucca (*Yucca glauca*), western ragweed (*Ambrosia psilostchya*), and broom snakeweed (*Gutierrezia sarothrae*) were common plant species within shortgrass prairie. Peterson and Boyd (1998) detail the vegetation found within shinnery oak prairie.

Study efforts were focused within CRP fields, which were interspersed across the landscape. The CRP fields were comprised of 4 common contract types: 1) fields planted in introduced grasses, particularly weeping lovegrass (*Eragrostis curvala*) and old world bluestems (*Bothriochloa* spp.) (CP1), 2) fields planted in native grass species such as yellow indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), switchgrass (*Panicum virgatum*), green sprangletop (*Leptochloa dubia*), sideoats grama,

and blue grama (CP2), 3) fields that were first seeded in non-native grasses and then later seeded in natives (CP10), and 4) fields enrolled in the United States Department of Agriculture State Acres for Wildlife Enhancement Program (SAFE). In addition to native grasses, forbs such as alfalfa (*Medicago* spp.), Maximillian sunflower (*Helianthus maximiliani*), Illinois bundleflower (*Desmanthus illinoensis*), and other natives were seeded in strips across fields enrolled in SAFE (M. Samaniego, USDA Farm Service Agency, personal communication).

The soils on the study area were primarily Amarillo and Arvana series (Girdner 1963). The soils within the Amarillo series are deep, medium- to coarse-textured, and have a reddish-brown subsoil. The Arvana series consists of shallow to moderately deep soils that are reddish-brown in color and moderately coarse textured. Arvana soils differ from Amarillo soils in having rock-like caliche within 91.4 cm of the soil surface (Girdner 1963). The Southern High Plains are characterized by a very warm and dry climate. See Grisham et al. (2016) for a detailed description of weather patterns in the shinnery oak prairie ecoregion of the LEPC range.

METHODS

Capture and Relocation

I captured LEPCs on 7 leks during the spring breeding season in 2015, 2016, and 2017. I used walk-in funnel traps (Toepfer et al. 1988), magnetic drop nets (Wildlife Capture Services, Flagstaff, AZ, USA), tension drop nets (Silvy et al. 1990), and rocket nets (Davis et al. 1980*a*) for capture. I took standard morphological measurements on all individuals captured, including weight (g), tarsus length (mm), wing cord length (mm), and pinnae length (mm). I assessed sex by presence of eye comb and pinnae length,

where males had a bright yellow eye comb and noticeably longer pinnae than females (Copelin 1963). I used plumage characteristics to assess age. Individuals with white spots within 2.54 cm of the tips of the outer 2 primary feathers were recorded as juveniles, and individuals lacking these spots were recorded as adults (Copelin 1963). Each bird was banded with a Texas Parks and Wildlife aluminum leg band. The main goal of my research was to assess female reproductive ecology, so I equipped every female with a 22 gram Satellite Platform Transmitting Terminal GPS transmitter (PTT, Microwave Telemetry, Columbia, MD, USA). I attached the PTTs using the figure-8 rump method (Bedrosian and Craighead 2007). I deployed PTTs on males only after peak female attendance at leks during mid-April. Satellite PTT data consisted of 4 GPS locations per day, with fixes taking place at 0100, 0700, 1300, and 1700 hrs Central Standard Time. I downloaded GPS data from the ARGOS website weekly. All methods were approved under Texas Tech University Animal Care and Use Protocol #14073-10.

Landscape Analysis

I developed a land cover layer for my study area by using ArcGIS 10.2 (Environmental Systems Research Institute, Redlands, CA, USA) to merge a Cropscape land cover layer (National Agricultural Statistics Service, U.S. Department of Agriculture) with a 2014 CRP layer representing all properties enrolled in CRP across the LEPC's range. I clipped the resulting layer to Bailey and Cochran Counties and grouped land cover classes into 5 groups for the landscape analysis. I chose to classify all of Bailey and Cochran Counties in order to assess landscape composition and CRP patch size to compare with results from Spencer et al. (2017) in Kansas. The final classes for the analysis were 1) native grass and forb CRP, 2) native grass CRP, 3) non-native CRP,

4) agriculture, and 5) native grassland. The native grassland category was characterized mostly by shrub/shortgrass vegetation communities and shinnery oak prairie. I used the program FRAGSTATS (McGarigal et al. 2012; University of Massachusetts, Amherst, MA, USA) to calculate area and interspersion metrics for the 5 cover classes across the study area. The metrics calculated for each class included percentage of landscape (PLAND), number of patches (NP), mean patch size (MN), area-weighted mean patch size (AM), and interspersion and juxtaposition index (IJI). I also calculated the contagion index (CONTAG) for the study area. The PLAND metric is the percentage of the landscape each cover class occupies. The NP metric is the number of individual patches for each cover class within the landscape. The MN metric is the average patch size in hectares for each class, and each patch is equally represented. The AM metric is the average patch size, where patches are weighted based on their size. The IJI, as a percent, gives the magnitude of interspersion of different patch types and their juxtaposition to each other. The IJI equals 100 when the corresponding patch type is equally adjacent to all other patch types. The CONTAG, also a percent, gives the degree of clumping of patches across the landscape. The index equals 100 when the landscape is one single patch (McGarigal et al. 2012).

Habitat Selection

I used selection ratios (Manly et al. 2002) to assess LEPC breeding season (March – August) habitat selection for the years 2015 – 2017 and non-breeding season (September – February) habitat selection for 2015 and 2016. I assessed habitat selection at the second order using a Type II design and at the third order using a Type III design (Johnson 1980, Erickson et al. 2001).

To quantify available habitat at the second order of selection, I generated a 4.8 km buffer around each lek and clipped the land cover layer from the landscape analysis to each buffer. Although I conducted the landscape analysis as though all of Bailey and Cochran Counties were available, I chose a 4.8 km buffer for available habitat because LEPCs in general spend the majority of their lives within this distance from a lek (Haukos and Zavaleta 2016). To quantify used habitat at the second order, I estimated breeding and non-breeding season utilization distributions for each PTT-marked bird using the Brownian Bridge Movement Model (BBMM, Horne et al. 2007). The BBMM takes into account starting and ending locations and the time elapsed between them, as well as the speed or mobility of the animal (Horne et al. 2007). The model is well suited for situations where there are large quantities of relocations that may be autocorrelated spatially and temporally and not independent (Walter et al. 2011). I calculated utilization distributions using the adehabitatHR package (Calenge 2006) in Program R (R Version 3.1.2, www.r-project.org, accessed 29 Jan 2015). I generated the 95% isopleth for each BBMM utilization distribution in R and imported it into ArcGIS as a shapefile (See Appendix) for the habitat selection analysis. I also considered the proportion of land cover classes within each BBMM home range as available habitat at the third order. To quantify selection at the third order of selection, I overlaid each individual's PTT locations over the land cover layer and determined the proportion of locations within each class.

I calculated a mean selection ratio, standard error, and 95% confidence interval for each land cover class using the adehabitatHS package (Calenge 2011) in R. I also calculated a standardized selection ratio for each cover class by dividing the mean

selection ratio by the sum of all mean selection ratios. If the confidence interval around a selection ratio overlapped one, then the associated land cover class was considered to be used in proportion to its availability. If the upper value of the confidence interval was less than one, then the cover class was considered to be avoided. If the lower value of the confidence interval was greater than one, then the cover class was considered to be selected for by LEPCs. I acknowledge that not every land cover type was used, even if it was considered available based on spatial scales and design within the 2 counties. Within the guidelines of traditional habitat terminology, land cover that was not used, regardless of availability, was not considered LEPC habitat (Hall et al. 1997). Therefore I defined habitat as land cover types that were selected for in proportion or in greater proportion to their availability for each spatial scale and design levels.

RESULTS

Capture

I captured 35 LEPCs and deployed PTTs on 25 individuals from 2015 to 2017. Nineteen PTTs were deployed on males, and 6 were deployed on females. Eleven of the PTT-marked males were adults, and 8 were sub-adults. Five of the PTT-marked females were sub-adults, and one female was an adult.

Landscape Analysis

Conservation Reserve Program fields constituted 17% (71,720 ha) of the study area, in 694 separate patches. Native grass CRP constituted 15.5% (64,350 ha) of the landscape in 575 patches, making it the most abundant enrollment type in the study area. Native grass and forb CRP constituted 1% (5,427 ha) of the total landscape in 84 patches, and non-native grass CRP constituted 0.5% (1,943 ha) in 35 patches. Agricultural fields

constituted 44% (183,463 ha) of the study area in 10,740 patches, and native grassland constituted 39% (159,947 ha) in 14,661 patches.

Average CRP field size was 65 ha (SE=13.0) for native grass and forb CRP, 112 ha (SE=16.5) for native grass CRP, and 56 ha (SE=26.5) for non-native grass CRP (Table 2.1). The average size of CRP fields with known active leks was 289 ha (SE=200, Range = 123 –1,324 ha). Average patch size for agriculture and native grassland were 17 ha (SE=15.3) and 11 ha (SE=2.9), respectively. Area-weighted mean patch size was 285 ha for native grass and forb CRP, 1,504 ha for native grass CRP, and 499 ha for non-native grass CRP. Area-weighted mean patch size was 147,923 ha for agriculture and 11,272 ha for native grassland. Interspersion and Juxtaposition Index estimates were 71.5% for native grass and forb CRP, 58.5% for native grass CRP, and 87.7% for non-native grass CRP. The Contagion Index estimate was 57.5% for the entire study area.

Habitat Selection

Second Order.— All but 3 LEPCs remained within 4.8 km of their lek of capture for the duration of the study. One female moved 55 km from her lek of capture into central Yoakum County, Texas after brood loss (See Supplemental Information). A second female captured in Cochran County moved 6 km to nest in Shinnery Oak Prairie in eastern New Mexico. A third female moved 7 km from her lek of capture in Bailey County after brood loss. These 3 individuals were censored from the habitat selection analysis.

There was evidence of selection for non-native grass CRP and native grass and forb CRP at the second order of selection during the breeding season. The mean selection ratio for non-native CRP was 4.16 (95% CI=1.92 – 6.39), and the mean selection ratio for

native grass and forb CRP was 3.57 (95% CI=2.41 – 4.73). There was also selection for these CRP types during the non-breeding season. The mean selection ratio for non-native CRP was 5.58 (95% CI=3.51 – 7.66), and the mean ratio for native grass and forb CRP was 2.86 (95% CI=1.88 – 3.83). Agriculture and native grassland were avoided during the breeding and non-breeding seasons, and native grass CRP was used in proportion to its availability (Table 2.2).

Third Order.—There was evidence of selection for native grass and forb CRP at the third order of selection for both the breeding and non-breeding seasons. The mean selection ratios were 1.33 (95% CI=1.18 – 1.49) during the breeding season and 1.35 (95% CI=1.11 – 1.59) during the non-breeding season. Native grass CRP was avoided during both seasons, with mean selection ratios of 0.83 (95% CI=0.69 – 0.97) and 0.81 (SE=0.07, 95% CI=0.64 – 0.98) during the breeding and non-breeding seasons, respectively. Non-native CRP, agriculture, and native grassland were used in proportion to their availability during both seasons at the third order of selection (Table 2.3).

DISCUSSION

The major finding of this chapter was that CRP was selected habitat by LEPCs, despite the fact that the study area was considerably more fragmented than other portions of the species range. Contagion values from 4 LEPC study sites in Kansas and Colorado ranged from 60% - 80% (Plumb 2015), which is 20% greater than the contagion estimate for my study area. Based on imagery from 2013, the mean grassland patch size was 24 ha (SE=3.8), and the area-weighted mean patch size was 49,100 ha throughout the LEPC's range in Kansas (Spencer et al. 2017). Fragmentation on my study site was primarily due to extensive agriculture throughout the area. The high IJI values for the 3 CRP types

suggest CRP fields are currently widely interspersed throughout the study area and serve as islands of habitat within a matrix of agriculture and shortgrass prairie. An interesting note is LEPC leks and subsequent home ranges occurred within CRP while there was native shinnery oak prairie as close as 6 km. Aside from the 2 movements I observed into shinnery oak prairie, movements between this study area and the shinnery oak prairie study area in Grisham (2012) were minimal, despite numerous leks occurring in both habitat types. I speculate a large swath of energy development extended east to west across the entirety of southern Cochran County may be inhibiting regular movements between the 2 habitat types.

The traditional scientific consensus is LEPC populations need large patches of grassland for long term persistence (Haufler et al. 2012, Van Pelt et al. 2013). Estimates of minimum grassland patch size for LEPCs range from 4,900 ha for a single lek to 20,236 ha for a local population (Haukos and Zavaleta 2016). Both my average (Range = 56 – 112 ha) and area-weighted average (Range = 285 – 1,504 ha) estimates for CRP patch size fall far short of that range. However, I captured and tracked LEPCs in CRP patches ranging from 2,282 ha to 4,992 ha, due to the juxtaposition of individual CRP fields. My results suggest the majority of CRP fields in the study area are too small to individually support LEPCs, but an aggregation of CRP fields totaling 2,500 ha may support multiple leks. In addition, Hagen et al. (2016) suggested LEPC occupancy would increase when the percentage of CRP land within 7.5 x 7.5 km grids exceeded 20%. However, my results suggest caution is warranted before considering non-native CRP as LEPC habitat.

The selection for non-native CRP in the study area at the second order of selection is contradictory to my hypothesis that LEPCs would not select non-native grass CRP. Monocultures of non-native grasses constituted the main type of CRP planted during the first 10 years of CRP (1985 – 1995) in Texas. There was no documentation of range expansion or population increases for LEPCs in Texas after the seeding of these initial CRP fields (Rodgers and Hoffman 2005). The one non-native CRP fields where my study efforts took place was 532 ha and bordered by large expanses of cotton and sorghum fields to the north and south. I hypothesize that LEPCs selected the field because it was the only available, large tract of grassland within a landscape consisting mainly of cultivated crops and smaller CRP fields. My results suggest non-native CRP was LEPC habitat year-round, but interestingly, the probability of adult survival decreased as the proportion of non-native CRP within the home range increased (Chapter IV). Combined, these results indicate non-native CRP fields may constitute an ecological trap for LEPCs due to their perceived value for day-to-day activities but ultimately lack the necessary vegetative structure and cover (see Hagen et al. 2013) to protect from predators and the elements.

Lesser prairie-chickens in my study area selected native grass and forb CRP fields at 2 scales of selection during the course of a year, which is consistent with my hypothesis. I observed selection by both sexes, and the probable driver for the selection of this CRP type was structural heterogeneity and abundant food resources, both resulting from diverse seeding mixes (Hagen et al. 2004, Hagen et al. 2013). Lesser prairie-chicken diets vary over the course of a year, ranging from mainly plant material in spring to invertebrates and plant material in summer to seeds and shinnery oak acorns in the fall

and winter (Jones 1964, Davis et al. 1980*b*, Doerr and Guthery 1983). Based on field observations, invertebrates were more abundant during the late spring and summer months in the native grass and forb field compared to the native grass field. These observations are consistent with the findings of Fields (2004), who concluded that interseeding forbs in CRP fields in Kansas increased invertebrate biomass and diversity. Native grass and forb CRP fields were selected by LEPCs year-round, and breeding season survival increased as the proportion of native grass and forb CRP within the home range increased (Chapter IV). However, this CRP enrollment type currently comprises only a minute portion of the landscape (1%), and LEPCs may benefit from increasing the amount of native grass and forb CRP on the landscape in this region.

While native grass and forb CRP fields were selected over native grass fields throughout the course of a year, native grass CRP fields still have benefits for LEPCs. I found 5 leks on the tract of property that had both native grass and forb and native grass CRP fields present. Three of the 5 leks were located in the native grass field, and one of the leks within the native grass and forb field was only active for one year. In addition, 3 of 4 nests monitored on the property were located within the native grass field. Lesser prairie-chicken nest sites generally have more grass cover and less bare ground compared to random points (Hagen et al. 2013, Haukos and Zavaleta 2016). For example, average grass cover at 36 nests in Texas was 21.7%, compared to 3.5% at random points, and average percent bare ground was 7.3% at nests and 27.8% at random points (Grisham et al. 2014). The native grass and forb CRP field had been planted 2 years prior to the study with a seed drill and had significant bare ground between rows of vegetation. The native grass field, on the other hand, had patches of dense grasses that provided adequate cover

for nesting (Hagen et al. 2013). Fields (2004) recommended seeding CRP fields in alternating strips of native grasses and native forbs, thereby providing habitat for nesting and brood rearing. Planting CRP fields in this manner, and implementing mid-contract management practices within the native forb strips, may provide a mosaic of habitat at finer spatial scales (i.e. within the core area) that combines the current benefits of native grass and native grass and forb CRP fields in Texas.

Lesser prairie-chickens in my study area used agricultural fields and shrub/shortgrass vegetation communities in proportion to their availability at the third order of selection. I acknowledge that LEPCs used these cover types for the duration of the study, but my results do not suggest adding more of them to the landscape would benefit LEPCs. Lesser prairie-chickens used agriculture and shortgrass prairie in proportion to its availability only on an individual basis (Type III design). My PTT data suggest that most relocations within crop fields were foraging events, and there were generally only 1 – 2 locations per day within cropland, with the rest located within CRP fields. At the second order of selection (i.e. Type II design, population level) LEPCs avoided agriculture and shrub/shortgrass prairie and placed their home ranges within CRP. I also documented no leks within shrub/shortgrass prairie. In addition, neither the proportion of cropland nor native grassland within the home range positively influenced LEPC survival during the study (Chapter IV).

Lesser prairie-chickens typically spend the majority of their lives within 4.8 km of a single lek or lek complex (Applegate and Riley 1998, Borsdorf 2013, see Appendix). However, long distance movements outside this 4.8 km threshold are a recently discovered component of the species' ecology, due to the use of PTTs. Dispersal

movements up to 71 km in length have been recorded by LEPCs in Kansas (Earl et al. 2016). Habitat loss and fragmentation are a major concern for the species, due to subsequent population declines and reduced gene flow. However, long range movements suggest the potential for greater connectivity between populations than previously thought (Earl et al. 2016). The long distance movements I recorded suggest connectivity exists for LEPCs in my study area and individuals in shinnery oak prairie in southern Cochran County and Yoakum County and eastern New Mexico. Due to movement of LEPCs out of CRP into shinnery oak prairie, and the genetic evidence presented in Corman (2011), the 2 groups constitute one population of LEPCs across the Southern High Plains of Texas and eastern New Mexico. Therefore, CRP fields may provide habitat for LEPCs throughout the shinnery oak prairie ecoregion and not just on the study area in Bailey and Cochran Counties.

I realize the limitation of a small sample size in this study. However, LEPC abundance within the shinnery oak prairie ecoregion is lower compared to the mixed-grass prairie and shortgrass prairie/CRP ecoregions in the northeastern portion of the species' range. The estimated 2016 population was 3,255 individuals in shinnery oak prairie, compared to 6,891 individuals in mixed-grass prairie and 14,025 individuals in shortgrass prairie/CRP (McDonald et al. 2016). Also, I hypothesize that LEPCs in my study area constitute a small portion of the shinnery oak prairie population due to the limited space available within CRP fields. The costs associated with satellite PTTs also limits the number of units that can be deployed on individual LEPCs. Despite a small sample size, my results show CRP fields seeded in native vegetation provide habitat for LEPCs year-round and that CRP fields smaller than the recommended patch size

requirement of 4,900 ha (Applegate and Riley 1998) are still beneficial for LEPCs. My results also suggest that LEPCs incur greater risk of mortality when occupying CRP fields seeded in non-native vegetation.

MANAGEMENT IMPLICATIONS

Grasslands enrolled in CRP are a tool that can be used to increase the amount of LEPC habitat throughout the shinnery oak prairie ecoregion in Texas. However, the vast majority of CRP fields are too small to individually support LEPC leks and are scattered throughout a cropland-dominated landscape. Strategically placing new CRP tracts adjacent to fields already occupied by LEPCs and targeting large agricultural fields for enrollment will increase grassland patch size. Based on my results, an aggregation of CRP fields 2,500 ha in size will support a lek complex. Benefits from new CRP tracts may be maximized if fields are seeded in alternating strips of native grasses and native forbs. New CRP tracts may also reduce landscape fragmentation and serve to connect LEPCs in my study area to individuals within surrounding shinnery oak prairie. Finally, either re-enrolling or keeping CRP fields in grasses after contract expiration will help to ensure long term conservation benefits for LEPCs.

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Table 2.1. Landscape composition and configuration results for Bailey and Cochran Counties, Texas, 2015-2017. Results were obtained using the program FRAGSTATS.

Cover Class[a]	PLAND[b] (%)	NP	MN (ha)	SE	AM (ha)	IJI (%)	CONTAG (%)
GFCRP	1.3	84	64.6	13.0	284.9	71.5	
GCRP	15.5	575	111.9	16.5	1,503.8	58.5	
NNCRP	0.5	35	55.5	26.5	499.0	87.6	57.5
Agriculture	44.2	10,740	17.1	15.3	147,923.00	29.1	
Native Grassland	38.5	14,661	10.9	2.9	11,272.49	20.7	

a. GFCRP = native grass and forb CRP, GCRP = native grass CRP, NNCRP = non-native grass CRP
b. PLAND = percentage of landscape, NP = number of patches, MN = mean patch size, AM = area-weighted mean patch size, IJI = interspersion and jutaposition index, CONTAG = contagion index

Table 2.2. Summary of design II, second order habitat selection for lesser prairie-chickens (*Tympanuchus pallidicinctus*) during the breeding and non-breeding seasons in Bailey and Cochran Counties, Texas, 2015-2017.

			95% CI		
Season	Habitat	ŵi [a]	Lower	Upper	Bi [b]
Breeding	Agriculture	0.17	0.07	0.27	0.02
	Native Grassland	0.28	0.05	0.49	0.03
	Non-native CRP	4.16	1.92	6.39	0.44
	Native Grass CRP	1.24	0.80	1.68	0.13
	Grass and Forb CRP	3.57	2.41	4.73	0.38
Non-Breeding	Agriculture	0.25	0.03	0.47	0.02
	Native Grassland	0.34	0.00	0.69	0.03
	Non-native CRP	5.58	3.51	7.66	0.55
	Native Grass CRP	1.10	0.77	1.43	0.11
	Grass and Forb CRP	2.86	1.87	3.83	0.28

a. Average selection ratio
b. Weighted selection ratio

Table 2.3. Summary of design III, third order habitat selection for lesser prairie-chickens (*Tympanuchus pallidicinctus*) during the breeding and non-breeding seasons in Bailey and Cochran Counties, Texas, 2015-2017.

			95% CI		
Season	Habitat	ŵi [a]	Lower	Upper	Bi [b]
Breeding	Agriculture	0.89	0.50	1.29	0.18
	Native Grassland	0.86	0.20	1.52	0.17
	Non-native CRP	1.03	0.93	1.14	0.21
	Native Grass CRP	0.83	0.69	0.97	0.17
	Grass and Forb CRP	1.33	1.18	1.49	0.27
Non-Breeding	Agriculture	0.85	0.31	1.38	0.17
	Native Grassland	0.87	0.58	1.17	0.17
	Non-native CRP	1.12	0.69	1.55	0.22
	Native Grass CRP	0.81	0.64	0.97	0.16
	Grass and Forb CRP	1.35	1.11	1.59	0.27

a. Average selection ratio
b. Weighted selection ratio

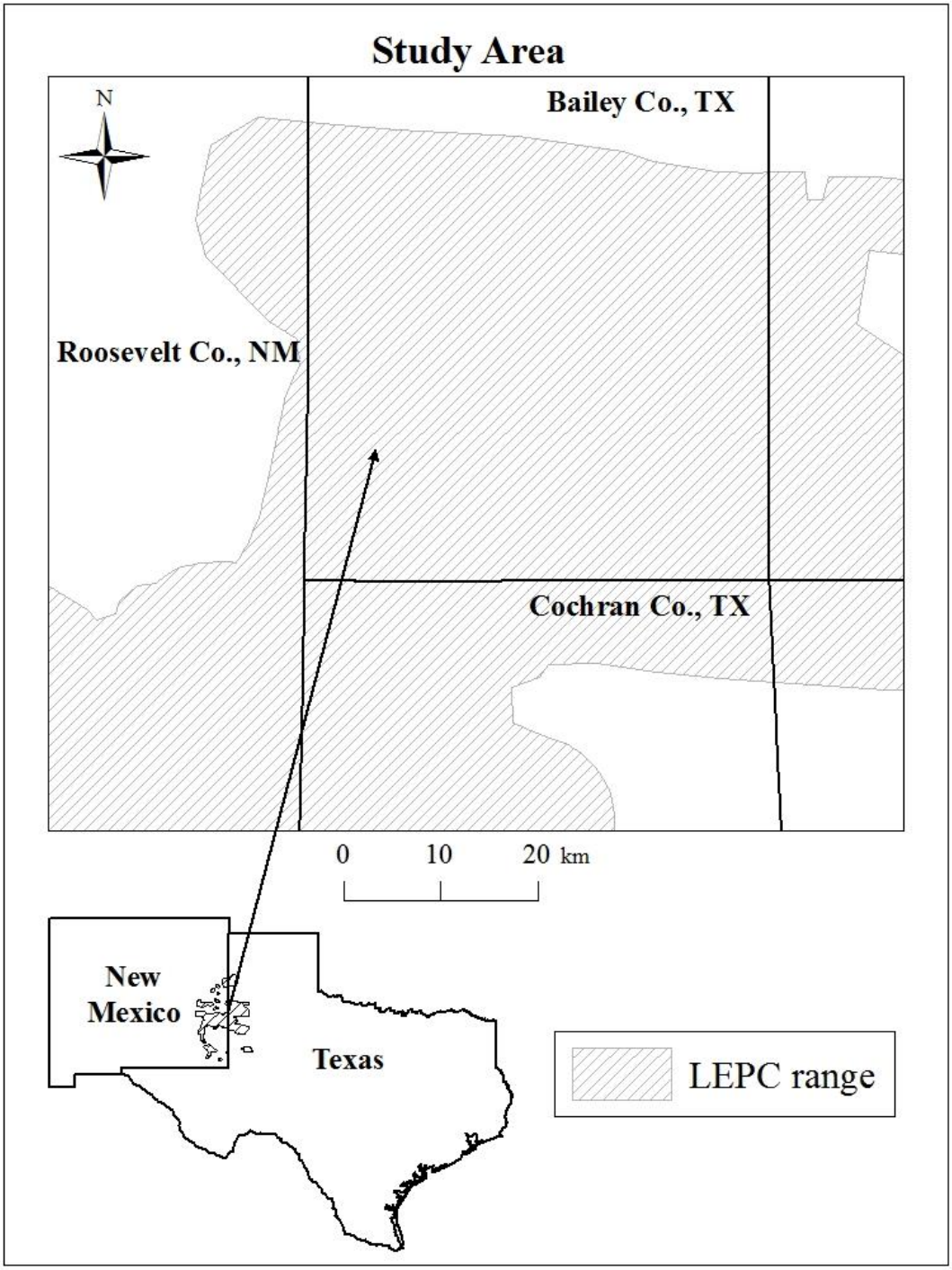

Figure 2.1. Bailey and Cochran County, Texas study area in the Sand Shinnery Oak Prairie ecoregion of the lesser prairie-chicken (*Tympanuchus pallidicinctus*) range, 2015-2017.

CHAPTER III

NESTING ECOLOGY OF LESSER PRAIRIE-CHICKENS IN CONSERVATION RESERVE PROGRAM LANDS IN THE SOUTHERN HIGH PLAINS OF TEXAS

ABSTRACT Due to significant range and population declines and the uncertainty of its status on the U.S. Endangered Species Act, the lesser prairie-chicken (*Tympanuchus pallidicinctus*) has received much attention in recent years. Considerable effort has been put into studying the life history of the species and the effects of management practices on its ecology, in an effort to guide conservation efforts and reduce population declines. One practice that has benefitted lesser prairie-chickens within their range in Kansas is the Conservation Reserve Program. In this federal program, producers are paid to take marginal croplands out of production and seed them in grasses and other permanent vegetation. Lesser prairie-chicken leks have been documented within Conservation Reserve Program fields in the Southern High Plains of Texas, but information is lacking regarding nest ecology and survival within these fields. I assessed lesser prairie-chicken nest survival within Conservation Reserve Program fields in Texas using the nest survival model in Program MARK. I also examined vegetation composition and structure at nest sites. I captured 6 females and outfitted each with a GPS Platform Transmitting Terminal. I located and monitored 8 nests and determined the fate of each nest. Four of the 8 nests hatched, and 4 were depredated. Average visual obstruction at nests was 3.62 dm (SE = 0.22) and was significantly greater than visual obstruction at random points. Grass cover at nests was 62% (SE = 9.5) on average, and no shrubs were documented at nest sites. The probability of a nest surviving the 28 day incubation period was 0.49 (95% CI = 0.16-0.77). Based on my results, Conservation Reserve Program fields provide suitable nesting habitat for lesser prairie-chickens in the High Plains of Texas.

KEY WORDS Conservation Reserve Program, lesser prairie-chicken, nest ecology, Texas, *Tympanuchus pallidicinctus*

The lesser prairie-chicken (*Tympanuchus pallidicinctus*, hereafter LEPC) occupies portions of Texas, New Mexico, Oklahoma, Kansas, and Colorado, in the southern Great Plains of North America. The species' occupied range has declined by an estimated 90% since 1900, due to substantial habitat loss and degradation (Hagen et al. 2004). The factors contributing to habitat loss include conversion of native prairie to agriculture, energy development, woody plant encroachment, and unmanaged grazing (Woodward et al. 2001, Hagen and Giesen 2005). Lesser prairie-chickens are now found in 2 geographically isolated populations in 4 habitat ecoregions. One population is located within the sand shinnery oak (*Quercus havardii*) prairie ecoregion of eastern New Mexico and western Texas. The other population is located in the sand sagebrush (*Artemesia filifolia*) prairie ecoregion in southeastern Colorado, southwestern Kansas, and the western Panhandle of Oklahoma, the mixed-grass prairie ecoregion in south central Kansas, northwest Oklahoma, and northeast Texas, and the shortgrass prairie/Conservation Reserve Program (CRP) ecoregion in northwestern Kansas (Van Pelt et al. 2013).

Loss of habitat and recurrent drought have resulted in significant LEPC population declines (Hagen and Giesen 2005). Prominent droughts across the southern Great Plains occurred during the 1930s, '50s, and early '90s and all contributed to LEPC declines (Sullivan et al. 2000). More recently, the drought of 2011 had significant effects on LEPC populations, particularly in the shinnery oak prairie ecoregion (Grisham et al. 2016*b*). Less than 2,000 LEPCs were estimated to remain within both portions of the

species' range in Texas (Timmer et al. 2013). Range-wide, the estimated LEPC population was approximately 26,000 individuals in 2016, with the majority of individuals occurring in the short-grass prairie/CRP ecoregion (McDonald et al. 2016). Due to significant range and population declines, LEPCs were listed as threatened under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service 2014) in May of 2014, but the listing ruling was vacated by judicial decision in September of 2015.

Nest survival greatly influences LEPC population persistence (Pitman et al. 2006*a*, Hagen et al. 2009). Therefore, a thorough knowledge of LEPC nesting ecology is essential for establishing effective conservation practices. Lesser prairie-chickens exhibit a "boom or bust" reproductive cycle. During years with poor rainfall and decreased habitat quality, nests are not as successful and recruitment is low. However, recruitment is much greater during years with improved habitat quality, which offsets the lack of production in "bust" years (Haukos and Zavaleta 2016). Nesting ecology differs across the LEPC range, as well as across years. Within shinnery oak prairie in Texas, LEPC females expend more energy towards individual survival compared to reproductive output. Females have smaller clutches, rarely attempt a renest, and have higher annual survival in the southwest portion of the LEPC range (Grisham et al. 2014).

Lesser prairie-chicken nests are usually located within 1.6 km of a lek, in areas that provide concealment and thermoregulation (Haukos and Zavaleta 2016). Nests are usually found in tall, residual grasses that provide visual obstruction (Riley et al. 1992, Davis 2009, Grisham et al. 2014). Shrubs such as sand shinnery oak (*Quercus havardii*) and sand sagebrush (*Artemesia filifolia*) are also used for nesting, often in response to heavy grazing pressure (Haukos and Smith 1989). Nest sites in general have greater

visual obstruction, horizontal cover, and litter cover and less bare ground than available at random (Haukos and Zavaleta 2016).

Lesser prairie-chickens are known to occupy CRP fields in the shinnery oak prairie ecoregion of the LEPC range and are part of a genetic metapopulation of LEPCs across the Southern High Plains of Texas and eastern New Mexico (Corman 2011, Chapter II). Many studies have examined LEPC nest survival in native shinnery oak prairie (Haukos 1988, Riley et al. 1992, Davis 2009, Grisham et al. 2014). However, no studies have examined nest ecology and survival within CRP fields in the High Plains of Texas. The objectives of my study were to 1) assess basic nesting ecology for LEPCs in CRP fields, 2) assess vegetative and microclimate characteristics at LEPC nest sites and compare to random points, 3) assess nest placement in relation to leks, and 4) estimate apparent nest success and nest survival within CRP lands. I had 4 specific hypotheses. First, nesting parameters and nest survival within CRP fields would be similar to that in Shinnery Oak Prairie (S = 0.43, SE = 0.006, 95% CI = 0.23-0.56; Grisham et al. 2014). Second, grass cover would be greater at nests compared to random points and to grass cover at nests within native prairie (Fields 2004, Grisham et al. 2014). Third, temperature and relative humidity would be greater at nest sites compared to the surrounding area (Grisham 2012). Fourth, the majority of nests would be within 1 km of a known lek (Davis 2009, Grisham 2012).

STUDY AREA

This study took place on private lands in Bailey and Cochran Counties in the Southern High Plains of Texas (Figure 3.1). The landscape within the study area was highly fragmented due to extensive conversion of native prairie to intensive agriculture.

Cotton (*Gossypium* spp.) and grain sorghum (*Sorghum* bicolor) were the primary crops produced, and both center pivot irrigation and dryland farming techniques were common. Beef cattle production was also present in the area but to a lesser extent than crop production. Native prairie within the study area was characterized by shrub/shortgrass vegetation communities that were bisected by shinnery oak prairie. Mesquite (*Prosopis glandulosa*), buffalo grass (*Bouteloua dactyloides*), blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), sand dropseed (*Sporobolus cryptandrus*), narrow-leaf yucca (*Yucca glauca*), western ragweed (*Ambrosia psilostchya*), and broom snakeweed (*Gutierrezia sarothrae*) were common plant species within shortgrass prairie. Peterson and Boyd (1998) detail the vegetation found within shinnery oak prairie.

Study efforts were focused in CRP fields, which were interspersed across the landscape. The CRP fields were comprised of 4 common contract types: 1) fields planted in introduced grasses, particularly weeping lovegrass (*Eragrostis curvala*) and old world bluestems (CP1), 2) fields planted in native grass species such as yellow indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), switchgrass (*Panicum virgatum*), sideoats grama, and blue grama (CP2), 3) fields that were first seeded in non-native grasses and then later seeded in natives (CP10), and 4) fields enrolled in the USDA State Acres for Wildlife Enhancement Program (SAFE). In addition to native grasses, forbs such as alfalfa (*Medicago* spp.), Maximillian sunflower (*Helianthus maximiliani*), Illinois bundleflower (*Desmanthus illinoensis*), and other natives were seeded in strips across fields enrolled in SAFE (Miguel Samaniego, USDA Farm Service Agency, personal communication).

The Amarillo and Arvana soil series were the most extensive in the area (Girdner 1963). The soils within the Amarillo series are deep, medium- to coarse-textured, and have a reddish-brown subsoil. The Arvana series consists of shallow to moderately deep soils that are reddish-brown in color and moderately coarse textured. Arvana soils differ from Amarillo soils in having rock-like caliche within 91.44 cm of the soil surface (Girdner 1963). The Southern High Plains are characterized by a very warm and dry climate. See Grisham et al. (2016*b*) for a detailed description of weather patterns in the shinnery oak prairie ecoregion of the LEPC range.

METHODS

Capture and Relocation

I captured LEPC females on 4 leks during the spring breeding seasons in 2015, 2016, and 2017. I used walk-in funnel traps (Toepfer et al. 1988), magnetic drop nets (Wildlife Capture Services, Flagstaff, AZ, USA), and tension drop nets (Silvy et al. 1990) for capture. I took standard morphological measurements on all individuals, including weight (g), tarsus length (mm), wing cord length (mm), and pinnae length (mm). I used plumage characteristics to assess age, where individuals with white spots within 2.54 cm of the tips of the outer 2 primary feathers were recorded as juveniles, while individuals lacking these spots were recorded as adults (Copelin 1963). Each bird was banded with a Texas Parks and Wildlife aluminum leg band.

I equipped each captured female with a 22 gram Satellite Platform Transmitting Terminal GPS transmitter (PTT, Microwave Telemetry, Columbia, MD, USA). I attached the PTTs using the figure-8 rump method (Bedrosian and Craighead 2007). Satellite PTT data consisted of 4 GPS locations per day, with fixes taking place at 0100, 0700, 1300,

and 1700 hrs Central Standard Time. I downloaded GPS data from the ARGOS website weekly. In addition to taking GPS fixes, each PTT transmitter was equipped with a Ground Track option. Each transmitter emitted a UHF signal from 1200 to 1700 hrs every day from 15 March to 15 July. I used the Ground Track signal to monitor females on nests and flush broods.

Nest Location and Ecology

Nest locations were determined from the GPS data. A female was considered to be incubating if GPS locations repeated themselves over the course of 3 days. I flushed each female off her nest once to determine clutch size (Grisham 2012) and then monitored the nest daily using the Ground Track UHF signals. If a female was found to be off her nest, I visited the nest site again to determine fate. Each nest was categorized as either successful (≥ 1 egg hatched) or unsuccessful (depredated or abandoned). If a nest was depredated, I identified the cause of depredation by examining the surrounding area for eggshell fragments, scat, or tracks (Grisham 2012). I also measured the distance from each nest to the female's lek of capture and to the nearest lek.

I determined nest initiation date, incubation start date, and hatch date (if applicable) for each nest. I determined incubation start date by examining the GPS data and considered the female to be incubating when GPS locations began repeating over the course of an entire day. Female lesser prairie-chickens generally lay one egg a day before starting incubation. Therefore, nest initiation date was determined by taking the incubation start date and back tracking one day for each egg in the nest. I also calculated apparent nest success, percent females attempting a nest, and percent females attempting a renest. I defined apparent nest success as the number of successful nests divided by the

total number of initiated nests (Davis 2009), and the percent females attempting a renest as the number of females making a second nest attempt divided by the number of females that had a failed first nest (Pitman et al. 2006*a*).

Nest Vegetation

I quantified nest vegetation structure within 3 days of nest failure or success for all nest sites and for paired random locations following the methodology described in Grisham (2012). I centered 2 perpendicular, 8 m transects in a north-south and east-west orientation over the nest bowl and noted the dominant plant the nest bowl was located in. I determined percent canopy cover of shrubs, grasses, forbs, bare ground, and litter at the nest bowl (hereafter "nest site") and at 4 m intervals north, south, east, and west of the nest (hereafter "nest area") using a 60 x 60 cm Daubenmire frame (Daubenmire 1959). I recorded a visual obstruction reading (VOR) from a distance of 4 m and a height of 1 m at the nest bowl (Robel et al. 1970). I also recorded litter depth from the center of the nest bowl out to 4 m north, south, east, and west of the nest bowl at 0.5 m intervals. I compared vegetation measurements between nest sites and random points and nest areas and random areas using Student's *t*-tests within Program R (R Version 3.1.2, www.r-project.org, accessed 29 Jan 2017).

Nest Microclimate

I placed one Maxim Integrated Semiconductor data logger (Maxim Integrated Products, Sunnyville, California, USA; hereafter "ibutton") inside each nest after I flushed the female to determine clutch size. I also placed an ibutton outside the nest in the same substrate the nest was located in (e.g. bunchgrass, forb, shrub). Each ibutton recorded air temperature and relative humidity at 10-min intervals. Temperature was

recorded in ^{o}C, and relative humidity was defined as the ratio of water vapor mass per kilogram of dry air (Grisham 2012). I retrieved both ibuttons after the nesting attempt was over and fate was determined.

I calculated minimum, maximum, and average values for temperature and relative humidity both inside and outside each nest. I then compared temperature and relative humidity inside and outside the nest using a t test within R. I also divided the ibutton data into six different periods over the course of a day and compared temperature and humidity inside and outside the nest (Grisham 2012). The periods were morning (0601 – 0900), mid-morning (0901 – 1200), mid-day (1201 – 1500), afternoon (1501 – 1800), evening (1801 – 2100), and night (2101 – 0600).

Nest Survival

I estimated LEPC nest survival using the nest survival model within Program MARK (White and Burnham 1999). The nest survival model uses the day the nest was found, the last date the nest was checked alive, the last day the nest was checked, and the fate of the nest to calculate daily survival rate (DSR; Dinsmore et al. 2002). I then estimated the probability of a nest surviving the entire incubation period by using the formula $S = DSR^{28}$, where 28 corresponds to the incubation period length in days (Grisham et al. 2014). Due to a very small sample size, I estimated nest survival using only a model that assumed constant survival across the incubation period.

RESULTS

Nest Location and Ecology

I captured 6 females during the three seasons of trapping (one in 2015, 4 in 2016, and one in 2017; Table 3.1). Due to a small sample size, I pooled all results across years.

A total of 8 nests were initiated. Percent females attempting a nest was 100%, and percent females attempting a renest was 33%. Average clutch size was 8 eggs (SE = 1), with a range of 5-10 eggs. Mean nest initiation date was Julian day 120 (30 April), and mean incubation start date was Julian day 129 (9 May). Mean hatch date was Julian day 158 (7 June). The average distances from nests to the nearest lek and the female's lek of capture were 1,044 m (SE = 154.5) and 1,810 m (SE = 739.9).

Seven nests were located within CRP fields. Two of the 7 nests were located in non-native grass CRP fields. Four nests were located in native grass CRP fields, and one nest was located in a native grass and forb CRP field. The eighth nest was located within native shinnery oak prairie. Four of the 8 nests hatched, and the other 4 were depredated. Two of the unsuccessful nests failed due to mammalian depredation. The source of depredation was not confirmed for the other 2 unsuccessful nests, although depredation by a snake was suspected for one of those 2 nests. One of 2 nests in non-native CRP hatched, and the brood was lost within 4 days of hatching. Two of 4 nests within native grass CRP hatched, and the one nest within native grass and forb CRP hatched. Two of the broods hatched in native CRP fields made it past the first 14 days post-hatch. The one nest within shinnery oak prairie was unsuccessful.

Nest Vegetation

I was not able to measure vegetation at 2 nests, due to lack of landowner permission. I measured vegetation at 6 nests, which included both first and second nest attempts. Of the nests examined, 4 had nest bowls located in grass, one within a forb, and one within a combination of forbs and grasses. No shrubs were recorded within Daubenmire frames at nest sites. Average visual obstruction at nests was 3.43 dm (SE =

0.27) and was significantly greater compared to random points (t_{10} = 2.46, P = 0.02, Figure 3.2). Grass constituted 62% of cover at nests, on average, but grass cover was not significantly greater at nests compared to random points (t_{10} = 1.75, P = 0.05). There was no significant difference between forb, litter, and bare ground cover between nests and random points (Table 3.3).

I detected no significant differences between vegetation composition at nest areas and random areas (Table 3.4). Grass cover was 35% greater at nest sites compared to nest areas, on average. Grass cover was comparable between random sites (41%, SE = 7.09) and random areas (49%, SE = 9.87). Two perennial broomweed (*Gutierrezia sarothraez*) plants at a nest area were the only shrubs recorded within Daubenmire frames for the duration of the study.

Nest Microclimate

I obtained 12,392 temperature and relative humidity recordings from nests and 12,393 recordings from ibuttons placed outside nests. Nest temperatures averaged 28.63ºC, with an average range of 22.79 to 31.86ºC. Outside temperatures averaged 22.01ºC, with an average range of 18.04 to 26.05ºC. Nest temperatures were significantly greater than outside temperatures ($t_{24,782}$ = 61.41, P < 0.001). Nest relative humidity averaged 67.91%, with an average range of 58.36 to 73.89%. Outside relative humidity averaged 63.27%, with an average range of 35.55 to 75.92%. Nest relative humidity was significantly greater than outside relative humidity ($t_{24,782}$ = 15.08, P < 0.001). Nests temperatures were warmer than outside temperatures during the course of a day, except during mid-day and afternoon hours (Table 3.5). Nest relative humidity was greater than outside humidity except during morning and night hours (Table 3.6).

Nest Survival

Females incubated nests from Julian Day 116 (26 April) to Julian Day 171 (20 June), which resulted in 56 estimates of daily nest survival. Daily survival rate was 0.975 (SE = 0.01, 95% CI = 0.936-0.991). The probability of a nest surviving the incubation period was 0.49 (95% CI = 0.16-0.77).

DISCUSSION

My findings indicate CRP fields play an important role in LEPC nesting ecology in the shinnery oak prairie ecoregion of the LEPC range. Lesser prairie-chicken movements between CRP fields and native shinnery oak prairie have been documented (Chapter II), which indicates there is connectivity between individuals in my study area and other LEPCs across the Southern High Plains of Texas and eastern New Mexico. Because there is connectivity between LEPCs across the Southern High Plains, CRP fields can likely provide suitable grassland for nesting across a broad landscape. In addition, my estimate of nest survival is consistent with previous studies. Nest survival in shinnery oak prairie from 2008 to 2011 was 0.43 (95% CI = 0.23 – 0.56; Grisham et al. 2014), and survival in the mixed-grass prairie and shortgrass prairie/CRP ecoregions from 2013 to 2014 was 0.39 (95% CI = 0.34 – 0.43, Lautenbach 2015).

I did not assess differences in nest survival or brood survival between different CRP enrollments due to sample size limitations. However, apparent nest success and brood success differed between the different CRP types. A greater proportion of nests hatched within native CRP fields compared to non-native CRP fields, and the only broods that survived to 14 days were hatched in close proximity to native grass and forb CRP. Non-native CRP fields do provide available grassland space in the High Plains of Texas,

and LEPCs will place their home ranges within large non-native tracts (Chapter II). However, non-native CRP fields do not appear to provide as good of structure for nesting and food resources for broods compared to CRP fields seeded in native vegetation.

Visual obstruction is an important predictor of LEPC nest site selection (Haukos and Smith 1989, Riley et al. 1992, Lautenbach 2015). Visual obstruction readings were 1 dm greater at nests compared to random points on average, and average VOR at nests fell within the recommendations given by Grisham et al. (2014) and Lautenbach (2015). Also, grass constituted the majority of cover at nest sites. Grass cover was 21% greater at nest sites compared to random points, but there was no significant difference between the 2 locations. The lack of significance is likely due to the CRP field seeding mixes. Grasses are the main component of CRP seeding mixes, and fields are usually planted uniformly with a seed drill, making grass cover highly available.

Vegetation at LEPC nests in my study area differed from vegetation at nest sites found from 2008-2011 in shinnery oak prairie in Texas (Grisham et al. 2014). Every nest I monitored was located within grasses or a mixture of grasses and forbs. Conversely, 25 of 36 nests (71%) located in shinnery oak prairie were located within sand sagebrush. No shrubs were recorded at nest sites within CRP, and average grass cover at nests within CRP (62%) was almost 3 times the grass cover at nests within shinnery oak prairie (21.7%). Lesser prairie-chicken nest survival throughout much of the shinnery oak prairie in Texas was limited by visual obstruction at nest sites, due to years of unmanaged grazing resulting in greater shrub cover and less grasses (Grisham et al. 2014). However, light herbicide applications applied to shinnery oak grasslands promote native grass growth and remove visual obstruction as a limiting factor for nest survival (Fritts et al.

2016). This evidence, along with my vegetation data from LEPC nests, suggests CRP fields seeded in native mid-grasses provide suitable visual obstruction for nesting during years of average rainfall. The lack of shrubs within CRP fields could be problematic during times of drought because shrubs may provide essential cover for nesting if grass production is decreased due to drought.

The majority of LEPC females in my study area nested approximately 1 km from a lek. Female movements were greatest during the pre-nesting period of the breeding season, and movements up to 3 km from a lek were documented during this period (S. Harryman, unpublished data). However, 7 of the 8 nests monitored were located either in the CRP field the female was captured in or an adjacent field. The tendency of females to nest in close proximity to leks in my study area is consistent with previous studies that have assessed LEPC nesting ecology (Pitman et al. 2006*a*, Davis 2009, Grisham 2012). Management efforts taken to improve nesting habitat can be maximized if they are focused within CRP fields that contain active leks and fields directly adjacent.

Lesser prairie-chicken females nesting in the shinnery oak prairie ecoregion experience warmer and drier conditions compared to individuals in the 3 ecoregions within the northeast portion of the LEPC range. Temperature and relative humidity is 7°C greater and 7% less, on average, on the High Plains of Texas compared to the northern portion of the LEPC range in Kansas during the nesting season (Grisham et al. 2013). Temperatures greater than 34°C have been identified as a threshold at which daily nest survival decreases despite adequate visual obstruction at the nest site (Grisham et al. 2016*a*). Nest temperatures averaged 27.81^{o}C in my study, and the highest average temperature at a nest was 31.86 ^{o}C. This suggests that native mid-grass species seeded in

CRP fields provide adequate microclimate conditions for nesting during years of average temperatures.

Lesser prairie-chicken females in eastern New Mexico were documented nesting in reverted cropland and fields seeded in weeping lovegrass during a drought year, while shinnery oak grasslands were used little (Merchant 1982). Reduced use of shinnery oak grasslands for nesting was attributed to the combined effects of heavy grazing and drought conditions. Similarly, native rangeland within the shortgrass prairie/CRP ecoregion in Kansas was used little by LEPC females for nesting, save during years of adequate rainfall when cover was increased in native prairie (Fields 2004). It was concluded that CRP fields allowed LEPC populations to persist during drought years by providing an ungrazed refuge for nesting (Fields 2004). I hypothesize that CRP fields in the Southern High Plains of Texas can likewise contribute to LEPC population persistence within the shinnery oak prairie ecoregion by providing nesting habitat during times of drought. However, the USDA Farm Service Agency currently permits grazing and haying of CRP fields during drought years (USDA Farm Service Agency, Conservation Fact Sheet, August 2016). Future research is warranted to examine LEPC nesting ecology within CRP fields during drought years.

MANAGEMENT IMPLICATIONS

Conservation Reserve Program fields seeded in native mid-grasses provide quality nesting habitat for LEPCs in the Southern High Plains of Texas. Maintaining visual obstruction between 2-4 dm within CRP fields will ensure adequate structure for nesting (Grisham et al. 2014). Seeding strips of native grass species across large non-native CRP tracts or re-seeding entire fields will provide better structure and food

resources for nesting females and broods. There is currently little oil and wind power energy production across the study area, and limiting additional anthropogenic features will benefit CRP fields as nesting habitat. Limiting emergency haying and grazing within 1 km of active leks will provide nesting cover for LEPCs during periods of drought.

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Table 3.1. Female lesser prairie-chicken (*Tympanuchus pallidicinctus*) capture results in Bailey and Cochran Counties, Texas, 2015-2017.

Year	Age	# PTT[a]
2015	Adult	0
	Sub-adult	1
2016	Adult	1
	Sub-adult	3
2017	Adult	0
	Sub-adult	1
	Total	6

a. Number of individuals fitted with a Platform Transmitting Terminal

Table 3.2. Nesting statistics for female lesser prairie-chickens (*Tympanuchus pallidicinctus*) in Bailey and Cochran Counties, Texas, 2015-2017.

Variable	n	2015-2017
% Hens Nesting	6	100
% Hens Renesting	2	50
% Nest Success	8	50
Mean Clutch Size	6	8
Mean Nest Initiation Date	8	30 April
Mean Incubation Start Date	8	9 May
Mean Hatch Date	8	7 June
Nearest Lek (m)	8	1,044

Table 3.3. Habitat characteristics at lesser prairie-chicken (*Tympanuchus pallidicinctus*) nest sites and random points in Bailey and Cochran Counties, Texas for the years 2015-2017.

Variable	Nest Site		Random Point		*t* value	*P*
	Mean	SE	Mean	SE		
VOR (dm)	3.43	0.27	2.17	0.44	2.46	0.02
% Grass	62.17	9.52	41.33	7.09	1.76	0.05
% Shrub	0.00	0.00	0.00	0.00	NA	NA
% Forb	15.00	6.61	15.67	6.28	-0.07	0.94
% Litter	14.00	3.91	27.00	6.44	-1.72	0.12
% Bare Ground	8.83	1.90	16.00	4.53	-1.46	0.18

Table 3.4. Habitat characteristics at lesser prairie-chicken (*Tympanuchus pallidicinctus*) nest areas and random areas in Bailey and Cochran Counties, Texas for the years 2015-2017.

Variable	Nest Area		Random Area		*t* value	*P*
	Mean	SE	Mean	SE		
Litter Depth (cm)	1.73	0.18	2.14	0.19	-0.90	0.39
% Grass	26.90	6.89	49.15	9.87	-1.85	0.95
% Shrub	1.00	1.00	0.00	0.00	NA	NA
% Forb	13.60	3.00	11.10	5.61	0.39	0.70
% Litter	16.80	4.65	13.30	2.67	0.65	0.53
% Bare Ground	41.70	6.36	26.45	4.77	1.92	0.09

Table 3.5. Average temperature, standard error, and direction of nest temperature relative to external temperature within lesser prairie-chicken (*Tympanuchus pallidicinctus*) nests in Bailey and Cochran Counties, Texas, 2015-2017.

Time	Nest		External		Nest Temp.
	Mean	SE	Mean	SE	
Morning	25.1	0.23	16.6	0.12	+
Mid-Morning	26.8	0.20	24.6	0.23	+
Mid-Day	30.8	0.23	35.8	0.41	-
Afternoon	32.2	0.23	33.9	0.33	-
Evening	29.0	0.19	24.2	0.18	+
Night	26.2	0.13	17.0	0.07	+
Full Day	27.8	0.08	23.2	0.11	+

Table 3.6. Average relative humidity, standard error, and direction of nest relative humidity compared to external relative humidity within lesser prairie-chicken (*Tympanuchus pallidicinctus*) nests in Bailey and Cochran Counties, Texas, 2015-2017.

Time	Nest		External		Nest RH
	Mean	SE	Mean	SE	
Morning	72.8	0.63	86.3	0.65	-
Mid-Morning	70.6	0.62	66.7	0.91	+
Afternoon	57.6	0.57	38.8	0.82	+
Mid-Day	62.0	0.59	42.0	0.88	+
Evening	63.6	0.57	55.0	0.89	+
Night	72.9	0.33	79.0	0.41	-
Full Day	68.2	0.22	65.8	0.33	+

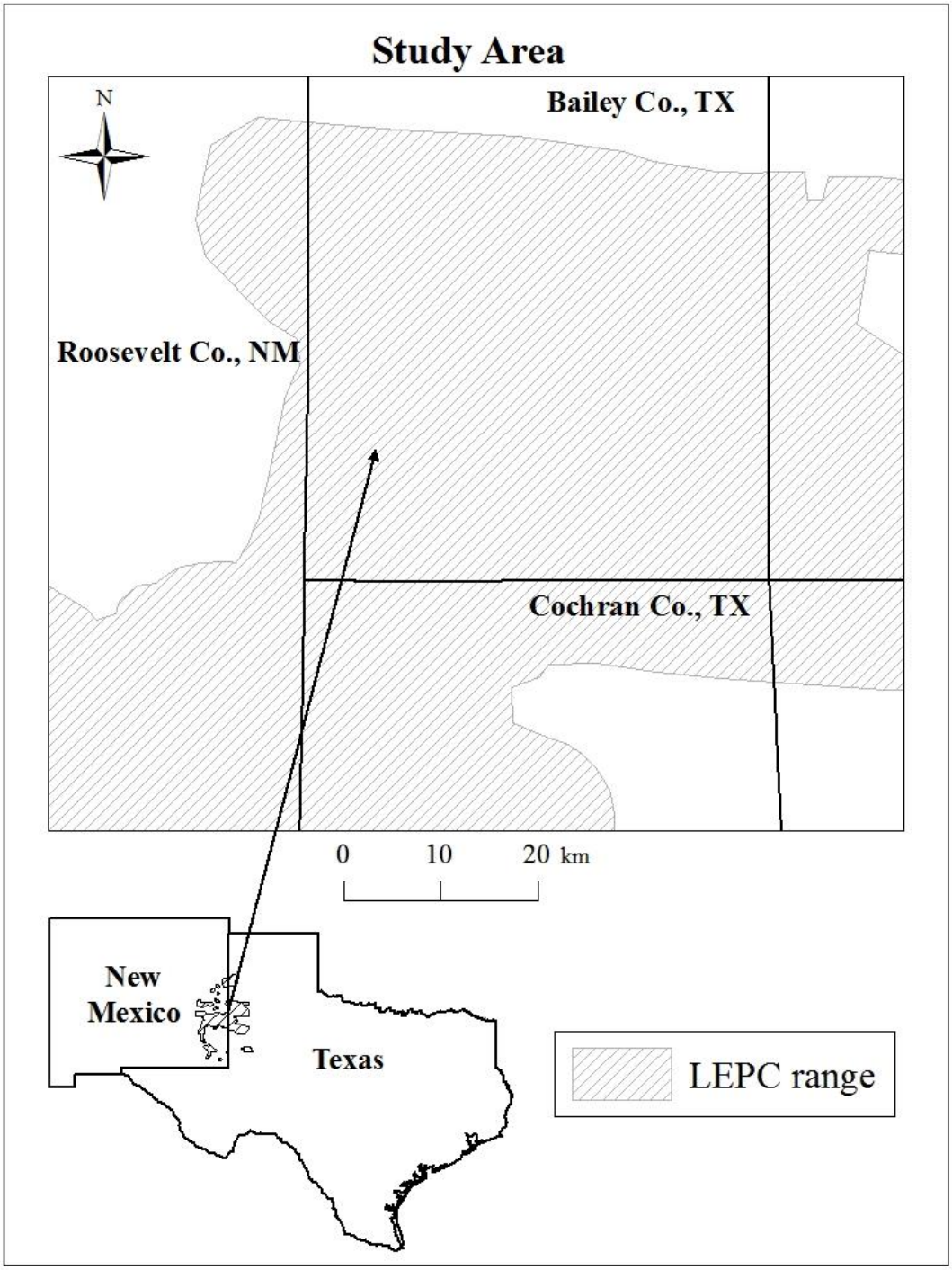

Figure 3.1. Bailey and Cochran County, Texas study area in the Sand Shinnery Oak Prairie ecoregion of the lesser prairie-chicken (*Tympanuchus pallidicinctus*) range.

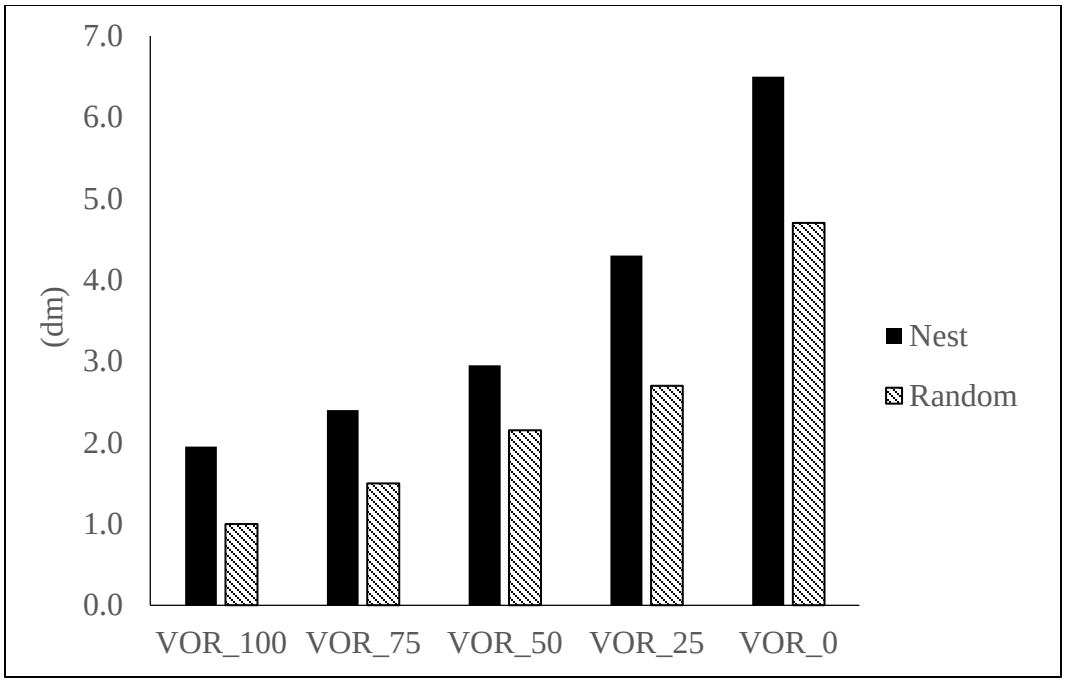

Figure 3.2. Visual obstruction reading averages at lesser prairie-chicken (*Tympanuchus pallidicinctus*) nest sites and random points in Bailey and Cochran Counties, Texas, 2015-2017.

CHAPTER IV

CAUSES OF MORTALITY AND SURVIVAL OF LESSER PRAIRIE-CHICKENS IN CONSERVATION RESERVE PROGRAM LANDS IN THE SOUTHERN HIGH PLAINS OF TEXAS

ABSTRACT The lesser prairie-chicken (*Tympanuchus pallidicinctus*) has received considerable attention in recent years due to population declines and the uncertainty of its status on the U.S. Endangered Species Act. Substantial effort is being put into studying the life history of the species and the effects of management practices on the species' ecology. Lesser prairie-chicken leks have been documented within Conservation Reserve Program fields in the Southern High Plains of Texas. However, information is lacking regarding the causes and timing of mortality and survival rates of individuals throughout the course of a year. I assessed lesser prairie-chicken breeding and non-breeding season survival within Conservation Reserve Program fields in Texas using the Known Fate model in Program MARK. I also assessed the effects of habitat composition and configuration within the home range on breeding season survival. Mammalian predators were the main source of mortality for lesser prairie-chickens in my study area, and the majority of mortalities took place during the late breeding season (June – August). The probability of a lesser prairie-chicken surviving the breeding season was 0.61 ± 0.08, and the probability of survival for the non-breeding season was 0.82 ± 0.11. Breeding season survival increased as the percentage of native grass and forb CRP within the home range increased, and survival decreased as the clumping of patches within the home range increased. Survival rates in my study area were similar to previous estimates from native Shinnery Oak Prairie, suggesting Conservation Reserve Program fields provide cover from predators and the elements during important life history stages such as lekking, nesting, brood-rearing, and the fall/winter months.

KEY WORDS Conservation Reserve Program, lesser prairie-chicken, survival, Texas, *Tympanuchus pallidicinctus*

The lesser prairie-chicken (*Tympanuchus pallidicinctus*, hereafter LEPC) inhabits portions of Texas, New Mexico, Oklahoma, Kansas, and Colorado, in the southern Great Plains of North America. The species' occupied range has declined by an estimated 90% since 1900, due to substantial habitat loss and degradation (Hagen et al. 2004). The factors contributing to habitat loss include conversion of native prairie to agriculture, energy development, woody plant encroachment, and unmanaged grazing (Woodward et al. 2001, Hagen and Giesen 2005). Lesser prairie-chickens are now found in 2 geographically isolated populations in 4 habitat ecoregions. One population is located within the sand shinnery oak (*Quercus havardii*) prairie of eastern New Mexico and western Texas. The other population is located in the sand sagebrush (*Artemesia filifolia*) prairie in southeastern Colorado, southwestern Kansas, and the western Panhandle of Oklahoma, the mixed-grass prairie in south central Kansas, northwest Oklahoma, and northeast Texas, and the shortgrass prairie/Conservation Reserve Program (CRP) ecoregion in northwestern Kansas (Van Pelt et al. 2013).

Loss of habitat and recurrent drought have resulted in significant LEPC population declines (Hagen and Giesen 2005). Prominent droughts across the southern Great Plains occurred during the 1930s, '50s, and early '90s and all contributed to LEPC declines (Sullivan et al. 2000). More recently, the drought of 2011 had significant effects on LEPC populations, particularly in the shinnery oak prairie ecoregion (Grisham et al. 2016). Less than 2,000 LEPCs were estimated to remain within both portions of the species' range in Texas (Timmer et al. 2013). Range-wide, the estimated LEPC

population was approximately 26,000 individuals in 2016, with the majority of individuals occurring in the shortgrass prairie/CRP ecoregion (McDonald et al. 2016). Due to significant range and population declines, LEPCs were listed as threatened under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service 2014) in May of 2014, but the listing ruling was vacated by judicial decision in September of 2015.

Lesser prairie-chickens are a source of prey for multiple mammalian and avian predators (Hagen and Giesen 2005). However, adult and sub-adult survival does not influence LEPC population persistence to the extent of nest success and brood survival (Hagen et al. 2009). Adult survival is lower during the breeding season (S=0.610, SE=0.097; Leonard 2008) compared to the fall and winter months (S=0.721, SE=0.076; Pirius et al. 2013). Male mortality is thought to increase during the breeding season due to conspicuousness on open lek sites as well as decreased fitness resulting from intense breeding behavior (Hagen et al. 2005, Wolfe et al. 2007). Female mortality is greater during the breeding season due to nest site searching and vulnerability while incubating and raising chicks (Haukos et al. 1988, Hagen et al. 2007, Wolfe et al. 2007, Grisham and Boal 2015). Female breeding season survival has been found to be higher in the shinnery oak prairie ecoregion. This portion of the LEPC range is warmer and dryer on average than the sand sagebrush, mixed-grass, and shortgrass/CRP ecoregions, and during years of drought and high temperatures, many females forgo nesting and focus on individual fitness (Grisham et al. 2013).

Lesser prairie-chickens are known to inhabit CRP fields in the shinnery oak prairie ecoregion of the LEPC range and are part of a genetic metapopulation of LEPCs across the Southern High Plains of Texas and eastern New Mexico (Corman 2011,

Chapter II). Many studies have examined breeding and non-breeding season survival of LEPCs in native shinnery oak prairie (Haukos et al. 1988, Leonard 2008, Jones 2009, Pirius et al. 2013, Grisham 2012, Holt 2012), but there are currently no estimates of LEPC survival in CRP lands in Texas. The objectives of my study were to 1) assess the causes and timing of LEPC mortalities in CRP fields in Texas, 2) estimate LEPC adult and sub-adult survival in CRP fields for both the breeding (March-August) and non-breeding (September-February) seasons and compare to estimates from shinnery oak prairie, 3) assess differences in survival between age classes and sex, and 4) assess the effects of landscape composition and configuration on LEPC survival. I had 4 specific hypotheses. First, mammalian predators would be the major of source of LEPC mortality in the study area, and most mortality events would take place during the breeding season (Hagen et al. 2007, Grisham and Boal 2015). Second, breeding and non-breeding season survival would be similar to estimates in shinnery oak prairie. Third, survival rates would be similar between sexes and age classes (Grisham and Boal 2015). Finally, survival rates would be lower for individuals who placed their home ranges within CRP fields seeded in non-native grasses, compared to individuals occupying CRP fields seeded in native vegetation (Rodgers and Hoffman 2005).

STUDY AREA

This study took place on private lands in Bailey and Cochran Counties in the Southern High Plains of Texas (Figure 2.1). The landscape within the study area was highly fragmented due to extensive conversion of native prairie to intensive agriculture. Cotton (*Gossypium* spp.) and grain sorghum (*Sorghum bicolor*) were the primary crops produced, and both center pivot irrigation and dryland farming techniques were common.

Beef cattle production was also present in the area but to a lesser extent than crop production. Native prairie within the study area was characterized by shrub/shortgrass vegetation communities that were bisected by shinnery oak prairie. Mesquite (*Prosopis glandulosa*), buffalo grass (*Bouteloua dactyloides*), blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), sand dropseed (*Sporobolus cryptandrus*), narrow-leaf yucca (*Yucca glauca*), western ragweed (*Ambrosia psilostchya*), and broom snakeweed (*Gutierrezia sarothrae*) were common plant species in shortgrass prairie. Peterson and Boyd (1998) detail the vegetation found within shinnery oak prairie.

Study efforts were focused in CRP fields, which were interspersed across the landscape. The CRP fields were comprised of four common contract types: 1) fields planted in non-native grasses, particularly weeping lovegrass (*Eragrostis curvala*) and old world bluestems (CP1), 2) fields planted in native grass species such as yellow indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), switchgrass (*Panicum virgatum*), sideoats grama, and blue grama (CP2), 3) fields that were first seeded in non-native grasses and then later seeded in natives (CP10), and 4) fields enrolled in the USDA State Acres for Wildlife Enhancement Program (SAFE). In addition to native grasses, forbs such as alfalfa (*Medicago* spp.), Maximillian sunflower (*Helianthus maximiliani*), Illinois bundleflower (*Desmanthus illinoensis*), and other natives were seeded in strips across fields enrolled in SAFE (Miguel Samaniego, USDA Farm Service Agency, personal communication).

The Amarillo and Arvana soil series were the most extensive in the area (Girdner 1963). The soils within the Amarillo series are deep, medium- to coarse-textured, and have a reddish-brown subsoil. The Arvana series consists of shallow to moderately deep

soils that are reddish-brown in color and moderately coarse textured. Arvana soils differ from Amarillo soils in having rock-like caliche within 91.44 cm of the soil surface (Girdner 1963). The Southern High Plains are characterized by a very warm and dry climate. See Grisham et al. (2016) for a detailed description of weather patterns in the shinnery oak prairie ecoregion of the LEPC range.

METHODS

Capture and Relocation

I captured LEPCs on 7 leks during the spring breeding seasons in 2015, 2016, and 2017. I used walk-in funnel traps (Toepfer et al. 1988), magnetic drop nets (Wildlife Capture Services, Flagstaff, AZ, USA), tension drop nets (Silvy et al. 1990), and rocket nets (Davis et al. 1980) for capture. I took standard morphological measurements on all individuals, including weight (g), tarsus length (mm), wing cord length (mm), and pinnae length (mm). I assessed sex by presence of eye comb and pinnae length, where males had a bright yellow eye comb and noticeably longer pinnae than females (Copelin 1963). I used plumage characteristics to assess age, where individuals with white spots within 2.54 cm of the tips of the outer 2 primary feathers were recorded as juveniles, while individuals lacking these spots were recorded as adults (Copelin 1963). I banded each bird with a Texas Parks and Wildlife aluminum leg band, and males were equipped with a unique set of color bands.

The main goal of my research was to assess female reproductive ecology, so I equipped every female with a 22 gram Satellite Platform Transmitting Terminal GPS transmitter (PTT, Microwave Telemetry, Columbia, MD, USA). I attached the PTTs using the figure-8 rump method (Bedrosian and Craighead 2007). I deployed PTTs on

males only after peak female attendance at leks during mid-April. Satellite PTT data consisted of 4 GPS locations per day, with fixes taking place at 0100, 0700, 1300, and 1700 hrs Central Standard Time. I downloaded GPS data from the ARGOS website weekly. In addition to taking GPS fixes, each PTT transmitter was equipped with a Ground Track option. Each transmitter emitted a UHF signal from 1200 to 1700 hrs every day from 15 March to 15 July. I used the Ground Track signal to find depredated birds via a mortality signal.

I also fit opportunistically captured males with a 9 gram necklace style VHF transmitter (American Wildlife Enterprises, Monticello, FL, USA). I located individuals equipped with a VHF transmitter 3-5 times a week during the breeding season using triangulation. I used an Advanced Telemetry Systems R2000 receiver (Advanced Telemetry Systems, Isanti, MN, USA) and a hand-held 3 element Yagi antenna to obtain bearings. I then used the LOAS 4.0 software program (Location of a Signal, Ecological Software Solutions LLC, Florida, USA) to obtain UTM location estimates.

Probable Causes of Mortality

I visited each lesser prairie-chicken recovery site, if granted landowner permission, to determine the cause of mortality. Repeated GPS locations over the course of two days signaled a mortality event. I visited the last recorded location and thoroughly searched the surrounding area until I found the kill site. After examining carcass and transmitter condition and the area surrounding the kill site, I attributed the cause of mortality to either mammal or avian predation or unknown cause. I used the guidelines given by Grisham and Boal (2015) to determine probable cause of mortality. I considered the kill to be by a mammalian predator if feathers were heavily damaged, with quills

chewed through, and if there was significant bite marks on the transmitter. I attributed the kill to an avian predator if feathers appeared to be plucked and there was little transmitter damage. Whitewash around the kill site also signaled an avian predator. If I could not attribute the cause of mortality to an avian or mammalian predator, I considered the cause of mortality as unknown. I attributed mortalities occurring within 48 hours after capture as capture myopathy.

Survival

I used known-fate models in Program MARK (White and Burnham 1999) to estimate breeding and non-breeding season survival of lesser prairie-chickens in my study area. I considered 1 March – 31 August as the breeding season and 1 September – 28 February as the non-breeding season (Behny et al. 2012*a*, Pirius et al. 2013). Due to a low sample size, I grouped individuals marked with PTTs and VHF transmitters. Two studies in the northeastern portion of the lesser prairie-chicken range found that survival did not differ between birds marked with PTTs and traditional necklace transmitters (Plumb 2015, Robinson 2015). Encounter histories were by month, and I coded each individual as either live (10), dead (11), or censored (00) each month. I developed model sets based on field observations and previous investigations of LEPC survival.

I developed 4 model sets to assess breeding season survival. For the first set, I modeled survival as a function of month (March-August), early-late breeding season (March-May, June-August), age, sex, and constant survival (Grisham and Boal 2015). The other 3 model sets were based off habitat composition and configuration within each individual's breeding season home range. I modeled non-breeding season survival as a function of constant survival across the entire non-breeding period. Lesser prairie-

chicken survival is high during the non-breeding season in nearby shinnery oak prairie (Pirius et al. 2013), and I simply wanted to obtain a survival estimate for comparison. I lumped encounter histories for both the breeding and non-breeding seasons across years, due to sample size limitations.

I assessed the effects of habitat composition and configuration on LEPC breeding season survival based off the framework of Robinson (2015), who studied the effects of landscape characteristics on LEPC survival in Kansas. I developed a land cover layer by merging a Cropscape layer (National Agricultural Statistics Service, U.S. Department of Agriculture) with a 2014 CRP layer representing all properties enrolled in CRP across the lesser prairie-chicken's range. I then grouped land cover classes into 5 groups, which included native grass and forb CRP (GFCRP), native grass CRP (GCRP), non-native grass CRP (NNCRP), agriculture (AG), and native grassland (Grassland). Native grassland was characterized primarily by shrub/shortgrass vegetation communities. I calculated a breeding season Minimum Convex Polygon (MCP) for each individual and calculated the proportion of all 5 cover types within each home range using ArcGIS 10.2 (Environmental Systems Research Institute, Redlands, CA, USA). I then used the program FRAGSTATS (McGarigal et al. 2012) to calculate landscape metrics within each MCP home range. These metrics included Total Area, Mean Patch Size, Contagion Index, and Interspersion/Juxtaposition Index (Table 4.4).

My assessment of survival based off landscape characteristics was exploratory, and the models within the 3 candidate sets were not *a priori*. For the landscape composition model set, I included one model for each cover class (n = 5), a global model with all 5 cover classes, an additive model with all 3 CRP types, additive models with all

pairwise comparisons of cover types (n = 10), and a constant model. I included a model for each landscape metric (n = 4), a global model with all 4 metrics, additive models with all pairwise comparisons of landscape metrics (n = 6), and a constant model for the landscape configuration model set. I then developed a final model set with the landscape variables that received support in the previous analyses to assess the combined effects of habitat composition and configuration on LEPC survival.

I used Akaike's information criterion for small sample sizes (AIC*c*), delta AIC*c* values (ΔAIC*c*), and Akaike weights (AIC*w*) to select the best approximating model within each model set (Anderson 2008). Models with ΔAIC*c* values ≤ 2 were considered competing models. I assumed model selection uncertainty if the top model had less than 90% of the Akaike weight. If model selection uncertainty occurred, I model averaged estimates of survival across all models in the model set (Anderson 2008).

RESULTS

Probable Causes of Mortality

I captured 35 lesser prairie-chickens during the 2015-2017 trapping seasons (Table 4.1). I deployed 10 PTTs in 2015, 5 PTTs in 2016, and 10 PTTs in 2017. Nineteen PTTs were deployed on males, and 6 were deployed on females. I also deployed VHF transmitters on 2 males during the 2016 season and on one male during the 2017 season. I recorded 16 mortalities over the course of the study. Four mortalities were recorded in 2015, 6 in 2016, and 6 in 2017. Eleven of the mortalities were males and 5 were females.

Ten mortalities (63%) were attributed to mammalian predation, and 2 mortalities (13%) were attributed to avian predators. Two mortalities (13%) were from an unknown cause due to lack of land access for examining the mortality site. Two mortalities (13%)

were attributed to capture myopathy. Three male mortalities (27%) occurred during the early breeding season (March – May). An additional 7 males (64%) were depredated during the late breeding season, and the final male mortality occurred during the early non-breeding season (September). Three female mortalities occurred during the post-breeding period, after a failed nest attempt. The fourth female mortality occurred during the non-breeding season (Figure 4.1).

Survival

Season, Age, and Sex.— I eliminated 3 males from survival analysis due to death within 2 weeks of initial capture. Thus, I used 19 males and 6 females to assess breeding season survival. I detected model selection uncertainty in my *a priori* model set that examined the effects of age, sex, and temporal trends on breeding season survival (Table 4.2). The top model S_{EL}, which modeled survival as a function of early/late breeding season, received 72% of the AIC*c* weight. According to this model, survival was higher during the early breeding season (0.97, SE = 0.02, 95% CI = 0.89-0.99) compared to the late breeding season (0.87, SE = 0.04, 95% CI = 0.78-0.93). The top model, S_{EL}, was the only model with ΔAIC*c* values ≤ 2, indicating that LEPC age and sex did not influence survival to the extent of temporal patterns within the breeding season. I obtained a model averaged survival estimate due to the model selection uncertainty, and the probability of a LEPC surviving the breeding season was 0.61 (SE = 0.08, 95% CI = 0.44-0.78). I used encounter histories for 7 males and 2 females to assess non-breeding season survival. Three males were tracked during both non-breeding seasons, which resulted in 12 encounter histories used in the analysis. Based on the one model, $S_{CONSTANT}$, the

probability of a LEPC surviving the non-breeding season was 0.82 (SE = 0.11, 95% CI = 0.50-0.95).

Habitat Composition.— There was model selection uncertainty in the habitat composition model set (Table 4.5). Four of the 18 models had ΔAIC*c* values ≤ 2. Those models included S_{GFCRP} (ΔAIC*c* = 0.00, AIC*c* weight = 0.16), $S_{CONSTANT}$ (ΔAIC*c* = 0.67, AIC*c* weight = 0.12), $S_{GFCRP+AG}$ (ΔAIC*c* = 1.18, AIC*c* weight = 0.09), and S_{NNCRP} (ΔAIC*c* = 1.26, AIC*c* weight = 0.09). Native grass and forb CRP appeared to have the largest impact on survival out of all cover types, because AIC*c* weights from all models including the parameter accounted for 43% of the variation in the data set. Native grass and forb CRP had a positive effect on survival (β_{GFCRP} = 0.01, SE = 0.02, 95% CI = -0.03-0.05), while non-native grass CRP had a negative effect (β_{NNCRP} = -0.003, SE = 0.01, 95% CI = -0.02-0.02). The model averaged estimate of survival across the 4 top models was 0.56 (SE = 0.11, 95% CI = 0.36-0.77).

Habitat Configuration.— I also detected model selection uncertainty in the habitat configuration model set (Table 4.6). Three of the 12 models were considered competing (ΔAIC*c* < 2). Those models included $S_{CONSTANT}$ (ΔAIC*c* = 0.00, AIC*c* weight = 0.25), $S_{CONTAGION}$ (ΔAIC*c* = 0.80, AIC*c* weight = 0.17), and $S_{PATCH\ AREA}$ (ΔAIC*c* = 1.82, AIC*c* weight = 0.10). Contagion within the home range had a negative effect on survival ($\beta_{CONTAGION}$ = -0.008, SE = 0.01, 95% CI = -0.03-0.02), and patch area had a slight positive effect ($\beta_{PATCH\ AREA}$ = 0.001, SE = 0.005, 95% CI = -0.01-0.01); however, all 95% confidence intervals overlapped zero. The model averaged estimated of survival across the top 3 models was 0.54 (SE = 0.22, 95% CI = 0.11-0.97).

Habitat Composition and Configuration.— There was model selection uncertainty in the final model set examining the additive effects of habitat composition and configuration on survival (Table 4.7). Six of the 9 models received support ($\Delta AIC_c < 2$). They included S_{GFCRP} ($\Delta AIC_c = 0.00$, AIC_c weight = 0.24), $S_{CONSTANT}$ ($\Delta AIC_c = 0.66$, AIC_c weight = 0.17), S_{NNCRP} ($\Delta AIC_c = 1.25$, AIC_c weight = 0.13), $S_{CONTAGION}$ ($\Delta AIC_c = 1.47$, AIC_c weight = 0.11), $S_{GFCRP+CONTAGION}$ ($\Delta AIC_c = 1.75$, AIC_c weight = 0.10), and $S_{GFCRP+PATCH\ AREA}$ ($\Delta AIC_c = 1.81$, AIC_c weight = 0.10). The percentage of native grass and forb CRP within the home range appeared to positively influenced survival, but 95% confidence intervals did overlap zero ($\beta_{NGFCRP} = 0.01$, SE = 0.02, 95% CI = -0.02-0.04). Non-native grass and forb CRP negatively influenced survival ($\beta_{NNCRP} = -0.002$, SE = 0.005, 95% CI = -0.01-0.01). Contagion also had a negative impact on survival ($\beta_{CONTAGION} = -0.004$, SE = 0.01, 95% CI = -0.03-0.02). The model averaged estimate of survival across the 6 top models was 0.56 (SE = 0.11, 95% CI = 0.35-0.77).

DISCUSSION

Lesser prairie-chicken survival in my study area increased as the proportion of native grass and forb CRP within the home range increased, which is consistent with my fourth hypothesis. In previous studies CRP had a net positive effect for LEPCs in Kansas (Ross et al. 2016), and my results suggest breeding season survival is influenced by the amount of grass and forb CRP within an individual's home range. Habitat composition within the home range appeared to have more influence on survival than habitat configuration, as the S_{GFCRP} model received twice the support as the top competing configuration model, $S_{CONTAGION}$, in the combined model set. The negative beta-estimate associated with non-native grass CRP was also consistent with my hypothesis and field

observations. During the first field season of this assessment, all 4 mortalities occurred within a CRP field that was mostly composed of weeping lovegrass, an introduced grass to Texas. Despite these findings, the beta-estimates for both native grass and forb and non-native CRP did overlap zero (See Appendix). However, due to the support received by models incorporating native grass and forb CRP, this analysis provided evidence that CRP fields seeded in native vegetation provided better resources for nesting and adult survival (Chapter III).

Habitat configuration did not influence survival to the extent of composition, but the model incorporating the Contagion Index received support in the final landscape model set. The Contagion Index is a measure of the clumping of patches across the landscape, and a value of 100% means there is a single patch present. The negative beta-estimate for Contagion suggests that LEPC survival decreases as patch clumping increases. This is similar to the findings of Robinson (2015), who found that LEPC survival in Kansas increased as the number of patch types increased within the home range. Lesser prairie-chickens have different habitat requirements throughout different life stages (Haukos and Zavaleta 2016). The presence of multiple CRP enrollments within the home range may provide a gradient of vegetation structure that provides habitat for lekking, foraging, roosting, and nesting. Therefore, my results support previous studies that suggest increasing habitat heterogeneity at multiple spatial scales is positive for LEPC populations (Fuhlendorf and Engle 2001, Robinson 2015, Grisham et al. 2016).

My results on the causes of LEPC mortalities are consistent with the findings of Grisham and Boal (2015), who examined LEPC breeding season survival in Shinnery

Oak Prairie in Texas. The majority of mortalities (40%) were attributed to mammalian predators. Coyotes (*Canis latrans*) were the most numerous potential mammalian predator throughout the study site, and I also observed signs of American badger (*Taxidea taxus*). I never observed a predation attempt by an avian predator while LEPCs were present on a lek site, but northern harriers (*Circus cyaneus*) frequently flushed birds off the lek while flying overhead. Other avian predators observed on the study site included red-tailed hawks (*Buteo jamaicensis*), ferruginous hawks (*B. regalis*), rough-legged hawks (*B. lagopus*), and prairie falcons (*Falco mexicanus*), but these species typically leave the study area during the lekking period (Behny et al 2012*b*). Swainson's hawks (*B. swainsoni*) arrived on the study area approximately half way through the lekking period and were the most numerous potential avian predator for the majority of the breeding season (Behny et al 2012*b*). Raptor abundance and diversity is greatest on the Southern High Plains during the fall and winter months (Behny et al. 2012*b*), but I observed few mortalities during that portion of the year. Therefore, I concluded that mammals were the main source of adult LEPC predation in my study area during the course of a year.

The temporal patterns I observed for male LEPC mortalities are consistent with findings in nearby shinnery oak prairie (Grisham and Boal 2015). Of 25 male LEPC mortalities documented in Texas, 17 (68%) occurred during the late breeding season months of June through August (Grisham and Boal 2015). Likewise, 64% of male mortalities in my study occurred during the late summer months (Figure 4.2). Increased male mortality during the latter portion of the breeding season was attributed to reduced fitness after the intense lekking period as well as drought effects (Grisham and Boal

2015). My study area experienced average to above average rainfall during the years of my study ($\bar{x}$=57 cm; West Texas Mesonet, http://www.mesonet.ttu.edu/), which suggests male survival in the Sand Shinnery Oak ecoregion is most likely a function of breeding activities, regardless of environmental conditions. It is interesting to note that peak male mortality occurred in April and May in both Kansas and Oklahoma (Jamison 2000, Wolfe et al. 2007). Additional research is warranted to assess the causes of increased male mortality during late summer in Shinnery Oak Prairie.

Only one female was depredated while incubating a nest during the three years of this assessment. This finding is contrary to previous studies that found female survival decreased significantly during nesting and brood-rearing (Hagen et al. 2007, Wolfe et al. 2007, Plumb 2015). Avian predators have been identified as a main source of mortality for females nesting in open grasslands similar to my study area (Wolfe et al. 2007, Plumb 2015). However, the relatively low abundance and diversity of raptors in my study area following spring migration (Behny et al. 2012, Boal 2016) partially explains the lack of female mortalities during nesting. Mammalian predators were still a potential source of depredation during nesting, but my estimates of visual obstruction at nests fell within the range recommended by previous studies to increase nest and female survival (Hagen et al. 2007, Grisham 2012, Lautenbach 2015, Plumb 2015, Chapter III). Also, I surmise the absence of overhead shrub cover at nests in my study area allowed for quick escape in the event of a mammalian predation attempt.

Female LEPC survival was found to be constant across the breeding season in shinnery oak prairie, and the constant survival rate was attributed to multiple females deferring nesting attempts during drought periods (Grisham and Boal 2015). My results

are similar in that survival did not decrease during the nesting period, but I did observe an increase in female mortalities post-breeding (Figure 4.2). Two females made long-distance dispersal movements after brood loss and both were depredated. Ruffed grouse (*Bonasa umbellus*) survival in Ohio decreased when individuals occupied unfamiliar space due to dispersal movements (Yoder et al. 2004). My results suggest LEPC survival also decreases after dispersal movements, due to lack of knowledge regarding food resources and escape cover. A third female was depredated after a failed nest attempt, and I hypothesize that similar to males, female fitness decreased after nest searching, egg laying, incubation, and in some cases dispersal, which made females more susceptible to depredation post-breeding. The use of modern PTTs allowed me to assess female survival, as well as long-distance movements after individuals left the study area. Individuals marked with traditional VHF transmitters were censored from survival analyses after dispersal movements to remove bias (Grisham and Boal 2015), plus the authors could not relocate the lost individuals after nest failure due to limitations of the VHF transmitters (B. Grisham, personal communication). The use of PTTs in this assessment revealed interesting movement patterns post-breeding and allowed for the estimation of breeding season survival without censoring lost individuals. The use of PTTs in future studies will allow for numerous new discoveries into mortality and survival for this species in shinnery oak prairie.

Based on my results, adult breeding and non-breeding survival does not limit LEPC abundance in my study area. My estimate of the probability of a LEPC surviving the breeding season is consistent with previous studies. Previous estimates of LEPC breeding season survival with sexes pooled range from 0.42 ± 0.163 to 0.71 ± 0.110

(Toole 2005, Leonard 2008, Jones 2009). It is recommended that separate estimates of survival be obtained for male and female LEPCs (Grisham 2012), but my sample size did not warrant separate analyses. I recorded only 2 mortalities during the fall and winter periods of my study, but there was no consistent patterns or causes of mortality (Figure 4.2). This finding is consistent with Robinson (2015), who concluded that female LEPC mortalities occurred at random during the non-breeding period in Kansas. In addition, my estimate of LEPC non-breeding season survival was greater than survival in shinnery oak prairie. Lesser prairie-chicken non-breeding season survival was 0.72 ± 0.076 from 2008-2011 and ranged from 0.57 – 0.85 between years (Pirius et al. 2013). The higher survival estimate may be due to the grass cover provided by CRP during the fall and winter months. Much of the shinnery oak prairie in Texas is a monoculture of shrubs due to years of unmanaged grazing and fire suppression (Grisham et al. 2014), and sand shinnery oak defoliates during the winter months (Peterson and Boyd 1998). Thus, it appears that one unanticipated, yet positive benefit of CRP in Texas is reliable cover for LEPCs during the non-breeding season.

Adult survival has been identified as an indicator of LEPC habitat quality (Haukos and Zavaleta 2016). Individuals occurring in habitat that is lacking key food and cover components will have lower survival than individuals occurring in areas with better or more resources. My results suggest CRP fields in the High Plains of Texas provide necessary resources that facilitate average LEPC survival during years of normal or surplus rainfall. Additional research will be needed to address the effects of drought on LEPC survival within CRP fields in Texas, particularly because CRP fields are traditionally hayed during drought years on the Southern High Plains (D. Lucia, U.S. Fish

and Wildlife Service, personal communication). Survival was positively influenced by the percentage of native grass and forb CRP within the home range. I acknowledge that the confidence interval around the beta-estimate for native grass and forb CRP overlaps zero, and I attribute this to a small sample size. Previous investigations into LEPC survival used sample sizes ranging from 113 to 311 individuals (Hagen et al. 2005, Hagen et al. 2007, Grisham and Boal 2015). Recent drought years across the Southern High Plains and the limited availability of CRP land across the study area (Chapter II) make obtaining sufficient sample sizes difficult for LEPC studies in my study area.

MANAGEMENT IMPLICATIONS

Lesser prairie-chicken adult survival in my study area was consistent with other survival estimates from across the species' range and appears to not contribute to population declines. Lesser prairie-chicken populations within my study area may benefit most if management actions within CRP fields are targeted at improving nesting and brood-rearing habitat. However, high adult survival may be best maintained if CRP tracts ≥2500 ha are kept in grasses after contract expiration and if a mixture of grasses and forbs is included in future CRP seeding mixes. Also, strategically placing new CRP fields in corridors between habitat patches will facilitate higher survival for individuals making long distance movements between patches, and subsequently increase habitat heterogeneity on the landscape for the species.

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Table 4.1. Lesser prairie-chicken (*Tympanuchus pallidicinctus*) capture results for the spring 2015-2017 trapping seasons. Individuals were captured in Conservation Reserve Program fields in Bailey and Cochran Counties, Texas.

Year	Sex	Age	Total #[a]	# PTT	# VHF
2015	Male	Adult	7	4	0
		Sub-adult	6	5	0
	Female	Adult	0	0	0
		Sub-adult	1	1	0
2016	Male	Adult	5	1	1
		Sub-adult	2	0	1
	Female	Adult	1	1	0
		Sub-adult	3	3	0
2017	Male	Adult	5	6	1
		Sub-adult	4	3	0
	Female	Adult	0	0	0
		Sub-adult	1	1	0
		Total	35	25	3

a. Total # = number of individuals captured, # PTT = number of individuals fitted with Platform Transmitting Terminal, # VHF = number of individuals fitted with Very High Frequency transmitter

Table 4.2. Output from five *a priori* models used to assess the effects of time, age, and sex on lesser prairie-chicken (*Tympanuchus pallidicinctus*) breeding season survival in Bailey and Cochran Counties, Texas, 2015-2017.

Model[a]	AIC*c*[b]	ΔAIC*c*	AIC*c* wt	Model Likelihood	K	Deviance
S_{EL}	82.27	0.00	0.72	1.00	2	78.19
$S_{.}$	86.15	3.88	0.10	0.14	1	84.13
S_{MONTH}	86.92	4.66	0.07	0.09	5	76.52
S_{SEX}	87.11	4.85	0.06	0.09	2	83.03
S_{AGE}	88.15	5.89	0.04	0.05	2	84.07

a. S_{EL} – Survival is a function of the early (March-May) or late (June-August) breeding season, S_{MONTH} – Survival is a function of the month of the breeding season (March – August), S. – Survival is constant across the breeding season, S_{AGE} – Survival is a function of age (Juvenile/Adult), S_{SEX} – Survival is a function of sex (Male/Female)
b. AIC*c* = Akaike's Information Criterion for small sample sizes, ΔAIC*c* = differences in AIC*c*, AIC*c* wt = Akaike weights, K = number of parameters

Table 4.3. Survival estimates, standard errors, and 95% confidence intervals for the top model, S_{EL}, in the *a priori* model set used to assess breeding season survival of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in Bailey and Cochran Counties, Texas, 2015-2017.

Parameter	Estimate	SE	95% CI	
			Lower	Upper
Early	0.97	0.02	0.90	0.99
Late	0.87	0.04	0.78	0.93
Cumulative	0.61	0.08	0.44	0.78

Table 4.4. Definitions of FRAGSTATS metrics used to assess effects of landscape configuration on lesser prairie-chicken (*Tympanuchus pallidicinctus*) breeding season survival in Bailey and Cochran Counties, Texas, 2015-2017.

FRAGSTATS Metric	Definition
Total Area	Total area of the landscape. Reported in hectares.
Mean Patch Size	Total area of the landscape divided by the number of individual patches. Reported in hectares.
Contagion Index	Degree of clumping of patches on the landscape, based on cell adjacencies. Expressed as a percent.
Interspersion/Juxtaposition Index	Degree to which patches are intermixed, based on patch adjacencies. Expressed as a percent.

Table 4.5. Output from eighteen models used to assess the effects of landscape composition within the home range on lesser prairie-chicken (*Tympanuchus pallidicinctus*) breeding season survival in Bailey and Cochran Counties, Texas, 2015-2017.

Model[a]	AIC*c*[b]	Δ AIC*c*	AIC*c* wt	Model Likelihood	K	Deviance
{GFCRP}	73.30	0.00	0.16	1.00	2	69.19
{Constant}	73.97	0.66	0.11	0.71	1	71.93
{GFCRP+AG}	74.48	1.17	0.09	0.55	3	68.25
{NNCRP}	74.56	1.25	0.08	0.53	2	70.45
{GFCRP+NNCRP}	75.32	2.01	0.06	0.36	3	69.09
{GFCRP+GCRP}	75.39	2.09	0.05	0.35	3	69.17
{GFCRP+Grassland}	75.40	2.10	0.05	0.34	3	69.18
{GCRP}	75.63	2.32	0.05	0.31	2	71.52
{Grassland}	75.63	2.33	0.05	0.31	2	71.52
{NNCRP+Grassland}	75.64	2.34	0.05	0.30	3	69.42
{Agriculture}	76.02	2.71	0.04	0.25	2	71.91
{GCRP+NNCRP}	76.02	2.72	0.04	0.25	3	69.80
{NNCRP+AG}	76.55	3.25	0.03	0.19	3	70.33
{All CRP}	77.00	3.70	0.02	0.15	4	68.63
{GCRP+Grassland}	77.22	3.91	0.02	0.14	3	70.99
{GCRP+AG}	77.48	4.18	0.02	0.12	3	71.26
{Grassland+AG}	77.68	4.37	0.01	0.11	3	71.45
{Global}	81.02	7.72	0.003	0.02	6	68.22

a. GCRP = Native Grass CRP, GFCRP = Native Grass and Forb CRP, NNCRP = Non-native Grass CRP, AG = Agriculture, Grassland = Native Grassland
b. AIC*c* = Akaike's Information Criterion for small sample sizes, ΔAIC*c* = differences in AIC*c*, AIC*c* wt = Akaike weights, K = number of parameters

Table 4.6. Output from twelve models used to assess the effects of landscape configuration within the home range on lesser prairie-chicken (*Tympanuchus pallidicinctus*) breeding season survival in Bailey and Cochran Counties, Texas, 2015-2017.

Model[a]	AIC*c*[b]	Δ AIC*c*	AIC*c* wt	Model Likelihood	K	Deviance
{Constant}	73.97	0.00	0.25	1.00	1	71.94
{Contagion}	74.77	0.80	0.17	0.67	2	70.66
{Patch Area}	75.79	1.82	0.10	0.40	2	71.68
{IJI}	76.00	2.03	0.09	0.36	2	71.89
{Total Area}	76.03	2.06	0.09	0.36	2	71.92
{Contagion+Patch Area}	76.58	2.60	0.07	0.27	3	70.35
{Contagion+IJI}	76.66	2.69	0.06	0.26	3	70.44
{Contagion+Total Area}	76.81	2.84	0.06	0.24	3	70.59
{Patch Area+Total Area}	77.80	3.83	0.04	0.15	3	71.58
{IJI+Patch Area}	77.84	3.87	0.04	0.14	3	71.62
{IJI+Total Area}	78.11	4.14	0.03	0.13	3	71.89
{Global}	80.49	6.52	0.01	0.04	5	69.93

a. Contagion = Contagion Index, Patch Area = Mean Patch Area, IJI = Interspersion and Juxtaposition Index
b. AIC*c* = Akaike's Information Criterion for small sample sizes, ΔAIC*c* = differences in AIC*c*, AIC*c* wt = Akaike weights, K = number of parameters

Table 4.7. Output from nine models used to assess the effects of landscape composition and configuration within the home range on lesser prairie-chicken (*Tympanuchus pallidicinctus*) breeding season survival in Bailey and Cochran Counties, Texas, 2015-2017.

Model[a]	AIC*c*[b]	Δ AIC*c*	AIC*c* wt	Model Likelihood	K	Deviance
{GFCRP}	73.30	0.00	0.24	1.00	2	69.19
{Constant}	73.97	0.67	0.17	0.72	1	71.94
{NNCRP}	74.56	1.26	0.13	0.53	2	70.45
{Contagion}	74.77	1.47	0.11	0.48	2	70.66
{GFCRP+Contagion}	75.06	1.75	0.10	0.42	3	68.83
{GFCRP+Patch Area}	75.11	1.81	0.10	0.40	3	68.89
{Patch Area}	75.79	2.48	0.07	0.29	2	71.68
{NNCRP+Patch Area}	76.57	3.26	0.05	0.20	3	70.35
{NNCRP+Contagion}	76.58	3.28	0.05	0.19	3	70.36

a. GFCRP = Native Grass and Forb CRP, NNCRP = Non-native Grass CRP, Contagion = Contagion Index, Patch Area = Mean Patch Area
b. AIC*c* = Akaike's Information Criterion for small sample sizes, ΔAIC*c* = differences in AIC*c*, AIC*c* wt = Akaike weights, K = number of parameters

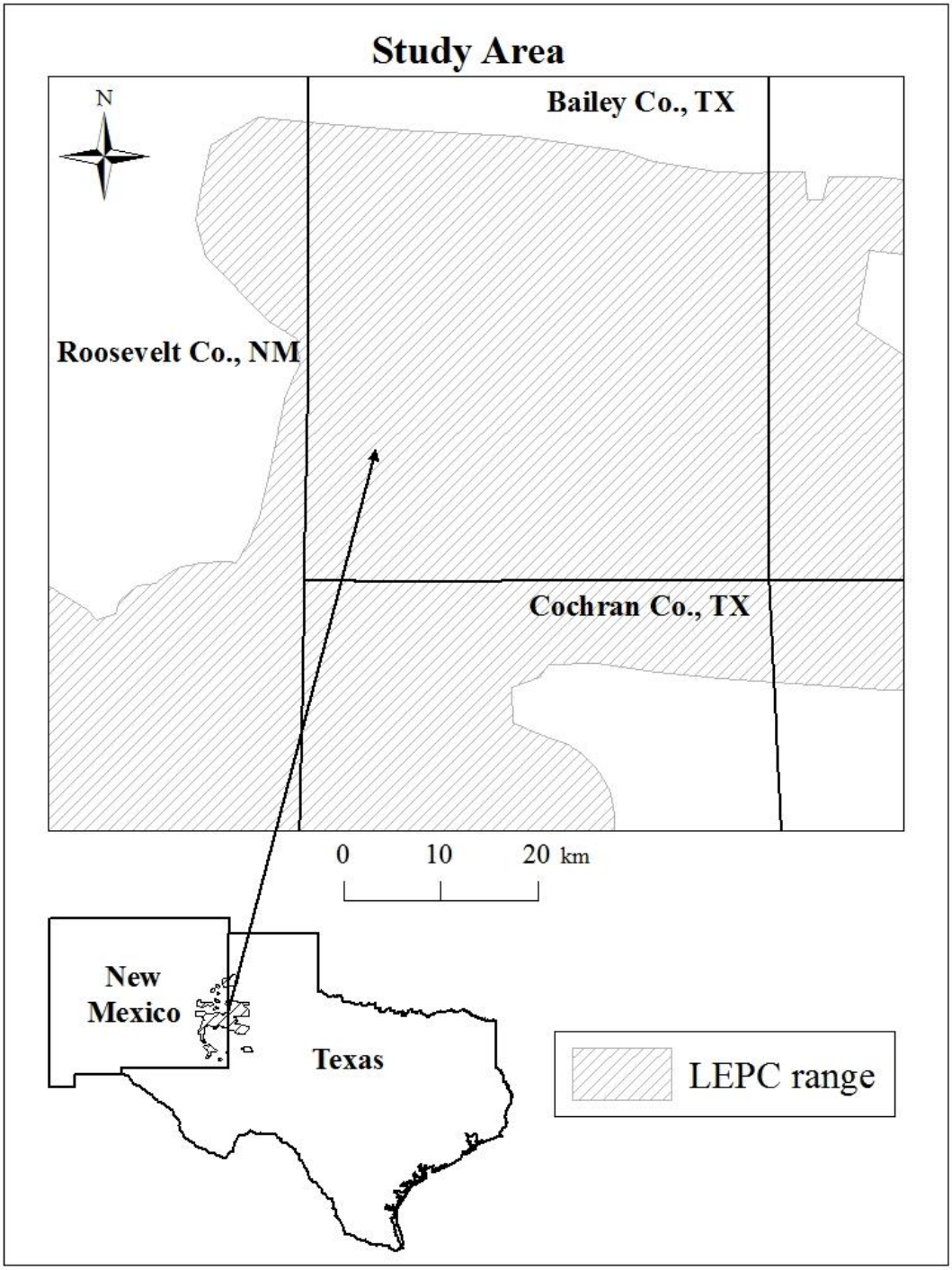

Figure 4.1. Bailey and Cochran County, Texas study areas in the Sand Shinnery Oak Prairie ecoregion of the lesser prairie-chicken (*Tympanuchus pallidicinctus*) range.

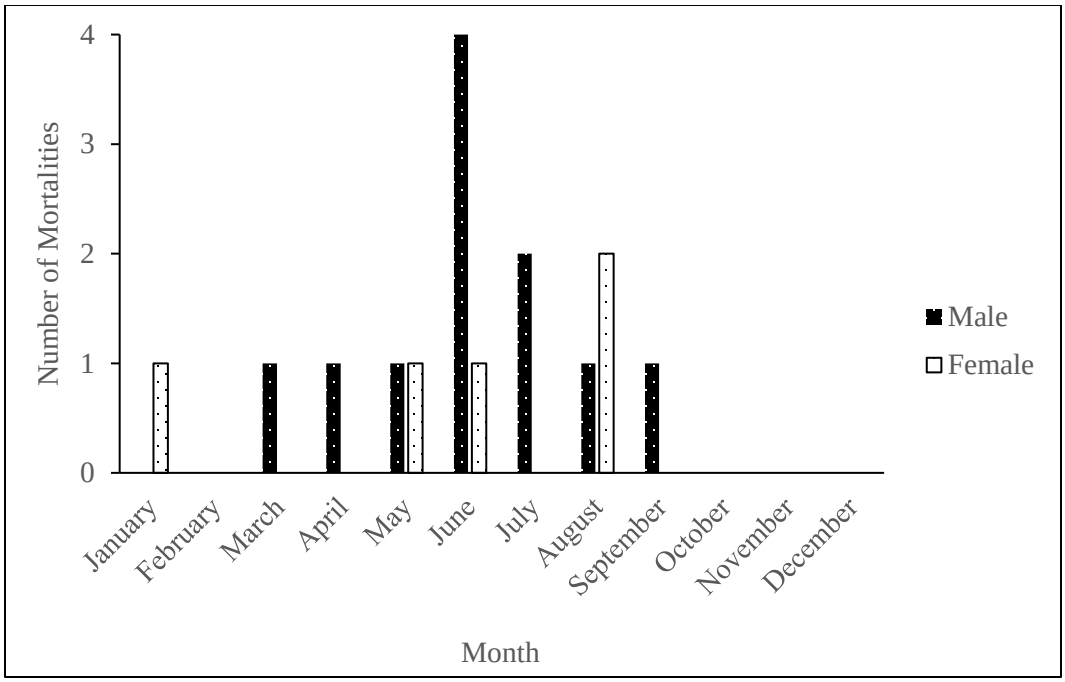

Figure 4.2. Distribution of lesser prairie-chicken (*Tympanuchus pallidicinctus*) mortalities over the course of a year in Bailey and Cochran Counties, Texas, 2015-2017.

APPENDIX

TABLES

Table A.1. Average 50% core area and 95% home range size of lesser prairie-chickens (*Tympanuchus pallidicinctus*) for six sub-seasons of the breeding season and for the cumulative breeding and non-breeding seasons. Home ranges were calculated using the Brownian Bridge Movement Model. Individuals were captured in Bailey and Cochran Counties, Texas from March to May 2015-2017.

Sex	Season	N	Core Area (ha)	SE	Home Range (ha)	SE
Male	Lekking	23	35	4.7	203	25.0
	Summer	21	30	3.1	188	15.9
	Cumulative Breeding	22	44	4.2	254	25.0
	Non-Breeding	9	95	9.4	678	81.4
Female	Pre-Nesting	8	51	10.8	285	50.9
	Nesting	8	20	10.6	112	36.4
	Brooding	2	11	0.7	55	1.8
	Post-Breeding	5	12	1.8	147	45.2
	Cumulative Breeding	7	25	6.0	239	36.1
	Non-Breeding	2	44	9.5	429	94.3

Table A.2. Average 95% home range size of lesser prairie-chickens (*Tympanuchus pallidicinctus*) for the six months of the non-breeding season. Home ranges were calculated using the Brownian Bridge Movement Model. Individuals were captured in Bailey and Cochran Counties, Texas from March to May 2015-2017.

Month	N	Home Range (ha)	SE	Range (ha)
September	12	254	38.5	64-514
October	11	491	38.1	320-702
November	11	571	130.7	265-1729
December	10	431	110.9	67-1327
January	10	535	107.2	31-1055
February	9	350	66.4	141-668

Table A.3. Average daily movement distances of lesser prairie-chickens (*Tympanuchus pallidicinctus*), summarized by six biological periods of the breeding season and the cumulative non-breeding season. Individuals were captured in Bailey and Cochran Counties, Texas from March to May 2015-2017.

Sex	Season	N	Daily Movement (m)	SE
Male	Lekking	1122	1623.1	28.5
	Summer	1037	1217.0	21.7
	Non-Breeding	1532	1866.8	25.6
Female	Pre-Nesting	126	1485.7	65.6
	Nesting	217	656.2	57.5
	Brooding	63	647.8	35.3
	Post-Breeding	266	1046.1	103.1
	Non-Breeding	329	833.2	30.4

FIGURES

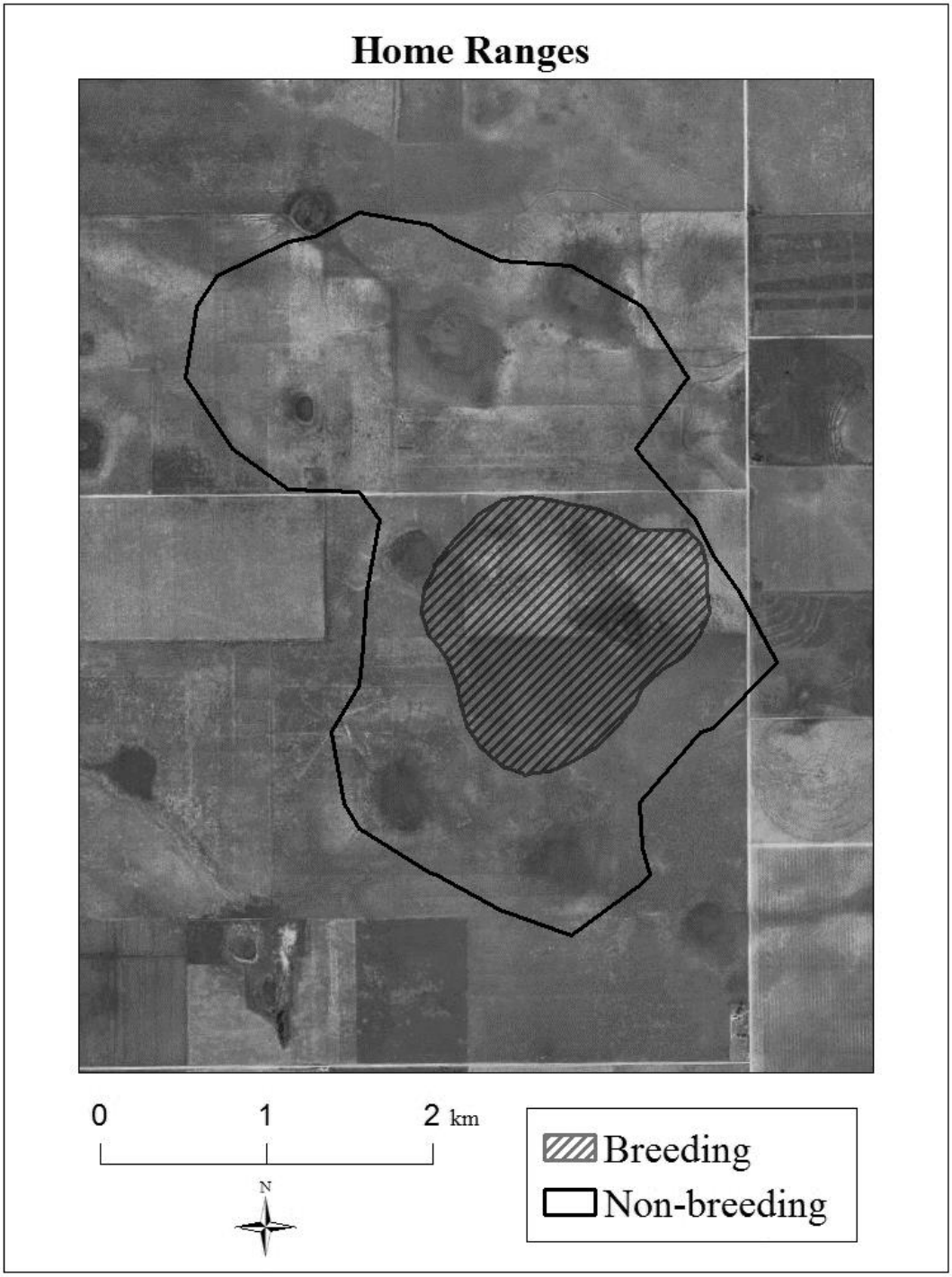

Figure A.1. Breeding and non-breeding season 95% home ranges for a male lesser prairie-chicken (*Tympanuchus pallidicinctus*) in Bailey County, Texas. Home ranges were estimated using the Brownian Bridge Movement Model.

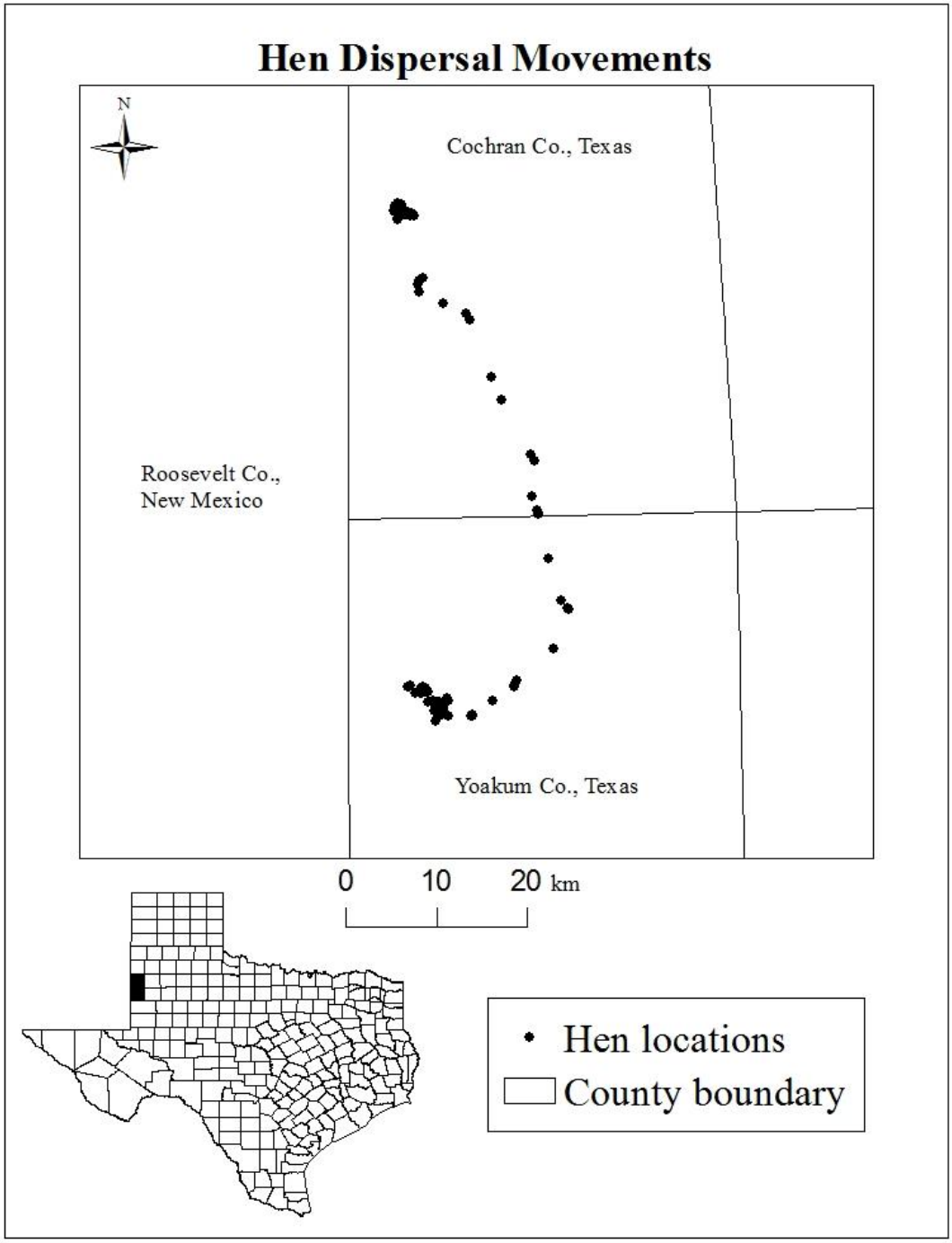

Figure A.2. Female long-distance movement from the Cochran County, Texas study area south into Yoakum County, Texas. The long-distance movement was undertaken by a single female on 31 May 2016 after total brood loss.

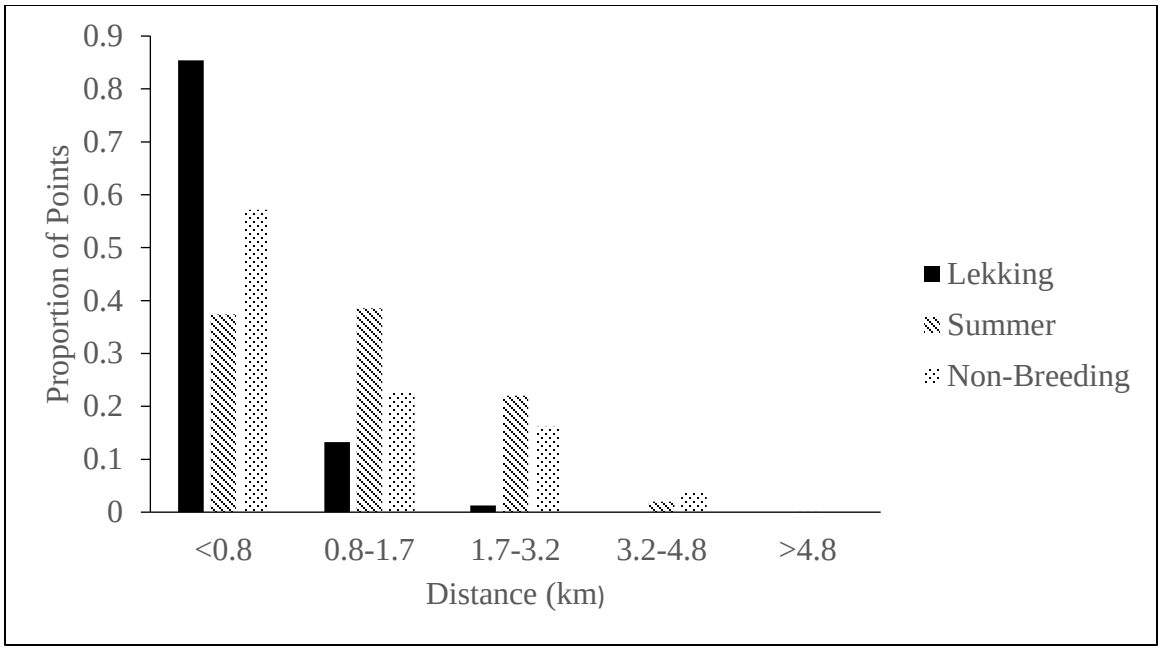

Figure A.3. Distance from nearest lek (km) for all male lesser prairie-chicken (*Tympanuchus pallidicinctus*) GPS locations. Distances are divided into the lekking season (1 March – 31 May), summer season (1 June – 31 August), and the non-breeding season (1 September – 28 February). Data were collected in Bailey and Cochran Counties, Texas, 2015-2017.

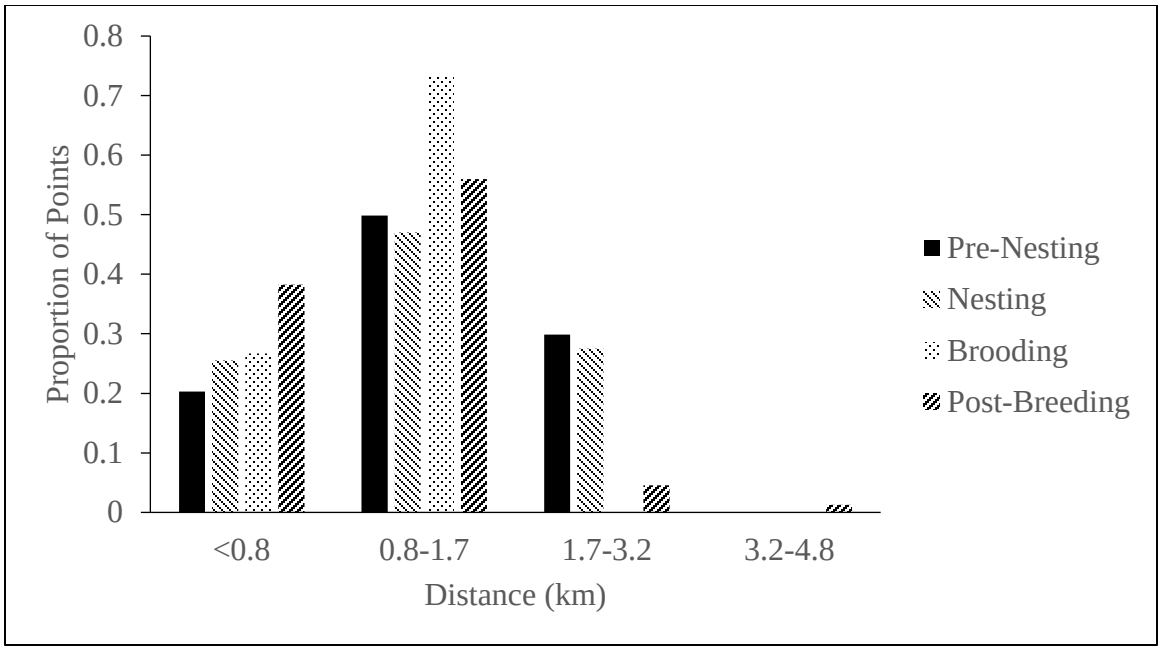

Figure A.4. Distance from nearest lek (km) for all female lesser prairie-chicken (*Tympanuchus pallidicinctus*) GPS locations. Distances are divided into the the pre-nesting, nesting, brooding, and post-breeding periods of the breeding season. Data were collected in Bailey and Cochran Counties, Texas, 2015-2017.

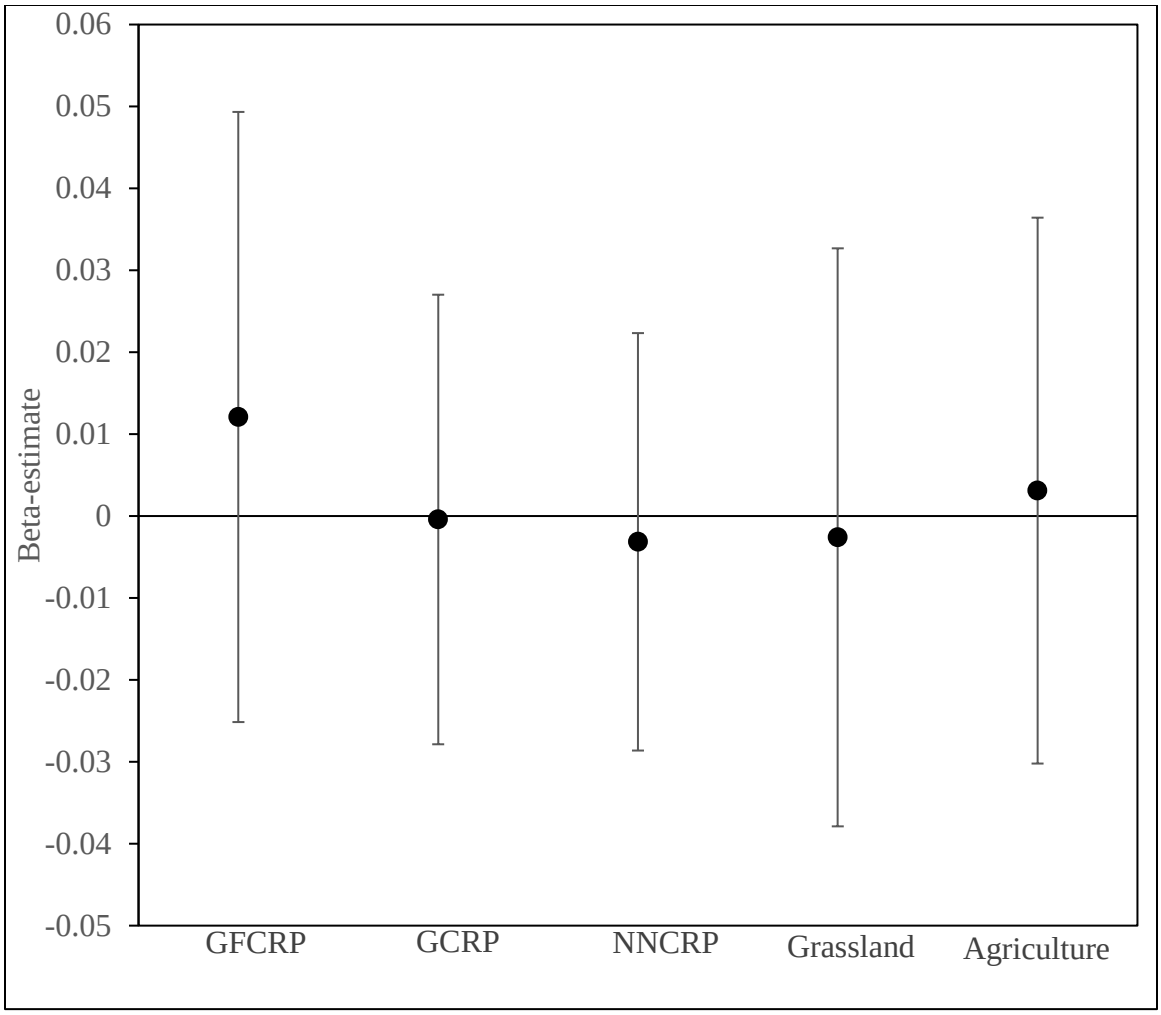

Figure A.5. Beta-estimates and 95% confidence intervals for the effects of native grass and forb CRP (GFCRP), native grass CRP (GCRP), non-native grass CRP (NNCRP), native grassland, and agriculture within the home range on lesser prairie-chicken (*Tympanuchus pallidicinctus*) breeding season survival. Data were collected in Bailey and Cochran Counties, Texas from 2015-2017.

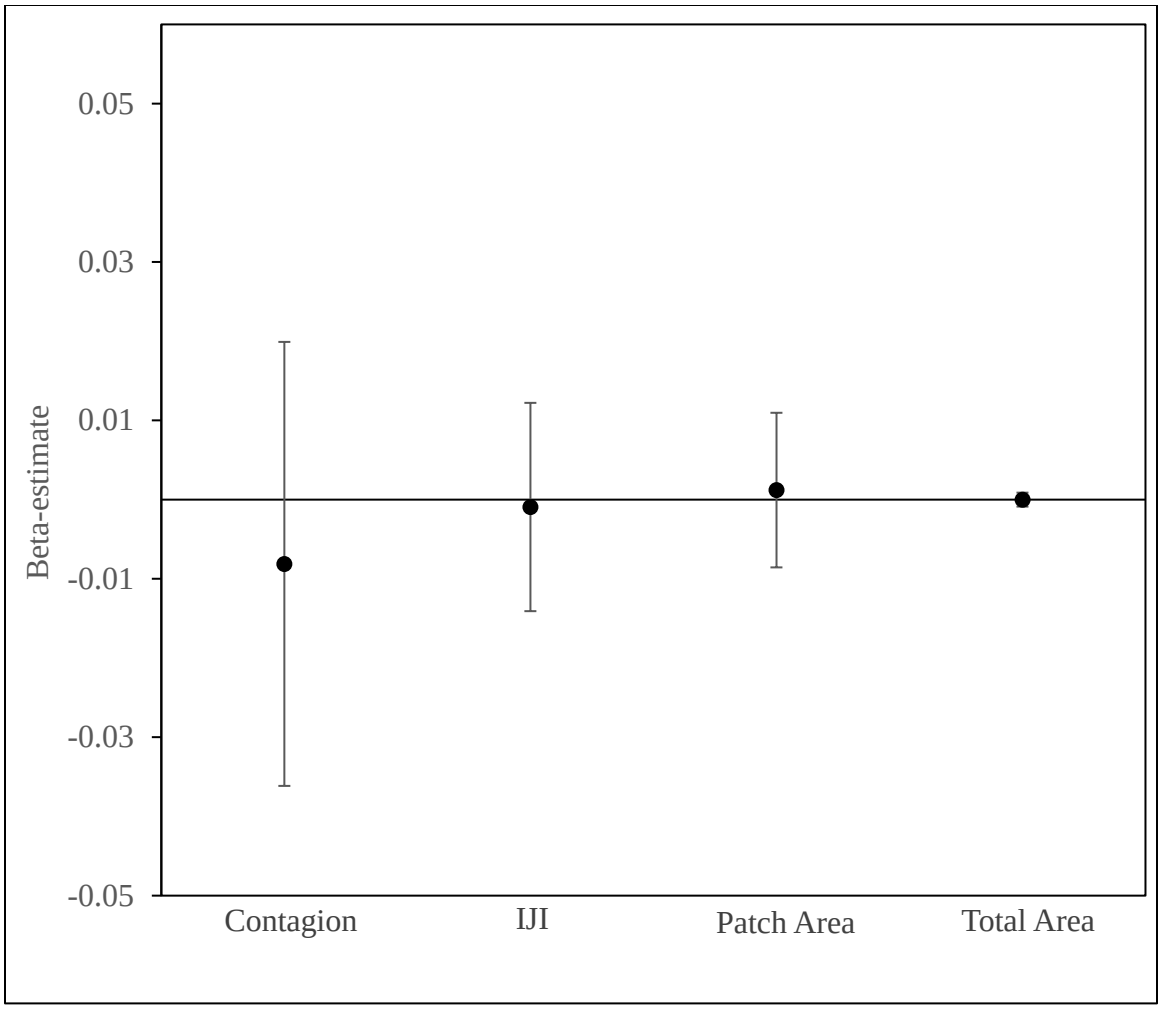

Figure A.6. Beta-estimates and 95% confidence intervals for the effects of contagion index, interspersion and juxtaposition index (IJI), average patch area, and total area within the home range on lesser prairie-chicken (*Tympanuchus pallidicinctus*) breeding season survival. Data were collected in Bailey and Cochran Counties, Texas from 2015-2017.

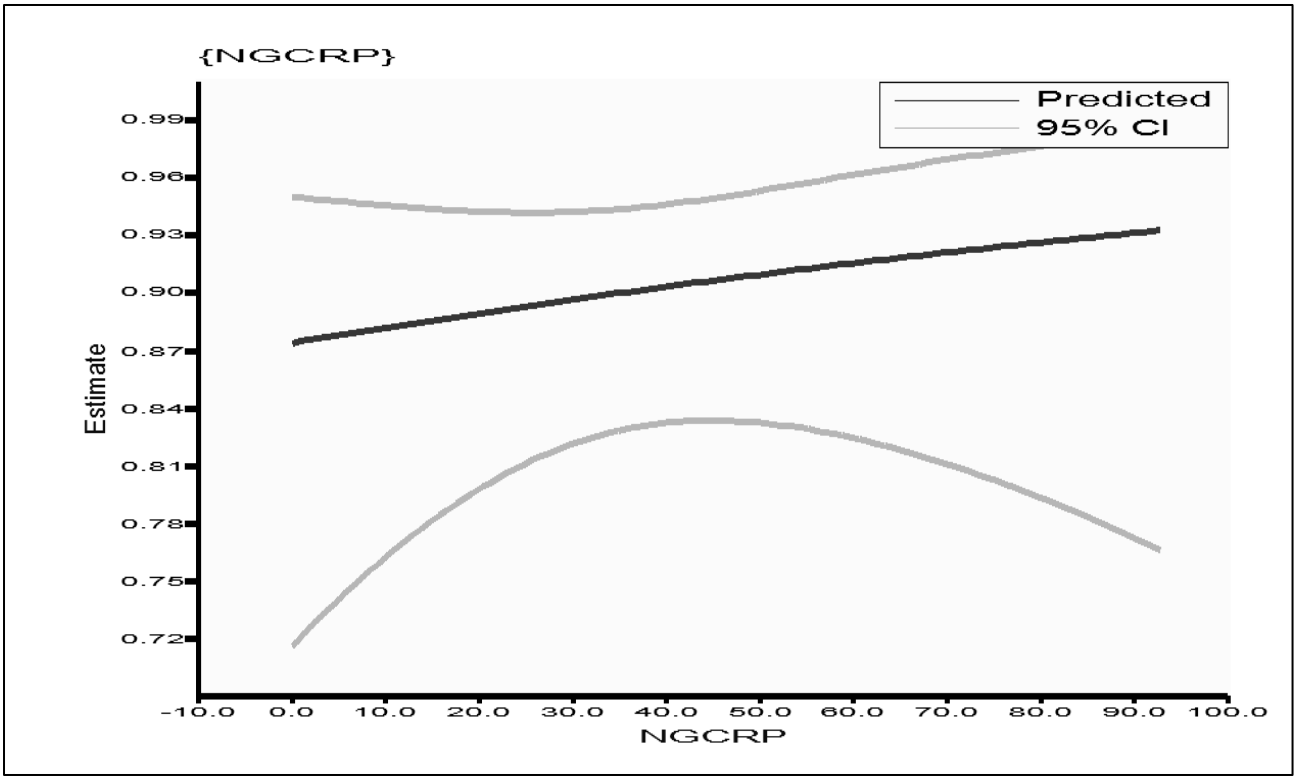

Figure A.7. Predictive plot showing survival rates of lesser prairie-chickens (*Tympanuchus pallidicinctus*) based on the percentage of native grass CRP within the home range. Data were collected in Bailey and Cochran Counties, Texas from 2015-2017.

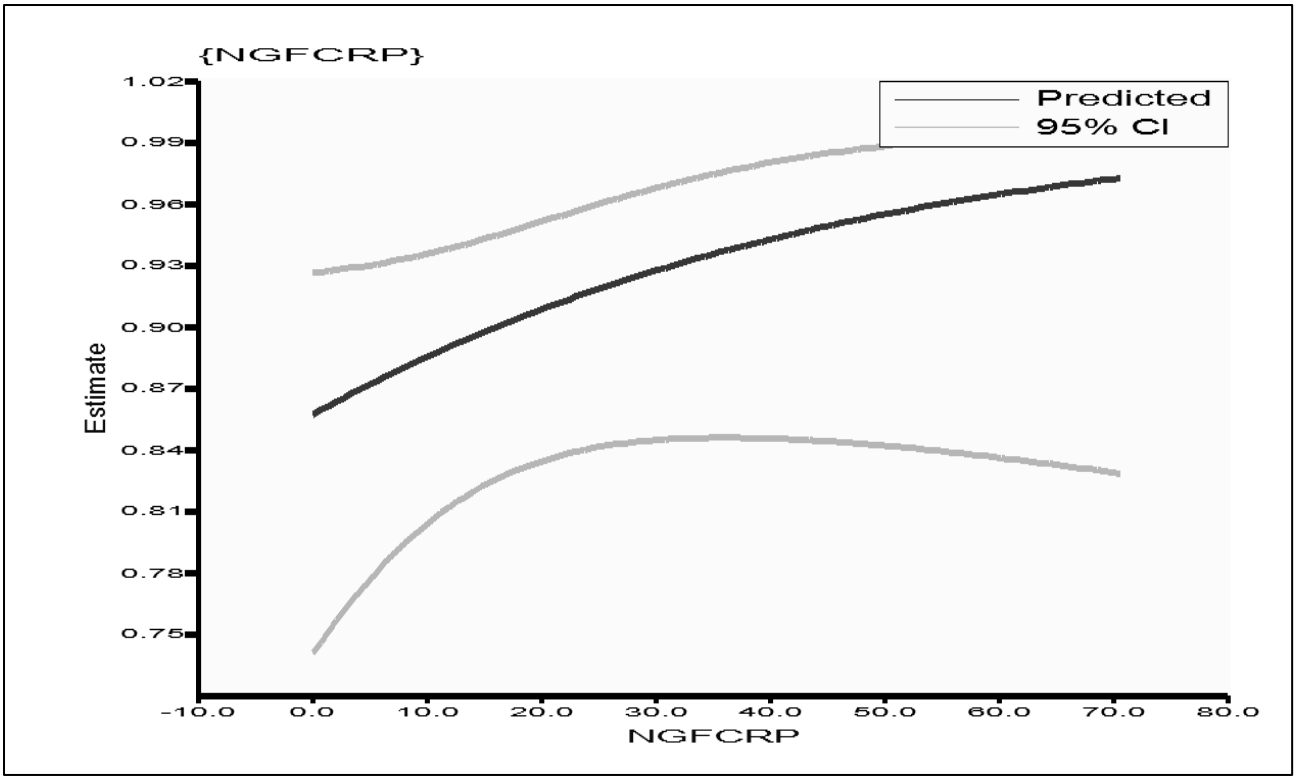

Figure A.8. Predictive plot showing survival rates of lesser prairie-chickens (*Tympanuchus pallidicinctus*) based on the percentage of native grass and forb CRP within the home range. Data were collected in Bailey and Cochran Counties, Texas from 2015-2017.

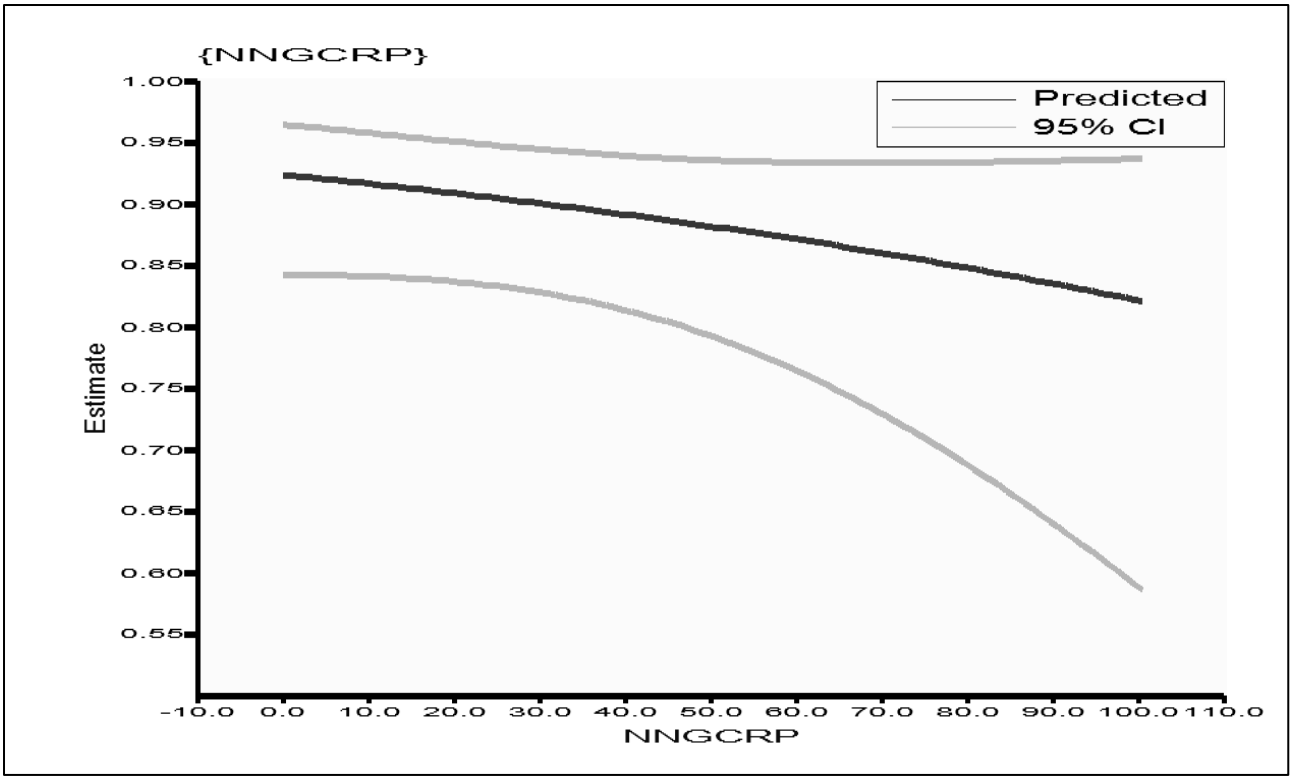

Figure A.9. Predictive plot showing survival rates of lesser prairie-chickens (*Tympanuchus pallidicinctus*) based on the percentage of non-native grass CRP within the home range. Data were collected in Bailey and Cochran Counties, Texas from 2015-2017.

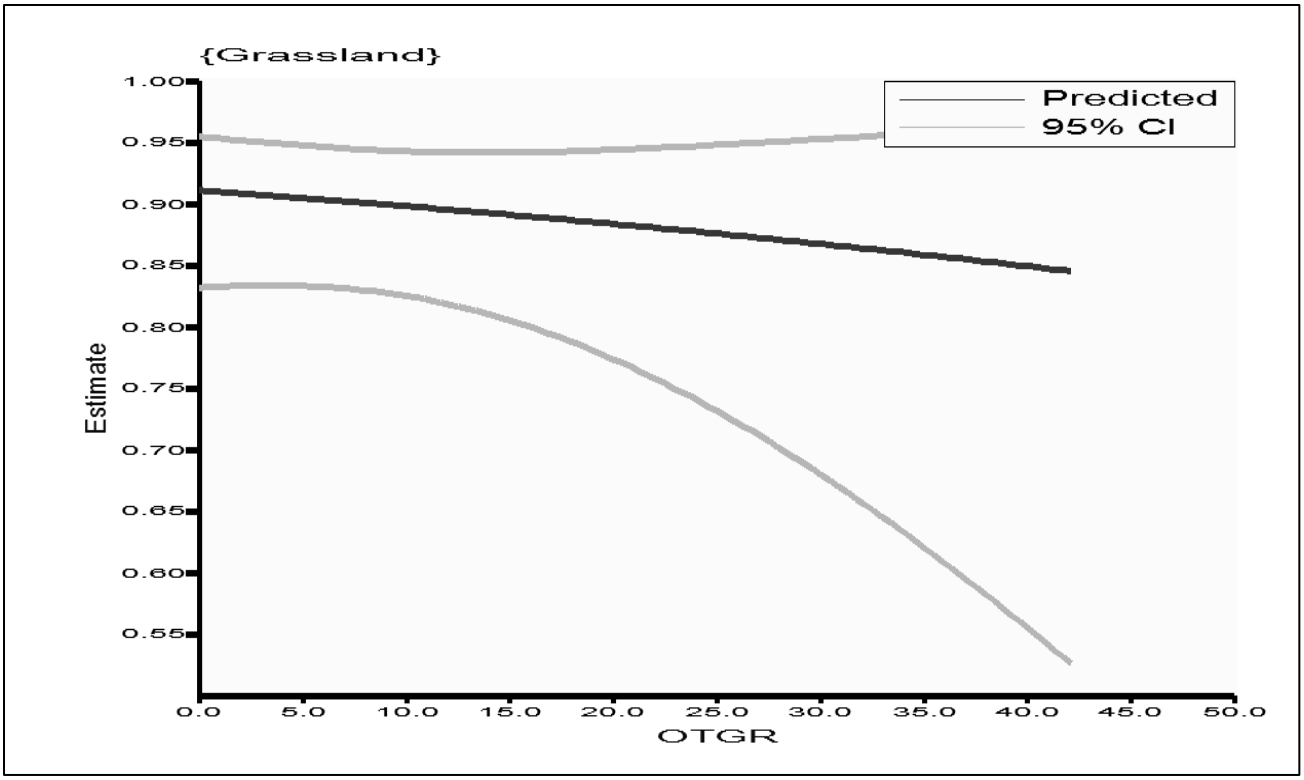

Figure A.10. Predictive plot showing survival rates of lesser prairie-chickens (*Tympanuchus pallidicinctus*) based on the percentage of native grassland within the home range. Data were collected in Bailey and Cochran Counties, Texas from 2015-2017.

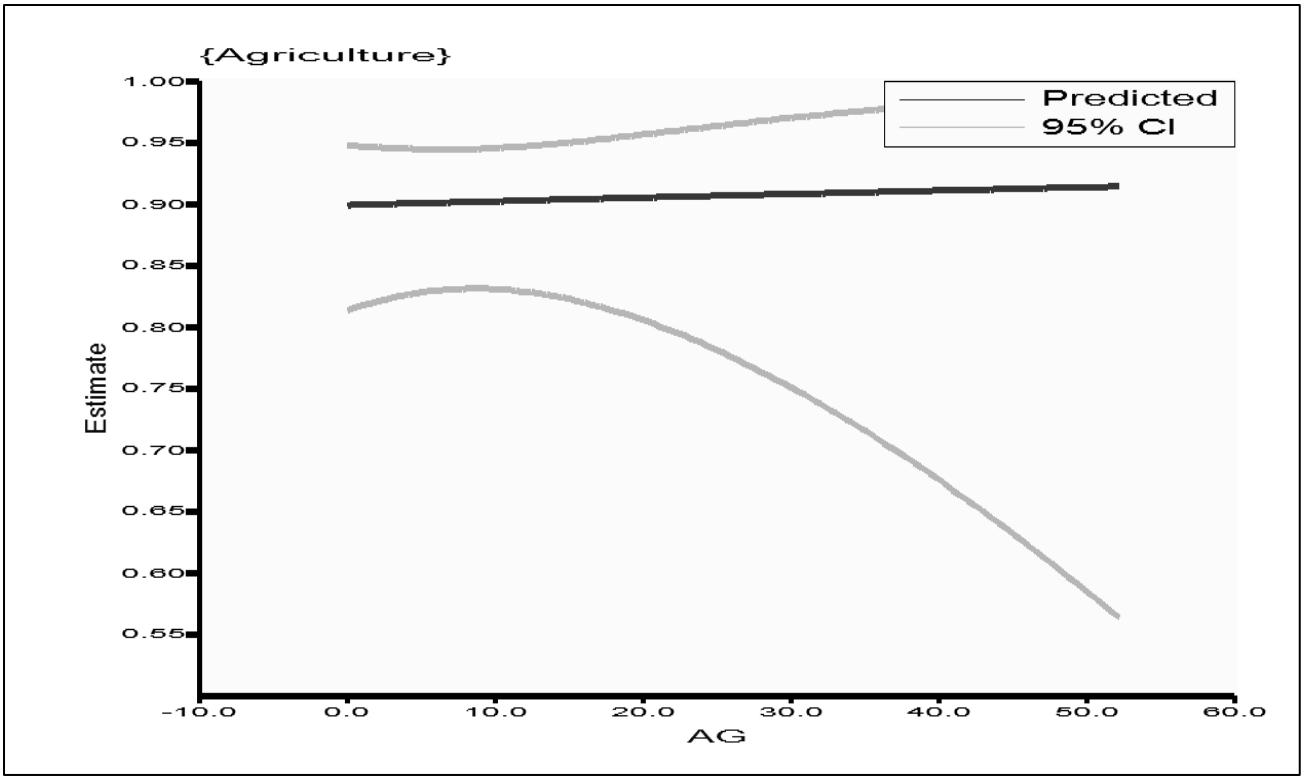

Figure A.11. Predictive plot showing survival rates of lesser prairie-chickens (*Tympanuchus pallidicinctus*) based on the percentage of agriculture within the home range. Data were collected in Bailey and Cochran Counties, Texas from 2015-2017.

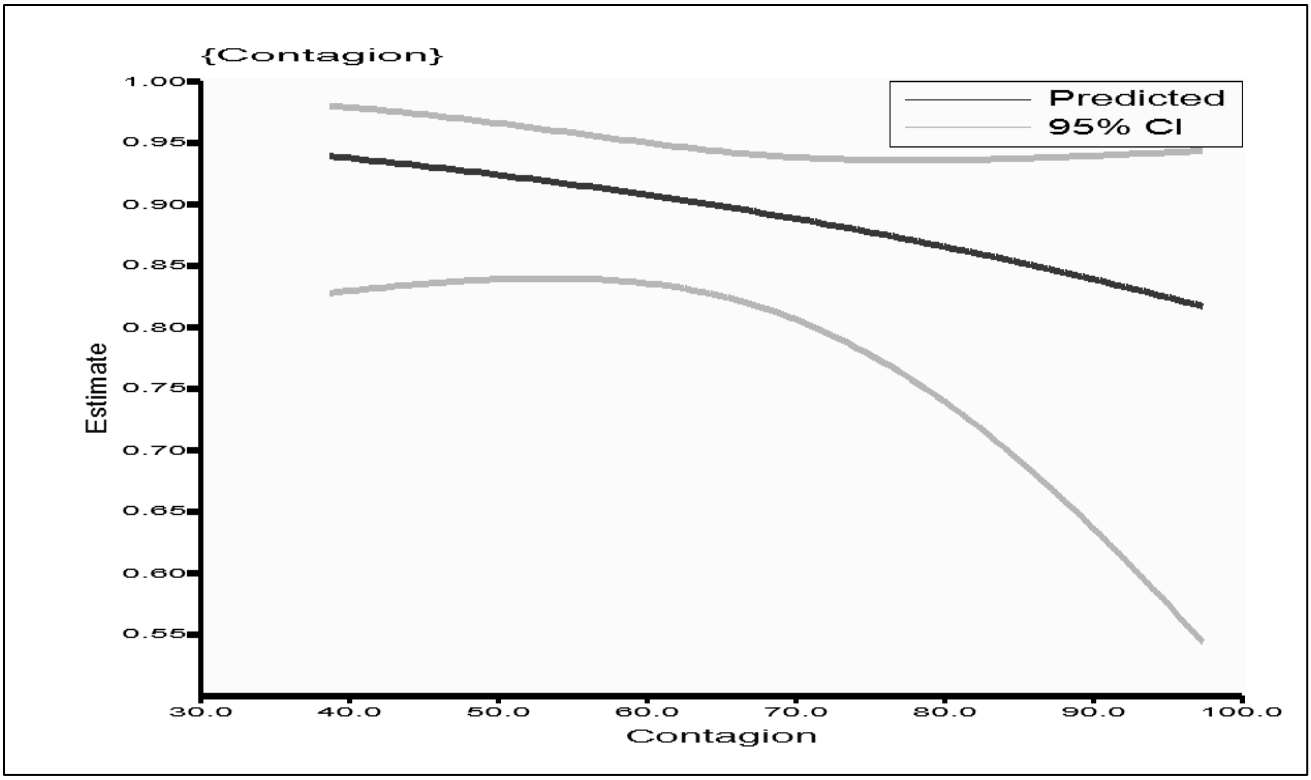

Figure A.12. Predictive plot showing survival rates of lesser prairie-chickens (*Tympanuchus pallidicinctus*) based on the contagion estimate (%) within the home range. Data were collected in Bailey and Cochran Counties, Texas from 2015-2017.

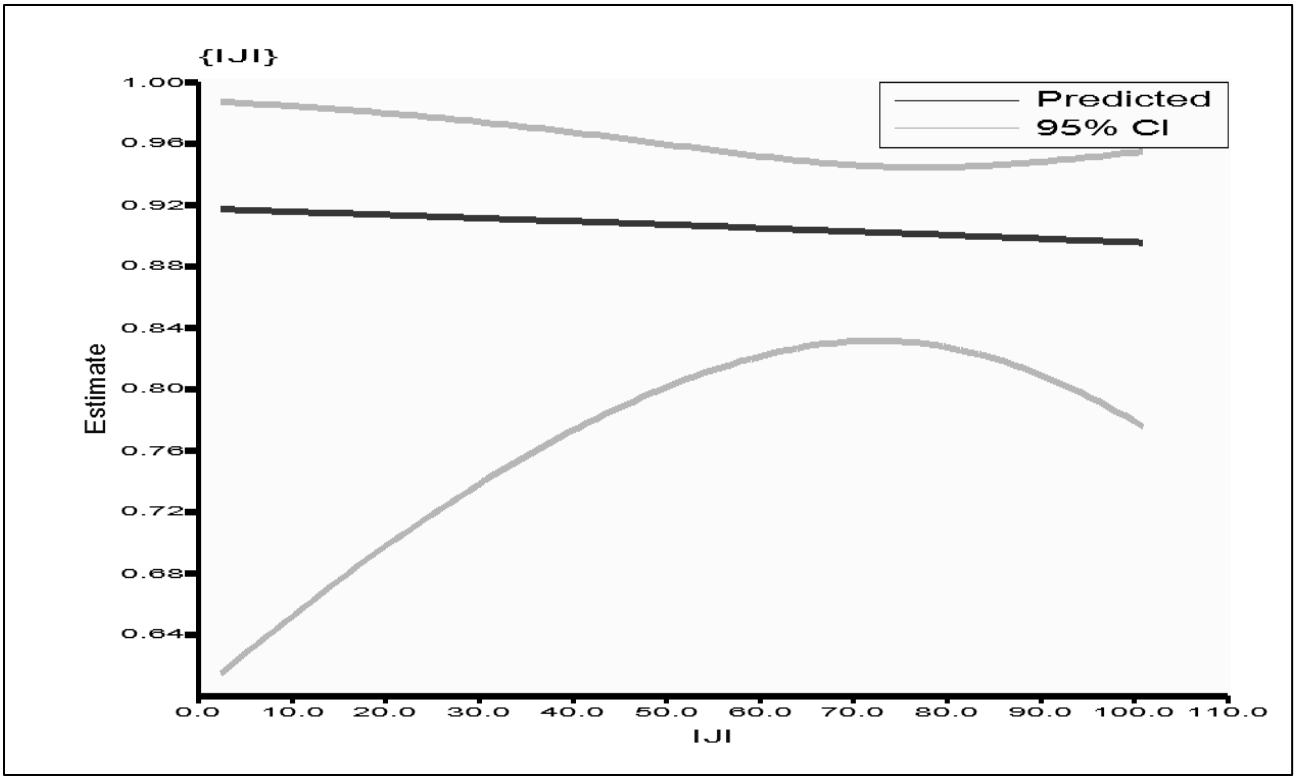

Figure A.13. Predictive plot showing survival rates of lesser prairie-chickens (*Tympanuchus pallidicinctus*) based on the interspersion and juxtaposition index (%) estimate of the home range. Data were collected in Bailey and Cochran Counties, Texas from 2015-2017.

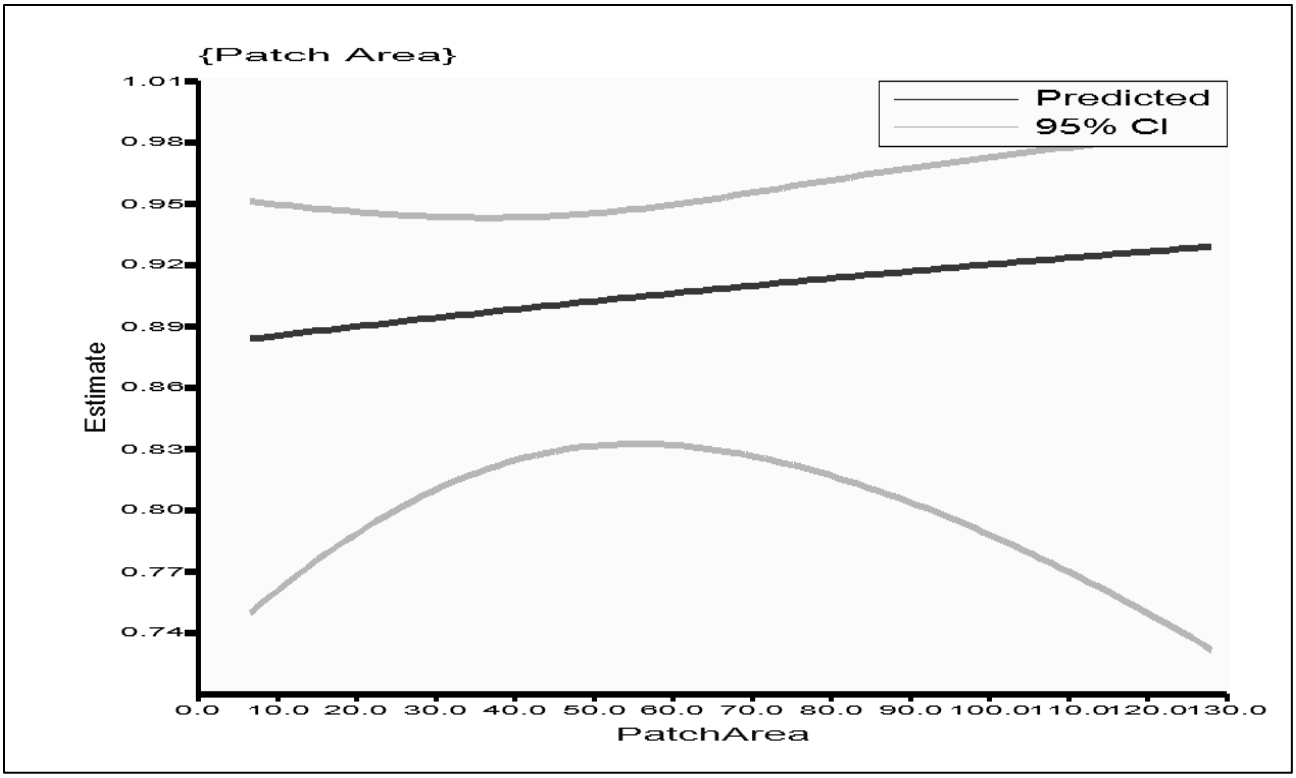

Figure A.14. Predictive plot showing survival rates of lesser prairie-chickens (*Tympanuchus pallidicinctus*) based on the average patch size (ha) of all cover classes within the home range. Data were collected in Bailey and Cochran Counties, Texas from 2015-2017.

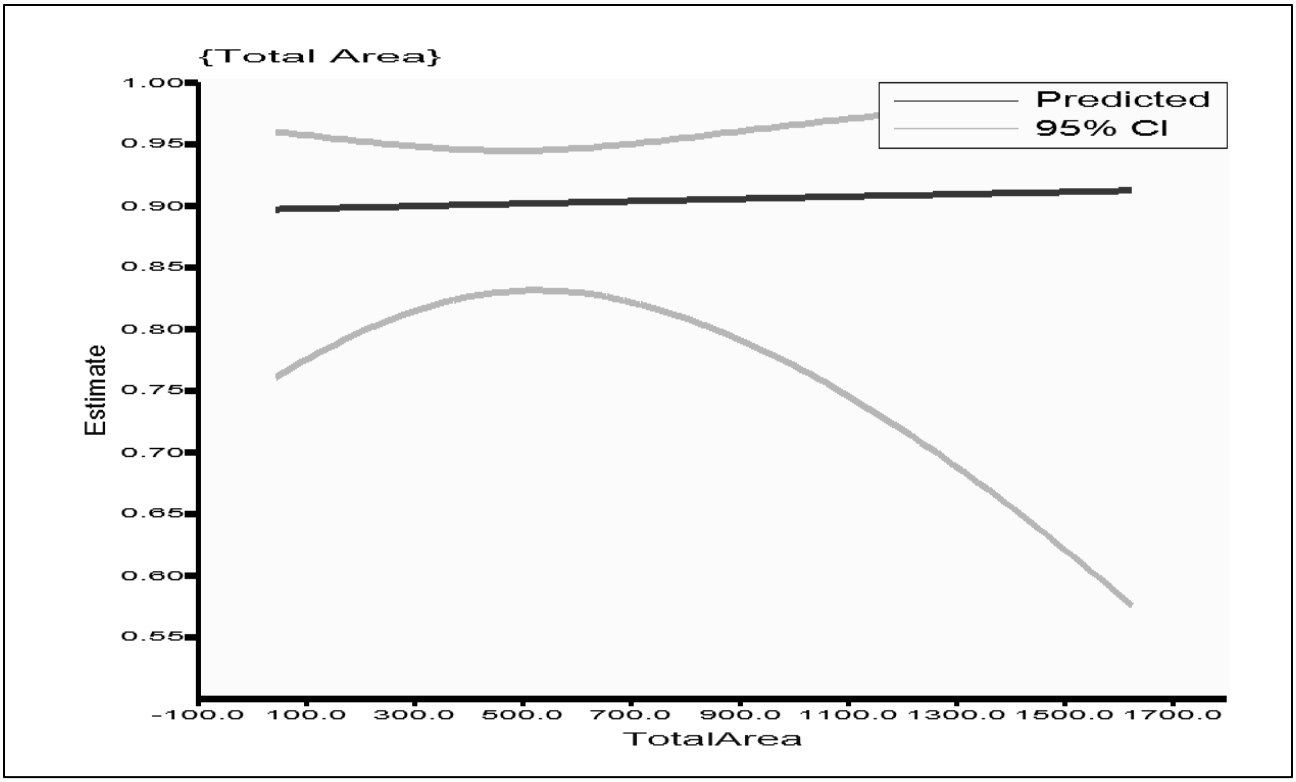

Figure A.15. Predictive plot showing survival rates of lesser prairie-chickens (*Tympanuchus pallidicinctus*) based on the total area (ha) of the home range. Data were collected in Bailey and Cochran Counties, Texas from 2015-2017.