Assessment of lesser prairie-chicken translocation through survival, space use, and resource selection

by

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Abstract

Translocation is defined as the deliberate movement of organisms from one site to another where the main objective is a conservation benefit. Translocations are used frequently as a management tool to restore or augment wildlife populations but generally have varying degrees of success. The lesser prairie-chicken (*Tympanuchus pallidicinctus*) is found in the southwestern Great Plains of the United States and currently occurs in four distinct ecoregions (Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, Sand Sagebrush Prairie, and Sand Shinnery Oak Prairie) across five states (Kansas, Colorado, Oklahoma, Texas, and New Mexico, USA). Recent estimates suggest the lesser prairie-chicken currently occupies only 15% of their estimated historical range. Within the current occupied range, lesser prairie-chicken populations have been experiencing moderate to severe population declines. Since a contemporary peak of an estimated 150,000 birds in the mid-1980s, lesser prairie-chicken populations have declined to an estimated abundance of 34,408 in 2020. The largest contemporary decline in population abundance and occupied range is occurring in the Sand Sagebrush Prairie Ecoregion. Historically, the Sand Sagebrush Prairie Ecoregion was the epicenter of the lesser prairie-chicken population despite a large area of vegetation in the ecoregion being decimated during the Dust Bowl of the 1930s. In 2020, only 171 birds were estimated for the ecoregion. In response to the extreme population decline and elevated extinction risk for the lesser prairie-chicken population in the Sand Sagebrush Prairie Ecoregion, myself, along with the Kansas Department of Wildlife and Parks, Colorado Parks and Wildlife, and U.S. Forest Service translocated lesser prairie-chickens from the Short-Grass Prairie/CRP Mosaic Ecoregion in northwest Kansas, where lesser prairie-chickens are currently most abundant, to release sites in sand sagebrush prairie landscapes on the

U.S. Forest Service, Cimarron and Comanche National Grasslands in southwestern Kansas and southeastern Colorado, respectively. I captured, marked, translocated, and monitored 411 lesser prairie chickens during spring 2016-2019 to understand how translocation affects demographic rates, space use, and habitat selection for assessing translocation as a conservation tool for this declining prairie-grouse. My objectives were to estimate lek counts, nest success, reproductive success, adult survival, home range establishment and land cover composition, and selection of habitat vegetation characteristics at local and broad scales to assess lesser prairie-chickens response to translocation in a novel landscape. Within two weeks of release, 22.8% of birds either died or were never located. I used known-fate and nest survival models in Program MARK to determine adult survival and nest success of lesser prairie-chickens. I estimated breeding season survival for both males and females to be 0.44 ± 0.02 (SE) and nest success as 0.37 ± 0.04 (SE) but with a declining trend for the entire study period (2017-2020). Overall, vital rates were average to low and male high counts on established lek started to decline in 2021, two years following active translocation. Habitat availability in a novel environment may become an increasing concern as translocated lesser prairie-chickens have consistently larger home ranges than their native counterparts. Home ranges of translocated birds was comprised of greater area of Conservation Reserve Program land than any other cover type on the landscape. Lastly, on a local scale (300 m), I found little selection for vegetation at used locations, but lesser prairie-chickens used thicker and taller cover for nest sites. This vegetation use was expected and conveys the importance of the vegetation structure needed at a translocation release site. My results highlight the importance of land management conservation and its role in the conservation of lesser prairie-chicken populations. The translocation may have some short-term success but current vital rates of lesser prairie chickens may not be enough to overcome inherent

limiting factors of the ecoregion for the population to become self-sustaining and the translocation to be deemed a long-term success.

Table of Contents

List of Figures

List of Tables

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Dedication

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Chapter 1 - Lesser prairie-chicken demographic response to translocation

Introduction

Translocation is defined as the deliberate movement of organisms from one site to another where the main objective is a conservation benefit (IUCN/SSC 2013). Translocations are used frequently as a management tool to restore or augment wildlife populations, but are not novel approaches to wildlife conservation (Scott and Carpenter 1987). Translocations have varying degrees of success as conservation strategies (Seddon et al. 2014, Hoffmann et al. 2015). Several species have been either translocated or reintroduced into formally occupied range, including bighorn sheep (*Ovis canadensis*), muskrats (*Ondatra zibethicus*), greater sage-grouse (*Centrocercus urophasianus)*, yellow-legged frogs (*Rana muscosa*), and western swamp turtle (*Pseudemydura umbrina*) to name a few (Reese and Connelly 1997, Mitchell et al. 2016, Werdel and Jenks 2018, Calatayud et al. 2020, Matykiewicz et al. 2021). However, translocation success is poorly documented and may be biased toward prolific and successful translocation projects (e.g., Scargle 2000, Schooler 2011). This may be due to the short-term nature of most translocation efforts and lack of accompanied subsequent research to measure success. The lack of determining success is especially concerning as often translocations are expensive and conducted on sensitive, threatened, or endangered species. Information on translocations is critical for assessing the viability of translocation as a future conservation tool (Griffith et al. 1989).

Several prairie grouse (*Tympanuchus* spp.) in North America have undergone translocations including greater prairie-chicken (*Tympanuchus cupido*), sharp-tailed grouse (*T. phasianellus*), and Attwater's prairie-chicken (*T. c. attwateri*); many of these species are either currently imperiled or extirpated from many areas of their historic ranges (Snyder et al. 1999). While other conservation tools including habitat management have been implemented, translocation is often considered because of its possible immediate and evident effects. However, prairie grouse have been among the most difficult groups to restore into historic range or augment low population abundance, in part because large numbers of birds (possibly >1,000) necessary to successfully restore or supplement populations (Toepfer et al. 1990). Research on previous translocations show that translocations with at least 100 birds are more successful than translocations with fewer birds (Snyder et al. 1999). The large number of birds needed for translocations requires a robust source population, which can often be difficult when overall populations are low.

The lesser prairie-chicken (*T. pallidicintus*) is a prairie grouse that has been translocated several times over the last 100 years. The first and previously largest published lesser prairie-chicken translocation took place in 1933, when 300 birds from Ellis County, Oklahoma were translocated to 15 sites within the state (Duck and Fletcher 1943, Horton 2000). However, translocations were not successful in establishing a lesser prairie-chicken population. Since then, there have been at least 10 attempts to translocate lesser prairie-chickens, and only one was noted to be successful (Rodgers 2016). Factors influencing translocation success include animal behavior, habitat quality, and the ability to accurately monitor translocated individuals (Berger-Tal et al. 2020). While previous lesser-prairie chicken translocations may not have considered all these factors, following this strategy will be key to a successful translocation for lesser prairie-chickens.

The lesser prairie-chicken is found in the southwestern Great Plains of the United States and currently occurs in four distinct ecoregions (Short-Grass Prairie/CRP Mosaic, Mixed-Grass

Prairie, Sand Sagebrush Prairie, and Sand Shinnery Oak Prairie) across five states (Kansas, Colorado, Oklahoma, Texas, and New Mexico, USA; McDonald et al. 2014; Figure 1.1). Occupied areas within these ecoregions are broadly described as semi-arid with abundant sandy soils and native shrubs including sand sagebrush *(Artemisia filifolia*) and sand shinnery oak (*Quercus havardii*) or mixed to tall grasses (Haukos and Zavaleta 2016, Spencer et al. 2017). Lesser prairie-chickens breed on leks where males gather from March - May, display, and often defend territories to attract females for mating. Females then initiate nests, incubate a clutch, and then provide uniparental care for any hatched chicks.

Recent estimates suggest that the lesser prairie-chicken currently occupies only ~15% of their estimated historical range (Boal and Haukos 2016, Rodgers 2016). Within the current occupied range, lesser prairie-chickens have been experiencing moderate to severe population declines (Hagen et al. 2017). Since a contemporary peak of an estimated 150,000 birds in the mid-1980s, populations have declined with current estimated population of 34,408 in 2020 (Nasman 2020). This decline is attributed to loss of quality habitat through anthropogenic development, unmanaged grazing, invasive plant species, and extensive conversion of native prairie to row-crop agriculture causing fragmentation and degradation of the quality of remaining habitat (Waddell and Hanzlick 1978). Population declines have been intensified by increasing frequency of severe droughts and extreme weather events (Ross et al. 2016). This has led to the enhanced probability of extirpations, which, coupled with loss of connectivity of among populations, has reduced the capacity of lesser prairie-chickens to occupy large areas of potential habitat (Garton et al. 2016, Hagen et al. 2017). Due to these continued threats, the lesser prairie-chicken has had a history of legal status in consideration for listing as a threatened or endangered species under the 1973 Endangered Species Act. Most recently (May 2021), a ruling has been proposed that would list lesser prairie-chicken as two distinct population segments, where the southern population segment (i.e., Sand Shinnery Oak Prairie Ecoregion) would be listed as endangered and the northern population segment (i.e., other ecoregions) would be listed as threatened with a 4(d) rule that tailors protections for the species (U.S. Fish and Wildlife Service 2021).

The largest contemporary decline in lesser prairie-chicken population abundance and occupied range is occurring in the Sand Sagebrush Prairie Ecoregion. Historically, the Sand Sagebrush Prairie Ecoregion was the epicenter of the lesser prairie-chicken population despite a large amount of the ecoregion's vegetation being decimated during the Dust Bowl of the 1930s. Jensen et al. (2000) reported an estimated high count of >86,000 birds in the ecoregion during the 1970s. More recently, a contemporary high count of ~75,000 was reported in the 1980s but, by the early 2000s, estimates dropped to ~25,000 birds (Garton et al. 2016, Hagen et al. 2017). The decline continued with an estimate of only 1,479 birds in 2016 in the Sand Sagebrush Prairie Ecoregion (McDonald et al. 2016). Hagen et al. (2020) found a high probability of extirpation within five years for the Sand Sagebrush Ecoregion. However, other ecoregions have not experienced such drastic declines and currently >70% of the extant population occurs primarily in the Short-Grass Prairie/CRP Mosaic and Mixed-Grass Prairie ecoregions of Kansas.

In response to the extreme population decline for the lesser prairie-chicken population in the Sand Sagebrush Prairie Ecoregion, myself, along with the Kansas Department of Wildlife and Parks, Colorado Parks and Wildlife, and U.S. Forest Service translocated lesser prairie-chickens from the Short-Grass Prairie/CRP Mosaic Ecoregion in northwest Kansas, where lesser prairie-chickens are currently most abundant, to release sites in sand sagebrush prairie landscapes on the U.S. Forest Service Cimarron and Comanche National Grasslands in southwestern Kansas and southeastern Colorado, respectively. Although lesser prairie-chickens were essentially extirpated from both National Grasslands by 2016 (Berigan 2019), a specific management plan developed in 2014 (US Forest Service 2014) and increased precipitation following the 2012-2013 intensive drought was thought to have improved habitat quality (i.e., improved vegetation composition and structure) on the National Grasslands sufficiently to support translocated birds. Although previous efforts to translocate lesser prairie-chickens and other prairie grouse have had mixed results (Duck and Fletcher 1943, Snyder et al 1999, Horton 2000, Hagen et al. 2004, Rodgers 2016), the extreme population decline and lack of immigration from other ecoregions make translocation one of the few remaining conservations options available to prevent extirpation in the Sand Sagebrush Prairie Ecoregion.

From 2016-2019, I, in conjunction with Kansas Department of Wildlife and Parks and Colorado Parks and Wildlife, translocated 411 lesser prairie-chickens. This effort is the largest known lesser prairie-chicken translocation (Snyder 1999, Giesen 2000). Translocated birds were monitored extensively during 2017 – 2021 to determine short-term success of the conservation strategy. My goal was to evaluate population vital rates of translocated lesser prairie-chickens and compare them with previously published work to assess short-term success of the translocation as a conservation tool. I evaluated the demographic vital rates of male and female lesser prairie-chickens in the initial years following a large translocation. These vital rates include lek counts, nest survival, apparent chick survival, and adult survival. My objectives were 1) to evaluate these vital rates that are critical to population persistence of lesser prairie-chickens between sexes, states, and among years, 2) compare translocated data to previously published literature on native birds in the Sand Sagebrush Prairie Ecoregion and throughout their range, and 3) assess the short-term outcomes of translocation as a conservation tool for lesser prairie-chickens. I predicted that all demographic rates for translocated birds would be lower than the estimated native conspecific demographic rates due to possible stress and the novel environment experienced by translocated lesser prairie-chickens.

Study Area

Capture Study Area

I captured lesser prairie-chickens during fall 2016 and spring 2017-2019 in the Short-Grass Prairie/CRP Mosaic Ecoregion, which had the greatest contemporary density of lesser prairie-chickens across their range (Nasman et al. 2020). I captured lesser prairie-chickens, with landowners' permission, on short- and mixed-grass prairie and cropland landscapes in Gove, Lane, Ness, and Finney counties in Kansas (1,357,189 ha; Figure 1.3). Land cover in these counties was a mixture of row-crop agriculture, U.S. Department of Agriculture Conservation Reserve Program (CRP) grassland, and native short-grass prairie intermixed with remnant mixed-grass prairie (McDonald et al. 2014, Dahlgren et al. 2016, Robinson et al. 2018a). Historical (1901 to 2015) mean monthly temperatures ranged from -10.8° C to 29.9° C, and annual precipitation ranged from 23.0 to 84.3 cm ($\bar{x}$ = 50.1 cm) in Lane County, Kansas. During the study period (2016 to 2020) mean monthly temperatures ranged from -3.5° C to 26.4° C, and annual precipitation ranged from 44.0 to 60.6 cm (Lane County, Kansas; NOAA 2021).

Vegetation at the capture sites mostly reflected the composition of the native short-grass prairie, but also contains species of mixed-grass prairie (Sullins 2017, Berigan 2019). Most common grass species included little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), composite dropseed (*Sporobolus compositus*), western wheatgrass (*Pascopyrum smithii*), buffalograss *(Bouteloua dactyloides*), blue grama (*B. gracilis*), hairy grama (*B. hirsuta*), sand dropseed (*Sporobolus cryptandrus*), and inland saltgrass (*Distichlis spicata*). Forb species included slimflower scurfpea (*Psoralidium tenuiflorum*), winterfat (*Krascheninnikovia lanata*), western ragweed (*Ambrosia psilostachya*), broom snakeweed *(Gutierrezia sarothrae*), white heath aster *(Symphyotrichum ericoides*), common prickly pear (*Opuntia monacantha*), and field sagewort (*Artemisia campestris*; McGregor and Barkley 1986). Dominant shrub species were sand sagebrush (*Artemisia filifolia*) and four-wing saltbush (*Atriplex canescens*; Fields et al. 2006). The planted CRP grasslands in Kansas were seeded with a native grass-forb mixture since 1986. These grass species include little bluestem, sideoats grama, big bluestem, switchgrass, western wheatgrass, blue grama, buffalograss, and indiangrass (*Sorghastrum nutans*). Forb species include alfalfa (*Medicago sativa*), white sweet clover (*Melilotus alba*), yellow sweet clover (*M. officinalis*), Maximillian sunflower (*Helianthus maximiliani*), prairie bundleflower (*Desmanthus illinoensis*), purple prairie clover (*Dalea purpurea*), and upright prairie coneflower (*Ratibida columnifera*; Fields et al. 2006).

Release Study Area

I released captured lesser prairie-chickens on either historic or current lek locations on the Comanche and Cimarron National Grasslands in Baca County, Colorado, and Morton County, Kansas, respectively (Figure 1.4). I then delineated the translocation study area boundaries by creating a minimum convex polygon around all points for released birds marked with radio transmitters once initial dispersal ended and they were settled. Therefore I excluded >5-km one-way movements after individuals established a home range (Robinson et al. 2018a; Chapter 2), using the Minimum Bounding Geometry tool in ArcGIS 10.7.1 (ESRI, Redlands, CA, USA; Figure 1.2). The translocation study area was 913,320 ha and comprised of 13% CRP, 10% National Grasslands, 29% private rangeland, 46% cropland, and 2% of other land cover type (roads, water, etc.). Vegetation on the Comanche and Cimarron National Grasslands was sand-sagebrush prairie with a gradient ranging from sparse to abundant densities of sand sagebrush. Vegetation composition and structure on the National Grasslands was largely dependent on soil type and grazing intensity. Composition included both short- and mixed-grass prairie interspersed with tall grasses, and sand sagebrush prairie. Common grass species included sand dropseed, blue grama, buffalo grass, and sand bluestem (*Andropogon hallii*). Forb species included yucca (*Yucca glauca*), blazing star (*Liatris* spp.), western ragweed, prairie sunflower (*Helianthus petiolaris*), annual sunflower (*H. annuus*), camphorweed (*Heterotheca subaxillaris*), fumewort (*Corydalis solida*), Indian blanket flower (*Gaillardia pulchella*), Russian thistle (*Salsola tragus*), pigweed (*Amaranthus hybridus*), tansy aster *(Machaeranthera tanacetifolia*), bush morning glory (*Ipomoea leptophylla*), evening primrose (*Calylophus serrulatus*), buffalo bur (*Solanum rostratum*), buffalo gourd (*Cucurbita foetidissima*), Texas croton (*Croton texensis*), and toothed spurge (*Euphorbia dentata*). The shrub community was dominated by sand sagebrush (Haukos et al. 2016). Vegetation in CRP fields surrounding the National Grasslands was similar to the capture study area. Common animal species within the region included coyote (*Canis latrans*), white-tailed deer (*Odocoileus virginianus*), thirteen-lined ground-squirrel (*Ictidomys tridecemlineatus*), northern harrier (*Circus hudsonius*), meadowlarks (*Sturnella* spp.), grasshopper sparrow (*Ammodramus savannarum*), dickcissel (*Spiza americana*), gopher snake (*Pituophis catenifer*), and prairie rattlesnake (*Crotalus virdis*). Historical (1901 to 2015) mean monthly temperatures ranged from -7.3 to 29.6º C, and annual precipitation ranged from 21.9 to 70.5 cm ($\bar{x}$ = 42.8 cm) in Morton County, Kansas. During the study period (2016 to 2020) mean monthly temperatures ranged from -0.17 to 26.8º C, and annual precipitation was above average most years and ranged from 32.4 to 56.9 cm (Morton County, Kansas; NOAA 2021).

Methods

Capture

With private landowner permission, I captured lesser prairie-chickens during lekking activity in September-October (2016) and March-April (2017-2019) in four northwestern Kansas counties within the Shortgrass Prairie/CRP Ecoregion (Figure 1.3). I used walk-in funnel traps and tension or magnetic drop nets for capture at lek sites (Haukos et al. 1990, Silvy et al. 1990). After capture, I fitted both male and female lesser prairie-chickens with either a 12- to 15-g bib-style very-high-frequency (VHF) transmitter (RI-2B Holohil Systems Ltd., Carp, Ontario, Canada or Series A3960, Advanced Telemetry System, Isanti, MN, USA) or a rump-mounted 22-g Satellite Platform Transmitting Terminal GPS (SAT-PTT) transmitter (PTT-100, Microwave Telemetry, Columbia, MD, USA). Care was taken that transmitter type would not exceed 3% of an individual birds body mass. I attached SAT-PTT transmitters using leg harnesses made of tubular Teflon® ribbon for durability and sewed in elastic for maneuverability (Bedrosian and Craighead, 2007, Dzialak et al. 2011). I determined sex of each bird from feather coloring and behavior on lek, aged birds as second-year (SY) or after-second-year (ASY) via the molt characteristics of the outer primary feathers (Ammann 1944). Few birds (<3%) had nondescript age characteristics or no age was recorded and was later labeled as after-hatch-year (AHY). I also took measurements of various morphometric data including, eye comb length and height, head length, culmen length, pinnae length, tarsus length, tarsus with longest toe length, tail length, flatten wing cord length, and mass of the bird (Aulicky 2020). Feathers from the breast and blood were also taken for genetic and disease analyses, respectively. I then marked individuals with a numbered aluminum leg band and a unique combination of plastic color bands for resighting (Coplin 1963).

During transportation to release sites, I minimized unnecessary stressors such as sounds, stops, and kept vehicle temperatures cool to reduce stress on the birds. I released birds within 11 hours after capture on the Cimarron or the Comanche National Grasslands. Chosen release sites were either historic lek locations or visually assessed as quality nesting habitat and reviewed annually (Figure 1.4). This research was conducted in accordance with guidelines on the use of wild birds in research and in compliance with state and federal regulations (Fair et al. 2010). All handling and capture protocols were completed and approved by the Kansas State University Institutional Animal Care and Use Committee Permit #3703, Kansas Scientific Wildlife Permits SC-024-2018 and SC-015-2019, and Colorado Scientific Wildlife Permits SC-128-2016, SC-079-2017, SC-076-2018, and SC-077-2019.

Monitoring

I monitored male and female lesser prairie-chickens during the breeding (Mar 15 – Sep 15) and nonbreeding season (Sep 16 – Mar 14) from April 2017 – August 2020. Birds fitted with a VHF transmitter were located ≥3 times per week using triangulation from 3-5 observer locations via handheld three-piece Yagi antennas and radio receivers (R4000, R410; Advanced Telemetry System, Isanti, MN, USA, or R1000; Communications Specialists, Orange, CA, USA). Triangulation consisted of compass bearings taken at each location ≥15 degrees apart and within 20 min to decrease error from bird movement. Recorded location and associated error was estimated with the Location Of A Signal software (LOAS; Ecological Software Solutions, Hegymagas, Hungary). If an individual could not be triangulated (out of receiver range, flew away, etc.) a second attempt was done at another time during the day or the following day. Fixed-wing aircraft was used to locate individuals with VHF transmitters that had dispersed and could not be found by ground scanning. Birds fitted with SAT-PTT transmitters had 8 to 10 GPS locations in 2-hour intervals recorded per day between 0600 and 2200 (18-m accuracy). Locations were uploaded to the Argos satellite system every 3 days and downloaded weekly.

Lek Counts

I monitored lekking activity during March 15 – May 31 (lekking season) during 2017-2021 based on grouping patterns from movements of multiple transmittered male lesser prairie-chickens. A lek is usually defined as having three or more males displaying, but because of the behavior of released birds after translocation (large dispersal, novel landscape) areas where at least one male displayed were defined as leks. I ground surveyed for leks by listening for auditory calls between sunrise and 1000 during favorable weather conditions (wind <24 km/h). I then flushed individuals to determine a count of male attendance. Leks were visited at least two times during the season to derive an accurate high count of male attendance. If active among years, I revisited leks in years following being found to assess trends in male high counts. I determined leks to be reported if 1) the lek was within the study area, 2) the lek had at least one translocated male attending, or 3) the lek was adequately surveyed.

Nest Survival

I monitored movements of marked hens closely for nesting behavior. Nesting was suspected if a female remained in the same location ≥3 consecutive days (Pitman et al. 2005, Lautenbach et al. 2019). For females with VHF transmitters, I carefully honed in on the hen's location in a spiral manner. I determined nests by sighting the female and quickly took a coordinates at, if hen flushed, or near the nest location and vacated the nest area to help alleviate any possible influence on nesting behavior. Flushing the hen was avoided but if it did occur, I counted eggs to determine clutch size. I estimated nest age to begin at the start of the 3 consecutive day period when females remained in the same location. I monitored each nest daily from a location approximately 100 m away and returned to the nest site when the female moved off nest or was killed. For females with PTT-SAT transmitters, nesting activity and location were estimated remotely by the female movements and continued to be monitored remotely until the female moved away from the estimated nest location or was killed. The exact nest was located by searching the area around the estimated location and once found was considered successful or failed using the same methods for VHF-marked females. Nest age was estimated similarly to VHF-marked birds.

I considered a nest successful if ≥1 egg hatched, identified by pipped eggshells. If eggs were undisturbed and not predated, the nest was concluded to be abandoned. Unsuccessful nests were examined for cause of depredation or trampling. I examined patterns of remaining eggshells and any possible nest bowl disturbance for signs of possible predators, broadly classified as mammalian, snake, or unknown. I based these classifications on eggshell patterns or fragments, nest material displaced, or cached eggs (Sargeant et al. 1998, Pitman et al. 2006a). Possible nest predators included large mammals such as coyote, badger, raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*) and small mammals such as thirteen-lined ground squirrel (*Ictidomys tridecemlineatus*), spotted ground squirrel (*Xerospermophilus spilosoma*), and other rodent and small mammal species. I classified nest bowls that were empty as snake predation. Common species of snakes that could depredate a nest include gopher snakes (*Pituophis catenifer*), prairie rattlesnakes (*Crotalus virdis*), and eastern yellowbelly racers (*Coluber constrictor flaviventris*). I categorized the predation type on unsuccessful nests with deficient, conflicting evidence, or where landowner permission was denied as unknown.

I estimated daily nest survival rates using nest success models in package RMark as an interface for Program Mark and Program R (White and Burnham 1999, Dinsmore et al. 2002, Laake 2013; R Version 4.0.5, https://www.r-project.org/, accessed 5 May 2021). I examined the influence of several variables on daily nest survival including: nesting attempt within the year (first or renest), hen age (SY or ASY), year (2017-2020), release site (CO or KS), cover type (CRP, Private Working Grassland, USFS land [Public - working land], and Crop), distance to known lek (km), and time (days). I identified cover type and distance from lek using a cover map comprised of U.S. Department of Agriculture's Cropland Data Layer (USDA-NASS 2019) and a 2014 shapefile provided by the U.S. Farm Service Agency to determine CRP locations. I ground proofed patches within 2 km of known leks and determined these data to be accurate. Advancing findings by Berigan (2019), I conducted a second model set only comprised of females that survived and nested in years greater than a year after their release. This model set contained all the same variables as previously listed, except for the year 2017 and age (both ASY and SY) as the female released in fall 2016 had died before the next breeding season and all birds are classified as ASY at the start of second breeding season after release. For both model sets, I fitted candidate models (n = 9 for all nests and n = 7 for at least one-year after release) for nest survival and ranked them using an Akaike's Information Criterion corrected for small sample size (AICc) using variables selected *a priori* (Burnham and Anderson 2002). Model weight (w_i), betas (β), and confidence intervals (CI) were evaluated and models with ΔAICc ≤ 2 were considered competitive. I used a 38-day exposure period with an average laying period of 10 days and incubation of 28 days to estimate overall nest survival, then applied the delta method to calculate variance around the estimate (Powell 2007, Lautenbach et al. 2019).

Chick Counts

After a successful nest was identified, I monitored the hen for brooding behavior. At approximately 35-days post hatch, a flush was conducted to estimate chick counts from each hen depending on availability of points from the SAT-PTT transmitters and weather. After 35 days, chick survival approximates adult survival (Hagen et al. 2009). Brood flushes were started one half hour before sunrise, with help of spotlights to increase likelihood of detection. When only the hen was found, but brooding behavior was strongly suspected, one more subsequent flush may have been conducted. I conducted brood flushes on hens with VHF transmitters using a similar method to nest determination mentioned above. For hens with SAT-PTT transmitters, a roosting location was acquired approximately 3 hours before the flush. I reported chicks that were counted during brood flushes at 35 days post hatch, not chicks that were seen prior to the flush or from an unmarked female. Apparent chick survival was calculated from number of chicks that survived to 35-days post hatch out of the total number of hatched eggs over the course of the study.

Adult Survival

I identified adult mortality events by either a signal change for VHF transmitters (within 2 days) or activity and movement data from SAT-PTT transmitters (within 7 days). I investigated mortalities immediately when possible after seeking proper landowner permission. Once the kill site or transmitter was located, I classified the cause of death as mammalian predator, avian predator, precipitation event, collision, or unknown causes following Hagen et al. (2007). I concluded a mammalian predator based on bite marks on transmitters and leg bands, feathers matted with saliva, cached carcasses, and nearby tracks or scat. Possible field site mammalian predators included: American badger (*Taxidea taxus*), coyote, bobcat (*Lynx rufus*), and swift fox (*Vulpes velox*). I identified avian predators via piles of plucked feathers, decapitated carcasses, removal of breast tissue, transmitters without tooth marks (especially with straps intact), and presence of avian scat. Potential avian predators in the area were red-tailed hawk (*Buteo* *jamaicensis*), ferruginous hawk (*B. regalis*), rough-legged hawk (*B. lagopus*), northern harrier (*Circus cyaneus*), prairie falcon (*Falco mexicanus*), and great-horned owl (*Bubo virginianus*). Evidence of a precipitation event morality would be apparent injuries to the back and neck immediately following a large storm system. Mortalities with conflicting evidence, deficient evidence, or on properties where I was denied permission was labeled as unknown.

I used known-fate models to estimate weekly adult survival for both male and female translocated lesser prairie-chickens using Program MARK (White and Burnham 1999). I did not evaluate birds that died before 15 March 2017 due to infrequent monitoring and birds that did not survive two weeks post release (Hagen et al. 2007). Due to the large dispersal movements following release (averaged 145 km, Berigan 2019), most VHF-marked birds were not found each week. When birds were missing for several weeks and then found as a mortality, I estimated the true date of mortality by finding the average week between the last known alive week and the week the mortality was found (n = 67). I investigated the influence of several variables on survival including: release site (KS, CO), transmitter type (VHF, SAT-PTT), sex (male, female), time (weekly), and additive and interactive combinations of these variables. I investigated age and year in an exploratory analysis and determined the variables to be not significant for the final model set. I conducted 2 model sets - the breeding season (Mar 15 – Sep 15) and nonbreeding season (Sep 16 – Mar 14). For both model sets, I fitted candidate models (n = 13 for each) for adult survival and ranked them using AICc (Burnham and Anderson 2002). Model weight (w_i), betas (β), and confidence intervals (CI) were evaluated with models where ΔAICc ≤ 2 considered competitive. For a visual representation of mortality patterns for the cumulative survival through time, I also conducted known-fate Kaplan-Meier models using the "survival" package in Program R for the breeding and nonbreeding seasons (Therneau 2015).

Results

Capture

I translocated 411 lesser prairie-chickens to the Cimarron and Comanche National Grasslands with 73% of birds released in 2018 and 2019 (Table 1.1). Twenty-six males and one female were captured in the fall of 2016, primarily for lek establishment the following spring in an effort to mitigate the effects of dispersal. Of the birds translocated, 394 were marked with transmitters (279 VHF and 115 SAT-PTT); 17 males were banded only. Females received more of the SAT-PTT transmitters due to their reproductive importance; however, SAT-PTT transmitters were only deployed in 2018 and 2019. Generally, females and males were evenly released between the National Grasslands (Table 1.1). Male age distribution between SY and ASY was even between release states, but there were more SY females captured and released than ASY females (Tables 1.2, 1.3).

Lek Counts

Leks on average were established or visited by translocated lesser prairie-chickens 39.7 km away from any of the release sites. The average male high count at all known occupied leks was 5.30 (range: 1-17) with occupied leks in Kansas averaging 4.97 (range: 2-12) and occupied leks in Colorado averaging 5.72 (range: 1-17) from 2017-2021 (Tables 1.4, 1.5). Average male counts on occupied leks in Kansas peaked in 2017-2019 during translocation with a range from 5.25 - 6.23 and decreased to 4.11 by 2021. This trend continued in Colorado, as average male high counts on occupied leks were highest in 2017-2020 with a range from 3.33 - 7.86 and decreased to 4.71 by 2021. Number of active leks and male high counts increased annually while translocation was on-going with a maximum of 122 males counted at 21 leks across the study area in 2020 (Figure 1.5). However, in 2021, the number of total males and active leks counted decreased to 70 and 16, respectively (Figure 1.6).

Nest Survival

A total of 141 nests were known to be initiated over the duration of the study (14 in 2017; 40 in 2018; 69 in 2019; 18 in 2020) with 77, 61, and 3 in Kansas, Colorado, and Oklahoma, respectively. Overall, 46.9% of the females translocated were known to nest; however, 79.3% of satellite-equipped females initiated a nest and likely is a better representation of nesting propensity. Females that survived one year post release and nested the following year included 15.5% (n = 32) of all females translocated (n = 207). Renest attempts were low, with only 9.2% of nests being renests (n = 13). Females nested on average 4.5 km (range: 88 m – 42.8 km) from known leks, but farther from their respective release sites ($\bar{x}$ = 18.9 km; range: 0.3 –78.8 km). Females nested an average distance of 4.2 km (range: 150 m – 37.5 km) from their previous nest within breeding season and 8.0 km (range: 12 m - 66.9 km) in successive breeding seasons. Over the duration of the study, 46.1% of nests were successful, 20.6% were depredated by mammals, 10.6% depredated by snakes, 9.9% experiencing hen mortality, 2.1% were abandoned, and 10.6% were unsuccessful due to unknown causes (Table 1.6).

I used 138 nests for my nest survival analysis from 2017-2020, as 3 nests were either not directly located, failed before the nest could be monitored, or had insufficient recorded data and were removed. Age AHY nests were low in the sample (n = 7) and due to similar nest survival rates were converted to ASY for this analysis. An interactive model between nest attempt and age was my most supported model (w_i = 0.33; Table 1.7, Figure 1.7) where first attempt nest survival rates vary little between age class but renest attempt survival rates vary greatly between age class although confidence intervals are wide. The second and third ranked models included a time dependent model (β_{time} = -0.016, SE = 0.008, 95% CI = -0.03 - 0.001; Figure 1.8) and the single variable nest attempt model. However, all competitive models had beta estimates that overlap zero at the 95% confidence level, indicating these parameters were spurious. However, interestingly the state model becomes competitive (ΔAICc < 2) when the nests from Oklahoma (*n* = 3) are removed. Nest success rates between Colorado and Kansas were 0.46 ± 0.07 (95% CI = 0.32-0.60) and 0.31 ± 0.05 (95% CI = 0.21-0.41), respectively. Overall, the estimated nest success rate for translocated hens was 0.37 ± 0.04 (95% CI = 0.29-0.45) from the null model. The land cover type model showed CRP had the greatest nest success estimate of 0.44 ± 0.27 (95% CI = 0.08-0.97), whereas Private Working Grassland had the lowest lowest nest success estimate of 0.14 ± 0.14 (95% CI = 0.00-0.41; Table 1.8). Lastly, nest success rates by year were 0.46 ± 0.15 (95% CI = 0.17-0.75) in 2017, 0.47 ± 0.09 (95% CI = 0.29-0.65) in 2018, 0.35 ± 0.06 (95% CI = 0.23-0.47) in 2019, and 0.20 ± 0.09 (95% CI = 0.02-0.38) in 2020.

A total of 38 nests were used for my second model set that evaluated influences on nest success of at least one year post-release females (7 in 2018, 13 in 2019, 18 in 2020). The model that tested year influence on nest success was my most supported model ($\beta_{year2018}$ = not estimable; $\beta_{year2019}$ = 1.18, SE = 0.57, 95% CI = 0.06 - 2.30; $\beta_{year2020}$ = 3.14, SE = 0.27, 95% CI = 2.60 – 3.67; Table 1.9). With no other models competitive (ΔAICc ≥ 2), this model was 98 times more likely than the next model. Annual nest success estimates for females post year of release are 0.22 ± 0.09 (95% CI = 0.05-0.40) in 2020, 0.63 ± 0.09 (95% CI = 0.34-0.91) in 2019, and all nests of this cohort hatched in 2018 (Figure 1.10).

Chick Counts

A total of 98 chicks were known to survive to 35 days post hatch over the course of the study (Table 1.10). Between release site states, 62 chicks were successful in Colorado and 36 chicks were successful in Kansas. Of the successful nests (*n* = 63), 50.8% had successful broods at 35 days. A total of 30 hens (14.4% of translocated hens) contributed to 32 successful broods with an average brood size of 3.06 chicks (range: 1-8) at 35 days. Apparent chick survival across the study area was as estimated as 19.44%.

Adult Survival

A total of 285 translocated lesser prairie-chickens were used for the known-fate survival analyses. Of those birds, 200 (70.1%) were equipped with VHF transmitters and 85 (29.8%) with SAT-PTT transmitters. A total of 126 birds were removed from analysis because they died within two weeks of release (*n* = 54, 28 SAT-PTT, 26 VHF); were not found after release (*n* = 40, 1 SAT-PTT, 39 VHF); were determined to have a slipped transmitter within 2 weeks of release (*n* = 9, 2 SAT-PTT, 7 VHF); released in the fall 2016 and did not survive to 15 March 2017 (*n* = 6, all VHF); or did not have transmitters when released and could not be monitored (*n* = 17).

Of the breeding season survival models, the most supported model was the effect of time on survival suggesting that survival varies throughout the year (Table 1.11; Figure 1.11). The time survival model was only 1.32 times more likely than the next model that included an interactive effect of transmitter, release site, sex, and an additive effect of time. The second best supported model suggested that males Colorado had greater survival than males in Kansas among transmitter types and females in Colorado had lower survival than females in Kansas among transmitter types (Figure 1.12). However, given the ranking of model with the interaction term without time in the model, the interactive term is probably not informative. These were the only 2 models that were competitive (ΔAICc $\leq$ 2). From the other models conducted, females and males had a breeding season survival rate of 0.44 ± 0.03 (95% CI = 0.38-0.50) and 0.45 ±

0.04 (95% CI = 0.37-0.53), respectively; sexes combined was 0.44 ± 0.02 (95% CI = 0.42-0.46). The Kaplan-Meier analysis shows the overall pattern of mortality throughout the breeding season, with evidence of relatively high mortality during the third week of April (Figure 1.13).

Of the tested nonbreeding season survival models, the most supported model was the effect of time on survival (Table 1.12; Figure 1.14). The time model was 900 times more likely than the next model, which was the constant model. No models were competitive besides the top model ($\Delta AICc \geq 2$). However, from the other models conducted, females and males had a nonbreeding season survival rate of 0.55 ± 0.04 (95% CI = 0.47-0.63) and 0.56 ± 0.06 (95% CI = 0.44-0.68), respectively; sexes combined was 0.55 ± 0.03 (95% CI = 0.52-0.58). The Kaplan-Meier analysis indicated a pattern of steady mortality throughout the nonbreeding season (Figure 1.15).

Cause of mortality was investigated for 177 translocated lesser prairie-chickens from 2017-2020. Over the duration of the study, 41.2% of mortalities were mammalian, 27.1% were avian, 1.6% from a precipitation event, 0.5% vehicle collision, and 29.3% were unknown (Table 1.13).

Discussion

Determining success of translocation as a conservation strategy for prairie grouse is difficult. Toepfer et al. (1990) suggested that determination of success of translocation or reintroduction may take as long as 5-20 years following release to evaluate if a population became established or increased in abundance and occupied range resulting in a self-sustaining population. However, this approach would be most applicable to translocations where released animals are not intensively monitored following release. As this was not the case for my study, the intensive marking and monitoring of released lesser prairie-chicken allow for the initial assessment of short-term success. Because of the considerable conservation concern for lesser prairie-chickens across their range (USFWS 2021), developing and assessing short-term metrics for determining potential success of translocation would be informative for development of management strategies for lesser prairie-chickens. I defined short-term success of this translocation if birds remained in targeted release areas; joined or established leks during the year of release; females nested during year of release; translocated birds exhibited similar demographic rates for adult survival, nest success, and brood survival as native birds; and there was evidence for a stable or increasing population following cessation of translocation efforts. However, I recognize that ultimate determination of success will need to be based on continued monitoring for at least 3-5 more years of averaged population estimates with in the area (until 2024-2026) allowing for determination of successful recruitment following mortality of initially translocated birds and possible weather cycles such as drought. Translocated lesser prairie-chickens did join existing or establish new leks; a large proportion did nest in the first year following release; and adult survival during the breeding season and nest success was at similar rates as native populations. However, many of the vital rates of the translocated population were near average to lower end of the ranges from previous studies. It remains unclear if these rates going forward are sufficient to establish new populations or augment existing populations to point where the long-term decline of lesser prairie-chickens in the Sand Sagebrush Prairie Ecoregion is reversed.

The initial largest obstacle to success of targeted translocations is the mortality and dispersal of lesser prairie-chickens following release, with 22.8% of all translocated birds falling into not being tracked after release or dying within the first two weeks after release during 2016-2020. This loss of translocated birds is attributed to the ≥5 km dispersal from the release locations by nearly all of the released lesser prairie-chickens; 97.5% of all PTT-SAT equipped birds dispersed from the release sites (Berigan 2019). A similar dispersal pattern presumably occurred in VHF-marked birds as well; however, due to the large distance covered by these birds, it was difficult to locate most VHF-marked individuals during dispersal following release. This dispersal indicates that targeted translocation of lesser prairie-chickens to a specific site or area within an ecoregion is difficult and unlikely to succeed. This has also been shown in studies where greater prairie-chickens have been translocated to Iowa and Missouri, USA, where the single surviving bird have moved upwards of 4,000 km before settling and 24% of translocated birds died during the dispersal movement, respectively (Kemink and Kesler 2013, Vogel et al. 2015). Direct demographic effects of dispersal and then continued average seasonal vital rates from the translocated population was reflected in the ongoing lek observations and male high counts, with counts increasing until one year post active translocation (2020) and then declining two years post active translocation (2021).

Lek Counts

Most leks were established or males visited leks away from the release sites (average 39.7 km). This is likely due to a combination of the initial dispersal following release (Berigan 2019), female space use (Aulicky 2020), and potential lack of quality nesting habitat surrounding the release site and few existing leks (Gerht et al. 2020). Although the vast area of the study site made searching for leks difficult but because birds were closely monitored, I am confident that all leks used or visited by translocated lesser prairie-chickens were located for surveys.

Male high counts and number of leks within the study area increased during years of on-going translocation with a peak one-year post active translocation. However, in the spring of 2020, I increased the lek search effort. This may have led to some leks found in 2020 that were established in previous years; therefore, there is a potential for an inflated number of new leks found in 2020. Nevertheless, many leks were ephemeral in nature, causing lek locations and lek numbers to be unstable (Aulicky 2020). In Kansas, results from the 2021 survey indicate many of the leks had a decline in male high counts, became inactive, or shifted locations (up to 800 m). Male high counts also declined in Colorado, which had fewer leks established throughout the study. Fewer leks in Colorado may be the result of lower availability of high quality nesting habitat, providing females relatively fewer nesting options (Chapter 3). All leks within the study area were established by translocated males primarily in response to female settling patterns (Aulicky 2020). The one exception was a native lek that was on average 70 km away from any release site, being supplemented by the translocated males in Colorado (Red Roof). Another native lek within the ecoregion (Buckeye), but 4 km outside the study area, had no evidence of attendance by translocated birds, but had an average male high count of 11 during 2019-2021 and remains relatively stable. This lek seems to be the exception, as an ecoregion-wide helicopter survey found the number of leks and associated male counts decreased drastically from 2018 to 2020 (Nasman 2020). Another native lek in Oklahoma may have attracted a few females to nest in the area, but male high counts are currently unknown for that individual lek. While the translocation may have initially created and augmented active leks, the ~43% decline in males at all leks in 2021 is concerning and may show that without ongoing translocation these leks and associated lesser prairie-chicken populations may not be sustaining; therefore, a potential indicator that translocation to the Sand Sagebrush Prairie Ecoregion may not be successful in the long-term.

Nest Survival

I documented nest attempt and nest age influences nest success of translocated females, similar to native populations based on published literature (Lautenbach et al. 2019). However, this indicates that translocated hens are susceptible to the same factors as native populations plus the effects of dispersal (Berigan 2019), making it difficult to achieve overall recruitment to increase populations.

Translocated hens generally nested much farther from known leks ($\bar{x}$ = 4.5 km) than reported 691 m and 1.04 km from native birds historically in the ecoregion (Pitman et al. 2006a, Giesen 1994, respectively) and the reported upper limit of 3.2 km from across the range (Haukos and Zavaleta 2016). Although leks may have formed that were not found given the large area in which released birds dispersed after release, it is unlikely that established leks were undiscovered near nest sites as nearby areas were searched extensively due to female proximity in the area. It was expected for hens to nest in areas farther from leks as leks often form where heavy areas of individual female space use overlap, so there may be a spatial lag effect and leks could move closer to those heavy space use areas over time (Aulicky 2020).

Renest attempts occurred at less frequency (9.2%) in the translocated population than the 23% - 41% previously reported for the ecoregion (Hagen 2003, Pitman et al. 2006b) and on the low end of the range for other ecoregions (7% - 79%; Patten et al. 2005, Grisham et al. 2014, Lautenbach et al. 2019). This may be due to the timing of the trapping and releasing process that was shown to delay nesting 15 days compared to native populations (Berigan 2019). This delay may make renesting unlikely due to the timing of nest failure in conjunction with lekking activity waning. Along with seasonal temporal variables, renesting could also be limited by the long dispersal effort reducing body reserves to the point that renesting was not physiologically possible. Nest-site fidelity was found to be at greater distances for translocated hens resenting within a breeding season (4.2 km) and between years (8.0 km) than the native conspecifics, which was 700 m -1.2 km within a breeding season and 918 m between years (Giesen 2000, Pitman et al. 2006a). Similarly, translocated birds nested farther from their release site ($\bar{x}$ = 18.9 km) than native birds from their lek-of-capture ($\bar{x}$ = 3.1 km; Pitman et al. 2005), although some release sites were not active leks. These greater distances from known leks, release sites, and initial nests are likely a cause of females being unfamiliar with the landscape following translocation and diffusing across the landscape assessing availability of quality nesting habitat.

I found that overall nest success rate of 37% across the study, which is slightly greater than historical nest success rates within the ecoregion that were estimated to be 20% - 33% (Hagen 2003, Pittman et al. 2006a), and can be considered a short-term success for the translocation. However, estimates of nest success from across the range vary greatly (67%, Copelin 1963; 47%, Riley 1978; 27%, Merchant 1982; 16%, Haukos et al. 1988; 28%, Riley et al. 1992; 41%, Patten et al. 2005; 48%, Fields et al. 2006; 76%, Davis 2009; 47%, Lyons et al. 2011; 43%, Grisham et al. 2014; 16% - 72%, Haukos and Zavaleta 2016; 39%, Lautenbach et al. 2019; 50.1%, Kraft et al. 2021). My estimate of nest success is average compared to other studies; however, there is a pattern of declining nest success as rates have decreased 50% from 2017-2020. This is likely reflective of availability of quality nesting habitat from above-average rainfall prior to translocation, demonstrating that nest success of translocated lesser prairie-chickens is reflective of environmental conditions.

Further, nest success rates for females that nested at least one-year post release initially had greater nest success than newly translocated birds as expected due to adjusting to landscape features such as lek and nesting habitat locations after translocation (Berigan 2019). Indeed, in

2018 and 2019 one-year post release birds did exceptionally well with high nest success rates of 100% and 63%, respectively. However, this initial strong nest success did not hold true in 2020 when all nests attempts were conducted by one-year post release birds and the nest success rate was similar to the overall rate across all birds (22%). This trend of declining nest success from 2017 to 2020 was more pronounced in the one-year post release birds than the annual estimates for all nests, but the pattern is similar and is likely due to annual variation in precipitation, which has been shown to effect nest success (Merchant 1982, Ross et al. 2018, Londe et al. 2020, Parker 2021). Regardless, this variation shows that one-year post release birds are as susceptible to lower nest success rates as newly translocated birds and may not be reliably exceptionally successful nesting females.

Nest success by cover type, while not a competing model, is important for land conservation and management purposes. Nests occurred most often in in CRP fields and were more successful in CRP than any other cover type. The availability of CRP has been shown to have overall positive demographic effects on lesser prairie-chickens in the northern region of lesser prairie-chicken range in Kansas (Sullins 2018), and ultimately can provide quality nesting vegetation cover and composition (Chapter 3). While the U.S. Forest Service National Grasslands had the second most nest occurrences, it had a much lower nest success rate than CRP (0.29 versus 0.44, respectively). This may be due to lacking quality nesting composition and structure across both National Grasslands possibly due to grazing pressure or woody encroachment (L. Bergian, unpublished data). CRP grasslands are not grazed outside of mid-contract management and emergency grazing allowances which contrasts substantially with the frequent grazing that occurs on the National Grasslands; therefore, CRP possibly provides quality nesting and other habitats for adult lesser prairie-chickens as it was the cover type with the greatest cover type found within home ranges of translocated lesser prairie-chickens (Chapter 2).

Lastly, depredation of translocated nests was by similar predators and frequency found in the ecoregion (Pitman et al. 2006a) and across the range (Haukos 1988, Riley et al. 1992, Boal 2016, Lautenbach et al. 2019, Parker 2021). These findings indicate that translocated nests are as vulnerable to predation, but not anymore susceptible, as native counterparts. Overall, translocated hens were able to locate nesting habitat (Chapter 3) following dispersal, initial nest success was relatively similar to native birds, and subject to similar predation sources as native birds.

Chick Counts

Chick survival and fledging success are important parameters for lesser prairie-chicken population growth and often are limiting (Jamison 2000, Pitman et al. 2006b, Hagen et al. 2009, Ross et al. 2018). I found that only 30 hens (14.4% of translocated hens) contributed to 32 successful fledged broods with an average brood size of 3.06 chicks. These counts seem within the range of other studies, with similar brood flushing time ranges, within the ecoregion. Schwilling (1955) found an average of 3.27 chicks for 11 broods and Jamison (2000) reported 6 broods that averaged 3.67 chicks. Other studies have found average 5.2 -7.5 chicks per brood over a 4-year study (Davison 1940), and 5.7 - 7.8 chicks per brood (Copelin 1963, Merchant 1982). Hagen (2003) found that 7.7% of all chicks survive to 34-days post hatch in the Sand Sagebrush Prairie Ecoregion. I estimated an apparent survival of 19.44% across the entire study period but number of chicks surviving to 35-days post hatch varied greatly among years with a range from 0 chicks in 2020 and 59 in 2019. I also found that 28.6% of successful nests had at least one chick survive to 35 days. Recent studies have found a range from 22% - 40% of nests had one successful brood over the course of the study (Davis 2009, Holt 2012, Grisham et al. 2012). A large study in the northern range of lesser prairie-chickens estimated brood survival from 0-35 days as 44.4% (J. Lautenbach, *in review*), indicating the translocation brood success is slightly lower than native birds across the species range. My findings indicated that translocated hens have lowered chick survival and chick recruitment than their native counterparts, signifying that chick recruitment and survival at these rates may be limiting establishment of a sustaining population into the future.

Adult Survival

Adult survival is the most immediate indicator of the translocation progress and possibly its short- and long-term success. Initially, I found that 22.8% of all translocated birds had either died within two weeks of release or were unable to be re-located after release. Because no previous lesser prairie-chicken translocation monitored birds directly after release it is difficult to compare these findings for lesser prairie-chickens (Snyder et al. 1999, Giesen 2000). However, greater sage-grouse translocations have shown a range of survival and the inability to re-locate released birds, two to three weeks post release (5%, 18.3% and 79%; Baxter et al. 2008, Gruber-Hadden et al. 2016, Musil et al. 1993, respectively) and 13% of translocated greater prairie-chickens were not found after release in Missouri (Carrlson et al. 2014). These findings indicate that a considerable loss of birds to dispersal and mortality after release is unavoidable and possibly could lead to a translocation failure.

The top-ranked model for breeding season survival was a weekly temporal model with the third week of April being the lowest estimated week for survival at ~0.88. However, in another study, female survival was relatively low and estimated as ~0.92 during the same week indicating that the patterns of mortality are similar between translocated and native birds, but translocated birds experienced slightly greater mortality associated with the period (Plumb 2015). However, a nearly 10% lower daily survival rate early in the breeding season (Mar-Apr) was reported for translocated greater prairie-chickens compared to a native population (Carrlson et al. 2014). Similarly, several translocation and reintroduction attempts of greater prairie-chickens in Iowa have shown little survival throughout the study periods (USFWS 2004). The second most supported model was an interactive model of transmitter, release site, sex, and an additive effect of time. The survival estimate was greatest for male lesser prairie-chickens released in Colorado marked with VHF transmitters and lowest for male lesser prairie-chickens released in Kansas marked with PTT-SAT transmitters. However, all confidence intervals overlapped indicating, that despite variation in point estimates of survival among these groups, uncertainty associated with the estimates resulted in a conclusion of no differences in survival among groups.

Breeding season survival varies greatly in the Sand Sagebrush Prairie Ecoregion with a range of 0.63-0.93 for sexes combined, which is greater than the translocation estimate of 0.44 (Haukos and Zavaleta 2016). However, other studies estimated female survival only, which varies from 0.49-0.76 within the ecoregion (Plumb 2015, Haukos and Zavaleta, 2016). The translocated female survival estimate of 0.44 is considerably lower than earlier ecoregion estimates. However, while the survival estimate is on the low end of survival estimates throughout the range, it is similar to another large study of native conspecifics of 0.45 in the Short-Grass Prairie/CRP Mosaic Ecoregion (Plumb 2015). This indicates that translocated lesser prairie-chickens have similar survival estimates compared to some native populations during the breeding season, but lower than most breeding season estimates. Translocated lesser prairie-chickens have greater mortality rates early in the breeding season than native counterparts, which affects short-term and possibly long-term success of the translocation.

The top-ranked model for nonbreeding season survival was a weekly temporal model with the fourth week of December being the lowest estimated week for survival at ~0.93; there were no other competing models. Although this analysis was pooled across years, this week could have lower survival due to colder temperatures and greater snowfall in 2018. Tracking of birds was also difficult during this time; therefore, some mortalities were estimated to have occurred during this week. Estimates also indicated a decrease in survival during the last two weeks of the nonbreeding season (Feb 28–Mar 7). This is likely occurring because of movements related to finding and initial displaying at leks by males as the breeding season approaches.

Nonbreeding season survival is not as well documented throughout the lesser prairie-chicken range, let alone for the Sand Sagebrush Prairie Ecoregion. Studies throughout the range have shown nonbreeding survival to range from 0.43-0.87 for a 6-month period (Haukos and Zavaleta 2016). The translocation survival rate for both males and females combined during the nonbreeding season was within range but on the lower end of these estimates (0.55). Lowered survival during the nonbreeding season for translocated birds could be due to the distribution and availability of quality habitat in the study site and extreme weather events. This indicates translocated lesser-prairie chickens likely have a survival deficit during the nonbreeding season compared to native populations, which may be difficult to overcome for a self-sustaining population.

Lastly, for cause specific mortality I found that the major source of mortality was mammalian followed by avian. Another recent large-scale study has shown the opposite where avian mortalities are the highest cause of mortality during the breeding season (Plumb 2015).

However, our cause-specific mortality rates for each mammals and raptors are within the range of other studies (15.4-61.9% and 0.0-76.9% respectively; Boal 2016). A study in Oklahoma and New Mexico found fence collision to account for 39.8% and 26.5% respectively, of mortalities for lesser prairie chickens (Wolfe et al. 2007). However, I found no mortalities attributed to fence collisions and only one vehicle collision.

Conclusions

I document that translocated lesser prairie-chickens have lowered but within range of previous documented vital rates to native conspecifics in the Sand Sagebrush Prairie Ecoregion and throughout the range after translocation induced mortality is removed. However, nearly one fourth of birds either died or were not re-located after release because of the large dispersal movements that occurred after release with translocated birds dispersing an average of 145 km over 1-2 months (Berigan 2019). While long-term success of translocation is currently uncertain, my results indicate that targeted translocation to a specific area may be extremely difficult due to dispersal and initial mortality. It has been previously suggested that translocations releasing more than 100 birds could be more successful in prairie grouse (Snyder 1999). However, this study shows that >400 birds may be necessary, especially for areas with little to no native population. However, my results also show that after the initial dispersal and mortality, translocated birds can be as demographically successful under favorable environmental conditions as their native counterparts. Determining long-term success of the translocation will depend on counts of active leks and attending males into the future. Although this translocation was very large and initially lek abundance and males high counts on leks increased, they have started to decline following cessation of translocation. This could be a factor in the boom-bust nature of population growth of lesser prairie-chickens as environmental conditions for survival and recruitment of lesser prairie-chickens were optimal for the Sand Sagebrush Prairie Ecoregion for all years during active translocation, but precipitation decreased during 2020 and 2021. Consequently, the population of both native and translocated lesser prairie-chickens is relatively small in the Sand Sagebrush Prairie Ecoregion and could fluctuate greatly during unfavorable environmental conditions jeopardizing the long-term success of translocation as a conservation strategy and, potentially, long-term persistence of populations within the ecoregion. With vital rates of the translocated population at the lower end of what is capable for lesser prairie-chickens during years of favorable environmental conditions, plus the added stress of translocation and dispersal, it may difficult to overcome initial low abundance and scattered occupancy of lesser prairie-chickens to create sustaining populations in the Sand Sagebrush Prairie Ecoregion.

This lesser prairie-chicken translocation was one of the largest efforts ever with hundreds of birds moved in a relatively short amount of time and extensive monitoring the first four years after initial release. As such, my results are valuable for assessing the varying degrees of success of translocations as a useful conservation tool in this declining prairie grouse population. Alternative procedures could be considered for future translocations such as soft release following habituation to the release site or brood translocation that may have a stronger outcome. However, these methods are time consuming, costly, and may not include sufficient number of birds needed for a successful translocation. Furthermore, there is also no guarantee that birds will not forgo dispersal, which would probably continue to affect initial survival. Future translocations will have to carefully assess methods to temper initial dispersal following release. However, a focus on lesser prairie-chicken habitat acquisition, conservation, preservation, and management could be more cost-effective in future.

Management Implications

Currently, as of May 2021, the lesser prairie-chicken throughout its range has been proposed to be either listed as threatened or endangered under the Endangered Species Act. There are several conservation efforts being made to maintain habitat in the mostly privately owned land of lesser prairie-chicken range such as federal programs that implement Habitat Conservation Plans (HCP), Candidate Conservation Agreement with Assurances (CCAA), Conservation Reserve Program (USDA), and other state programs that could provide additional habitat for targeted lesser prairie-chicken areas (Oklahoma Land Access Program, Walk-in Hunting Areas [KS & CO], etc.). Translocations are costly and have shown little success for lesser prairie-chickens (Synder et al 1999, Giesen 2000). This large-scale translocation was successful in the short-term relative to efforts associated with other prairie grouse, but current results show that long-term success may not be a given. Before future translocations, lesser prairie-chicken habitat should be assessed within the scale of the average net displacement of 20 km. Area-specific targeted translocations would be near impossible if the high-quality habitat does not exist. If translocation is deemed a viable option, then long-term (5–years) post translocation monitoring of leks with associated funding should be in place at a minimum before translocation to determine long-term success. However, I recommend financial and personnel resources be used for lesser prairie-chicken habitat management (with sustainable grazing practices), acquisition, and preservation throughout their range before translocation is considered. I also recommend that public lands management develop and implement specific plans for the management of lesser-prairie chickens and continue to monitor the goals and assess the progress of the plan annually to establish tangible conservation and management for lesser prairie-chickens.

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Tables

Table 1.1 Total number of lesser prairie-chickens translocated to the U.S. Forest Service Cimarron and Comanche National Grasslands in Kansas and Colorado, USA, respectively, during 2016-2019. Birds are categorized by release site (Cimarron, Comanche), sex (Male, Female), and year (2016, 2017, 2018, 2019).

	Cimarron, KS		**Comanche, CO**		
	Male	**Female**	**Male**	**Female**	Annual Total
Fall 2016	13	0	13	1	27
Spring 2017	16	19	29	19	83
Spring 2018	32	37	39	36	144
Spring 2019	40	49	22	46	157
Release Site Total	101	105	103	102	**411**

Table 1.2 Age and transmitter type totals of lesser prairie-chickens translocated to the U.S. Forest Service, Cimarron National Grasslands in Kansas, USA, during 2016-2019. Birds are categorized by release site, sex (Male, Female), transmitter type (very-high frequency [VHF], satellite GPS [SAT-PTT], Banded Only), age (second-year [SY], after-second-year [ASY], and after-hatch-year [AHY]), and year (2016, 2017, 2018, 2019).

	Fall 2016	**Spring 2017**	**Spring 2018**	**Spring 2019**
Male				
VHF				
SY	4	8	5	11
ASY	9	8	6	16
AHY	-	-	1	-
SAT-PTT				
SY	-	-	14	3
ASY	-	-	5	3
Banded Only				
SY	-	-	-	3
ASY	-	-	1	4
AHY	-	-	-	-
Female				
VHF				
SY	-	13	15	22
ASY	-	5	4	9
AHY	-	1	1	-
SAT-PTT				
SY	-	-	11	14
ASY	-	-	4	4
AHY	-	-	2	-
Annual Total	**13**	**35**	**69**	**89**

Table 1.3 Age and transmitter type totals of lesser prairie-chickens translocated to the U.S. Forest Service, Comanche National Grasslands in Colorado, USA, during 2016-2019. Birds are categorized by release site, sex (Male, Female), transmitter type (very-high frequency [VHF], satellite GPS [SAT-PTT], Banded Only), age (second-year [SY], after-second-year [ASY], and after-hatch-year [AHY]), and year (2016, 2017, 2018, 2019).

	Fall 2016	**Spring 2017**	**Spring 2018**	**Spring 2019**
Male				
VHF				
SY	7	14	6	8
ASY	6	14	9	9
AHY	-	1	2	-
SAT-PTT				
SY	-	-	7	2
ASY	-	-	6	3
Banded Only				
SY	-	-	4	-
ASY	-	-	4	-
AHY	-	-	1	-
Female				
VHF				
SY	-	14	11	20
ASY	-	4	3	10
AHY	-	1	1	-
SAT-PTT				
SY	-	-	16	13
ASY	1	-	4	3
AHY	-	-	1	-
Annual Total	**14**	**48**	**75**	**68**

Table 1.4 High counts of male lesser prairie-chicken attendance at leks and average male counts of occupied leks in Morton and Stanton counties, Kansas, USA, surveyed within the study area from 2017-2021. Leks were surveyed from 15 March – 15 May.

	During Translocation			After Translocation	
Lek ID	**2017**	**2018**	**2019**	**2020**	**2021**
Broken Windmill	6	7	12	12	11
Circus	5	9	6	5	0
Lost	3	4	0	0	0
Kanorado	- [a]	3	2	0	0
T3	- [a]	3	- [a]	5	2
Conestoga	- [a]	- [a]	7	4	0
L48	- [a]	- [a]	- [a]	2	0
Connie48[b]	- [a]	- [a]	- [a]	- [a]	3
Wheaties*	- [a]	- [a]	9	8	3
Bluestem*	- [a]	- [a]	- [a]	2	2
Llama	- [a]	- [a]	- [a]	2	- [a]
Yukon*	7	- [a]	- [a]	8	8
Stanton	- [a]	- [a]	- [a]	4	0
Hail	- [a]	- [a]	- [a]	5	0
X	- [a]	- [a]	- [a]	2	0
L47	- [a]	- [a]	- [a]	3	2
L4*	- [a]	- [a]	2	0	3
Saunders*	- [a]	- [a]	- [a]	5	3
Total	**21**	**26**	**38**	**67**	**37**
Average males/ occupied lek	**5.25**	**5.20**	**6.34**	**4.79**	**4.11**

[a]Lek not surveyed , not found during that year, or not possibly formed yet.

[b]Connie48 is a merged lek of Conestoga and L48.

*Lek location shifted throughout the duration of the study

Table 1.5 High counts of male attendance at leks and average male counts of occupied leks in Baca and Prowers counties, Colorado, USA, surveyed within the study area from 2017-2021. Leks were surveyed from 15 March – 15 May.

	During Translocation			After Translocation	
Lek ID	**2017**	**2018**	**2019**	**2020**	**2021**
Chihuahua	3	11	11	17	12
Las Vacas Blancas	- [a]	3	8	7	5
Boston	- [a]	5	7	8	1
Santa Fe	- [a]	4	0	0	0
Loamy Plains	3	0	0	0	0
Buffalo Point	- [a]	- [a]	- [a]	3	4
Vilas Top	- [a]	2	2	0	0
Little Silo	- [a]	- [a]	3	8	5
Crossroads	- [a]	- [a]	- [a]	3	0
Big Bird	- [a]	- [a]	- [a]	- [a]	1
Red Roof[b]	4	4	8	9	5
Total	**7**	**29**	**39**	**55**	**33**
Average males/ occupied lek	**3.33**	**4.83**	**6.5**	**7.86**	**4.71**

[a]Lek not surveyed , not currently found, or not possibly formed yet.

[b]Active native bird lek prior to translocation (confirmed translocated birds attended)

Table 1.6 Nest fate for translocated lesser prairie-chickens in Kansas and Colorado, USA, during 2017-2020.

Year	Successful	Nest Depredated		Hen Depredated	Abandoned	Unknown	Total
		Mammal	Snake				
Kansas							
2017	2	-	-	-	-	1	3
2018	11	3	4	1	-	4	23
2019	16	8	4	6	2	6	42
2020	2	5	5	-	-	1	13
Total	**31**	**16**	**13**	**7**	**2**	**12**	**81**
Colorado							
2017	6	3	1	-	1[a]	-	11
2018	12	2	-	1	0	2	17
2019	14	7	1	4	0	1	27
2020	2	1	-	2	0	-	5
Total	**34**	**13**	**2**	**7**	**1[a]**	**3**	**60**

[a] Hen incubated for >35 days, upon investigation eggs were determined not viable

Table 1.7 A priori candidate models used to estimate nest survival rates for lesser prairie-chickens translocated to U.S. Forest Service (USFS), Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020. Tested models included the variables Nest Attempt (First, Renest), Land Cover (Conservation Reserve Program [CRP], USFS, Crop, and Private Working Grasslands), Age (SY, ASY), Year (2017, 2018, 2019, 2020), State (KS, CO, OK), Time (days), Distance from Known Lek (km), and null (intercept only).

Model	K[a]	Δ AICc[c]	AICc[b]	w_i[d]	Deviance[e]
Nest Attempt * Age	4	0.00	695.32	0.33	687.30
Time	2	0.85	696.16	0.22	692.16
Nest Attempt	2	1.91	697.22	0.13	693.22
Land Cover	4	2.83	698.14	0.08	690.13
Null	1	2.98	698.29	0.07	696.29
Age	2	3.42	698.73	0.06	694.73
State	3	3.84	699.15	0.05	693.15
Year	4	4.42	699.74	0.04	691.73
Distance From Known Lek	2	4.97	700.29	0.03	696.28

[a]Number of parameters.

[b]Akaike's Information Criterion, corrected for small sample size.

[c]Difference in Akaike's Information Criterion, corrected for small sample size.

[d]Akaike weights.

[e]Deviance or -2*loglikelihood.

Table 1.8 Nest survival ($\hat{S}$) estimates from 4 different land cover types for lesser prairie-chickens translocated to U.S. Forest Service (USFS), Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020. Cover types include Conservation Reserve Program (CRP), USFS, Crop, and Private Working Grasslands.

		Survival Estimate		
Land Cover Type	**# of Nests**	$\hat{S}$	**SE**	**95% CI**
CRP	90	0.44	0.27	0.08-0.97
USFS	35	0.29	0.07	0.15-0.43
Private Working Grasslands	4	0.14	0.14	0.00-0.41
Crop	9	0.19	0.12	0.00-0.43

Table 1.9 A priori candidate models used to estimate nest survival rates for lesser prairie-chickens post one-year-after translocation to U.S. Forest Service (USFS), Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020. Tested models include the variables Nest Attempt (First, Renest), Land Cover (Conservation Reserve Program [CRP], USFS, Crop, and Private Working Grasslands), Year (2018, 2019, 2020), State (KS, CO, OK), Time (days), Distance from Known Lek (km), and null (intercept only).

Model	K[a]	Δ AICc[c]	AICc[b]	w_i[d]	Deviance[e]
Year	3	0.00	165.10	0.98	159.07
Time	2	9.10	174.20	0.01	170.19
Null	1	10.60	175.70	0.00	173.70
Nest Attempt	2	12.51	177.61	0.00	173.60
Distance from Known Lek	2	12.56	177.66	0.00	173.64
Land Cover	4	13.10	178.20	0.00	170.15
State	3	13.63	178.73	0.00	172.71

[a]Number of parameters.

[b]Akaike's Information Criterion, corrected for small sample size.

[c]Difference in Akaike's Information Criterion, corrected for small sample size.

[d]Akaike weights.

[e]Deviance or -2*loglikelihood.

Table 1.10 Number of chicks known to survive 35 days post hatch from broods (n = 32) for lesser prairie-chickens translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020.

	Number of Chicks		
Year	**Kansas**	**Colorado**	**Total**
2017	1	16	**17**
2018	17	5	**22**
2019	18	41	**59**
2020	0	0	**0**
Total	36	62	**98**

Table 1.11 A priori candidate models used to estimate breeding season (Mar 15 – Sep 15) survival rates for translocated adult lesser prairie-chickens translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020. Models include variable combinations of release site (KS, CO), transmitter type (VHF, GPS), sex (male, female), and null (intercept only).

Model	K[a]	Δ AICc[c]	AICc[b]	w_i[d]	Deviance[e]
Time	26	0.00	2038.53	0.57	137.13
Sex * Transmitter * Release Site + Time	33	0.57	2039.09	0.43	123.58
Sex * Transmitter + Time	33	10.70	2049.23	0.00	133.72
Site + Time	33	10.74	2049.27	0.00	133.76
Transmitter + Time	33	13.07	2051.60	0.00	136.08
Sex + Time	33	14.02	2052.55	0.00	137.03
Transmitter * Time	52	35.35	2073.88	0.00	119.94
Sex * Transmitter * Time	104	99.62	2138.15	0.00	78.07
Sex * Transmitter * Release Site	8	103.69	2142.22	0.00	276.98
Transmitter	2	109.51	2148.04	0.00	294.82
Sex * Transmitter	4	109.66	2148.19	0.00	290.97
Null	1	109.93	2148.46	0.00	297.24
Transmitter * Release Site * Sex * Time	208	238.24	2276.77	0.00	0.00

[a]Number of parameters.

[b]Akaike's Information Criterion, corrected for small sample size.

[c]Difference in Akaike's Information Criterion, corrected for small sample size.

[d]Akaike weights.

[e]Deviance or -2*loglikelihood.

Table 1.12 A priori candidate models used to estimate nonbreeding season (Sep 16 –Mar 14) survival rates for translocated adult lesser prairie-chickens translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020. Models include variable combinations of release site (KS, CO), transmitter type (VHF, SAT-PTT), sex (male, female), and null (intercept only).

Model	K[a]	Δ AICc[c]	AICc[b]	w_i[d]	Deviance[e]
Time	26	0.00	1031.42	0.99	124.03
Transmitter * Release Site * Sex + Time	33	10.52	1041.94	0.01	120.37
Null	1	12.46	1043.88	0.00	186.78
Site + Time	33	13.41	1044.83	0.00	123.26
Sex * Transmitter + Time	33	13.95	1045.37	0.00	123.80
Transmitter + Time	33	13.96	1045.38	0.00	123.81
Transmitter	2	14.14	1045.56	0.00	186.46
Sex + Time	33	14.15	1045.57	0.00	124.00
Sex * Transmitter	4	18.09	1049.51	0.00	186.40
Sex * Transmitter * Release Site	8	23.23	1054.65	0.00	183.52
Transmitter * Time	52	41.38	1072.80	0.00	112.54
Sex * Transmitter * Time	104	97.42	1128.84	0.00	61.11
Transmitter * Release Site * Sex * Time	208	258.51	1289.93	0.00	0.00

[a]Number of parameters.

[b]Akaike's Information Criterion, corrected for small sample size.

[c]Difference in Akaike's Information Criterion, corrected for small sample size.

[d]Akaike weights.

[e]Deviance or -2*loglikelihood.

Table 1.13 Percent of cause specific mortality of lesser prairie-chickens (n = 177) translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, by season (breeding, nonbreeding) and sex (female, male) during 2017-2020. Breeding season was defined as March 15-September 15 and nonbreeding season was September 16-March 14.

	Mammal	Avian	Unknown	Precipitation Event	Collison
Breeding Season					
Female (*n* = 72)	48.6	26.4	22.2	1.4	1.4[a]
Male (*n* = 47)	40.4	25.5	29.8	4.3	-
Nonbreeding Season					
Female (*n* = 31)	25.8	35.5	38.7	-	-
Male (*n* = 27)	40.7	22.2	37.1	-	-

[a]Vehicle collision – found on road

Figures

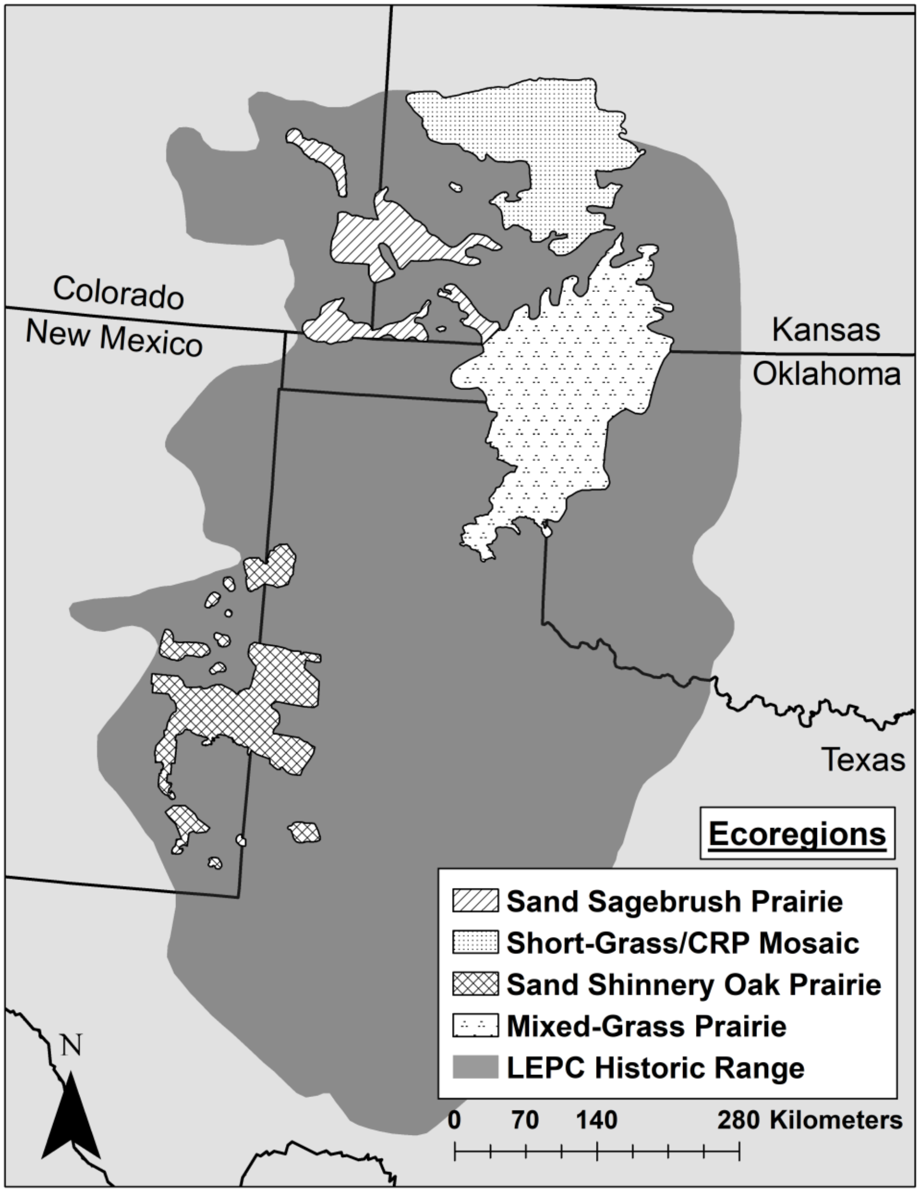

Figure 1.1 The four lesser prairie-chicken (LEPC) ecoregions in Kansas, Colorado, Oklahoma, New Mexico, and Texas, USA, with estimated historic range.

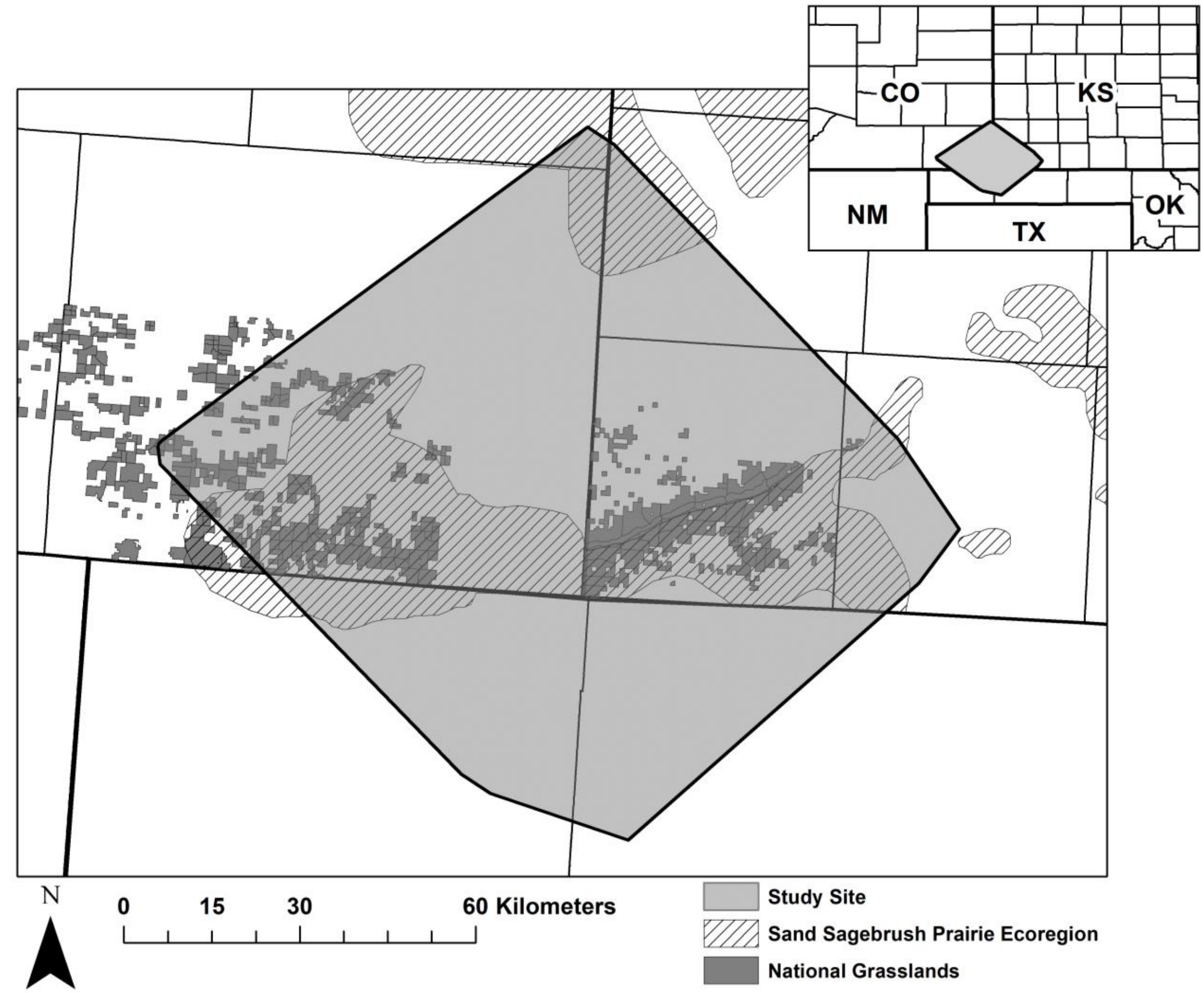

Figure 1.2 The study area representing where lesser prairie-chickens settled after translocation and release on the U.S. Forest Service, Cimarron and Comanche National Grasslands in Kansas, Colorado, and Oklahoma, USA, detailing Cimarron (KS) and Comanche National Grasslands (CO) and the Sand Sagebrush Prairie Ecoregion of the lesser prairie-chicken range.

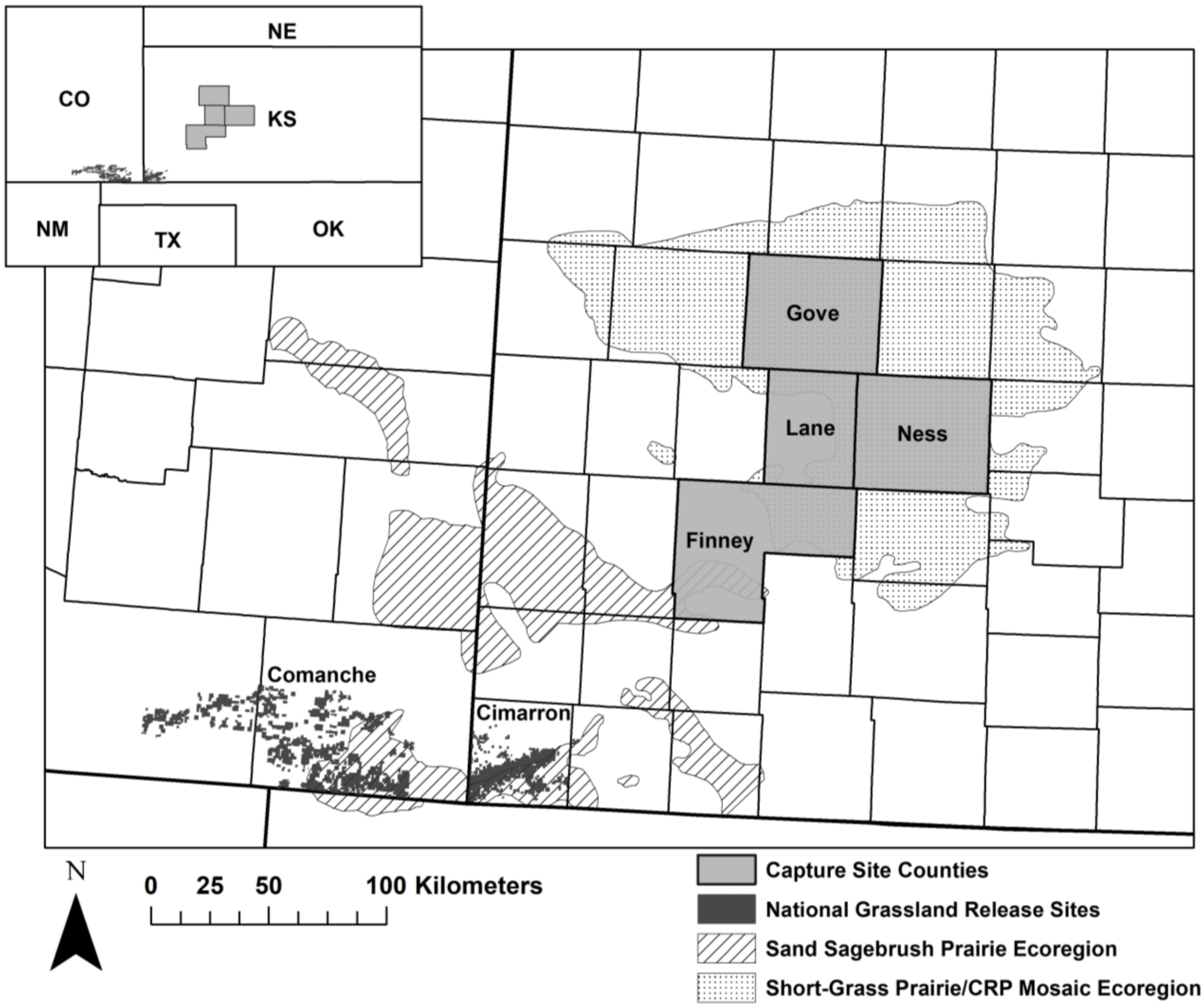

Figure 1.3 Locations of 4 capture counties (Gove, Lane, Ness, and Finney) in Kansas, USA, where lesser prairie-chickens were trapped on leks and released on the U.S. Forest Service, Cimarron and Comanche National Grasslands in Kansas and Colorado, USA, respectively, shown in dark gray. The capture site leks were in the Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion and release sites were in the Sand Sagebrush Prairie Ecoregion of the lesser prairie-chicken range.

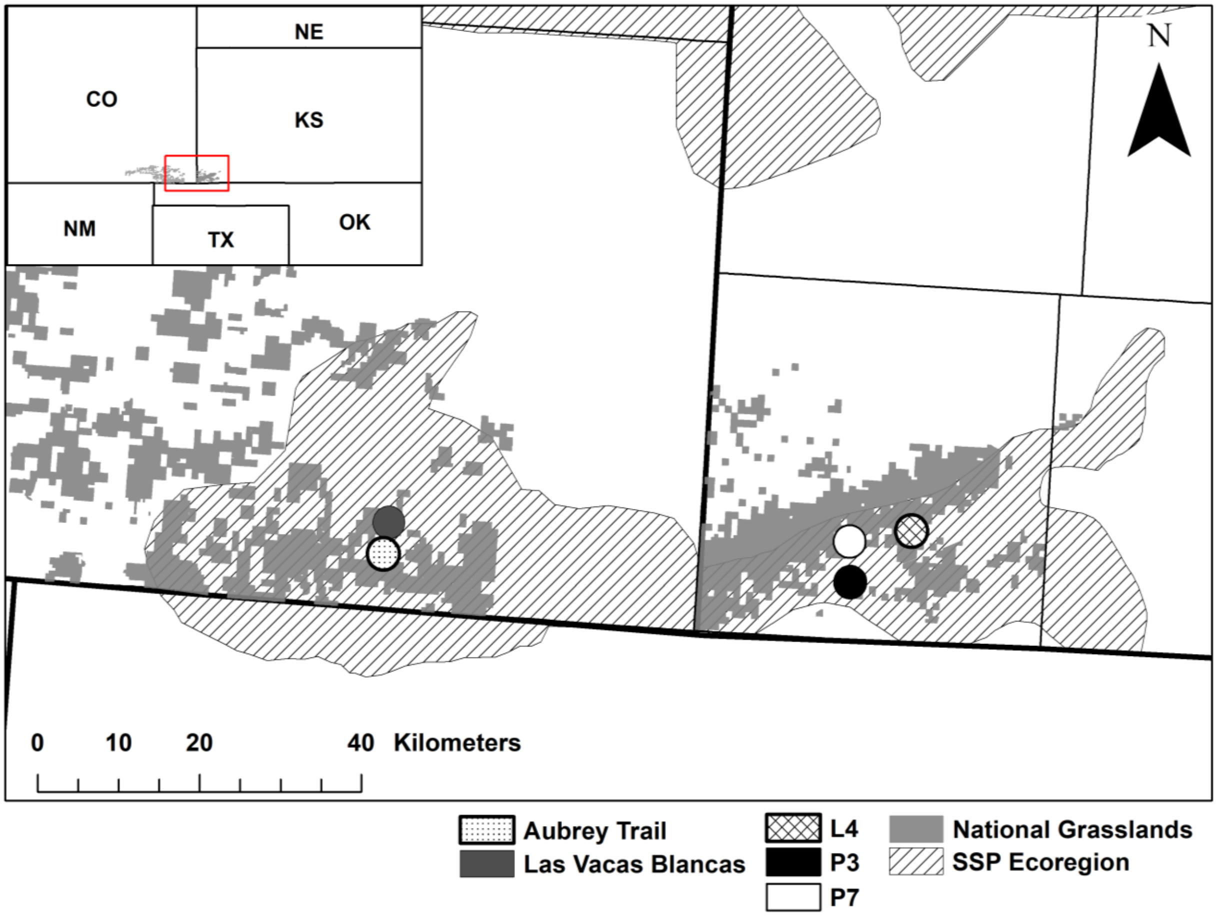

Figure 1.4 Locations of release sites (either active or historic leks) on the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas (KS) and Colorado (CO), USA, respectively, during 2016-2019 in the Sand Sagebrush Prairie Ecoregion (SSP). Release sites were utilized as follows: CO Aubrey Trail (2016-2017) and Las Vacas Blancas (2018-2019); KS L4 (2019), P3 (2016-2018), and L7 (2018). Locations are buffered by a 2-km radius.

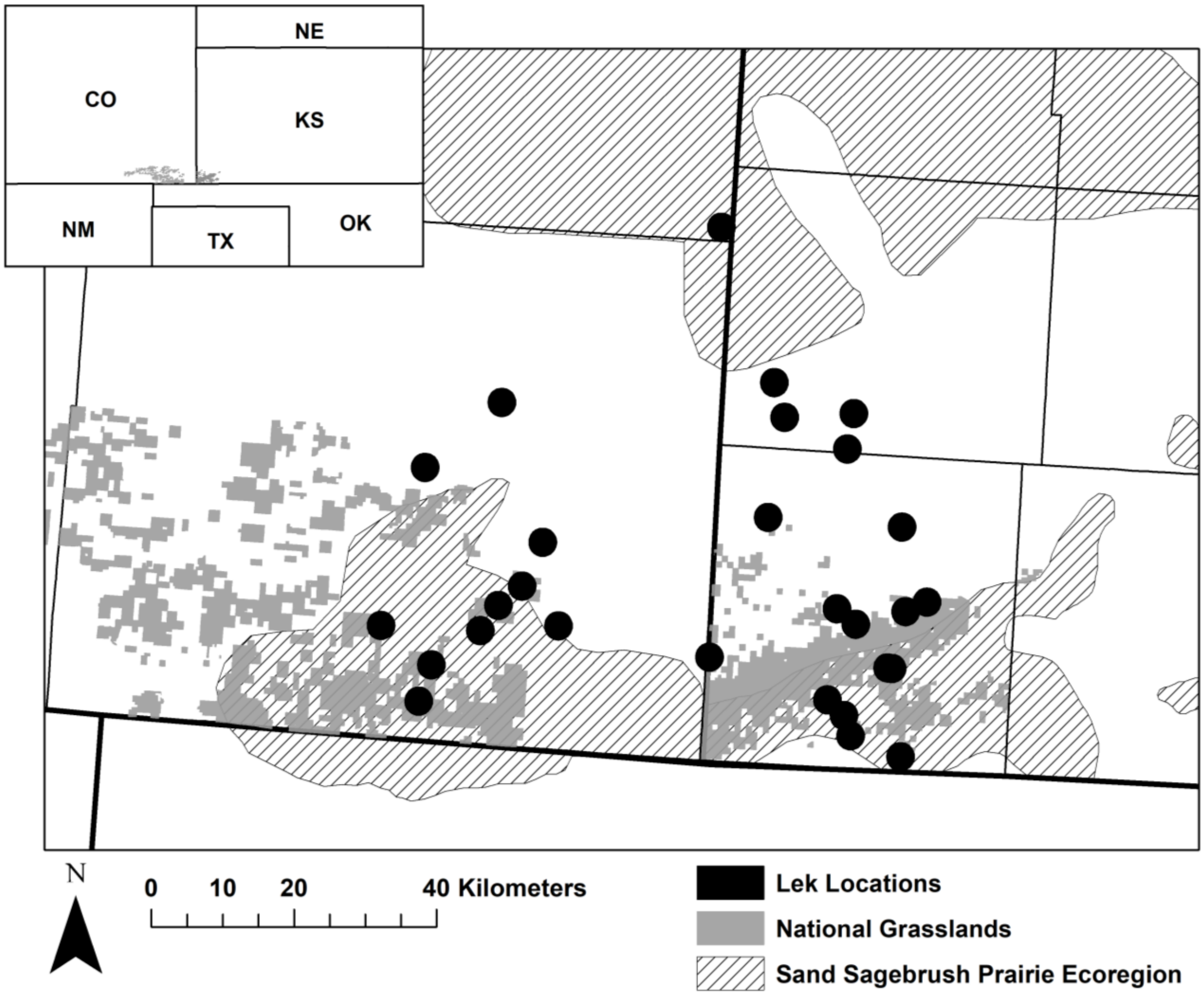

Figure 1.5 Locations of leks attended by lesser prairie-chickens on the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas (KS) and Colorado (CO), USA, respectively, and adjacent areas in the Sand Sagebrush Prairie Ecoregion during 2016-2019. Leks were documented in the translocation study area between 2017 and 2021. Lek locations are buffered by a 2-km radius.

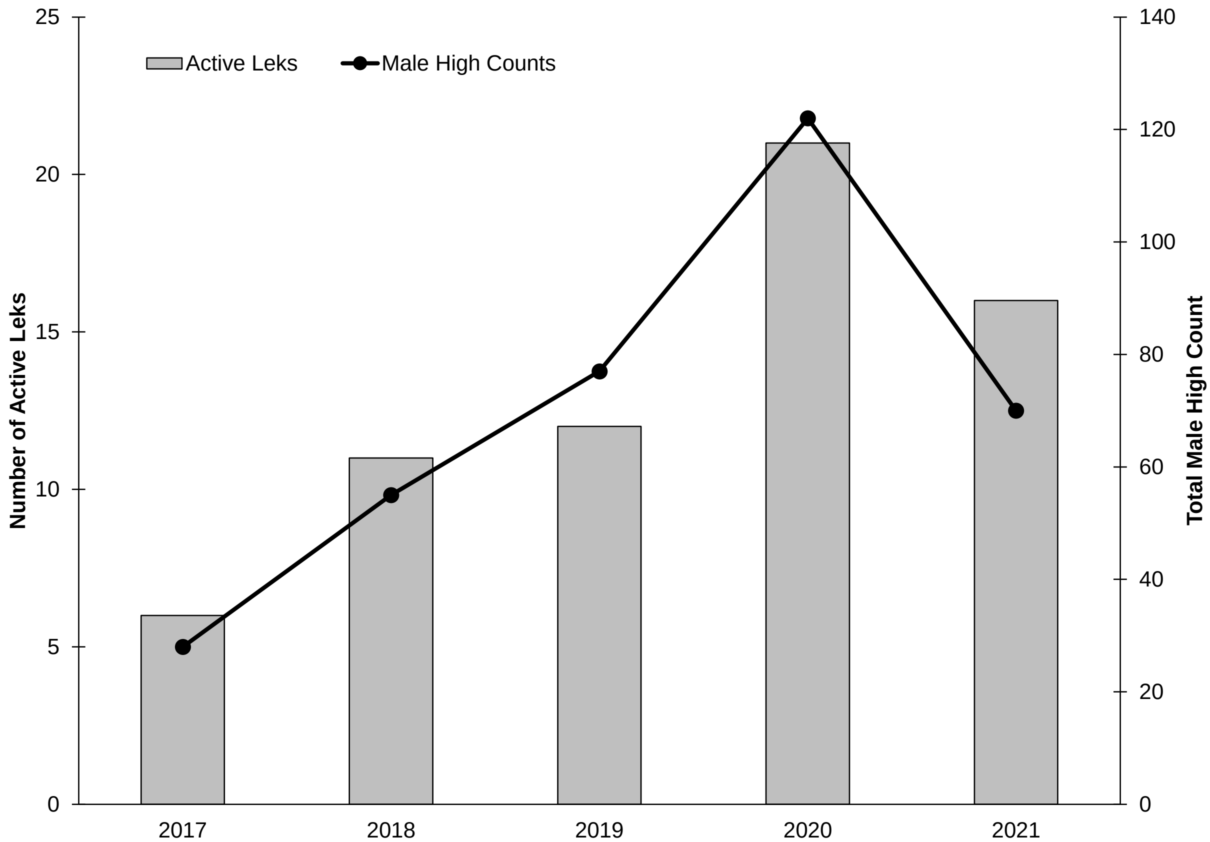

Figure 1.6 Total number of known active leks and high counts of male lek attendance for lesser prairie-chickens in the Sand Sagebrush Prairie Ecoregion during 2017-2021.

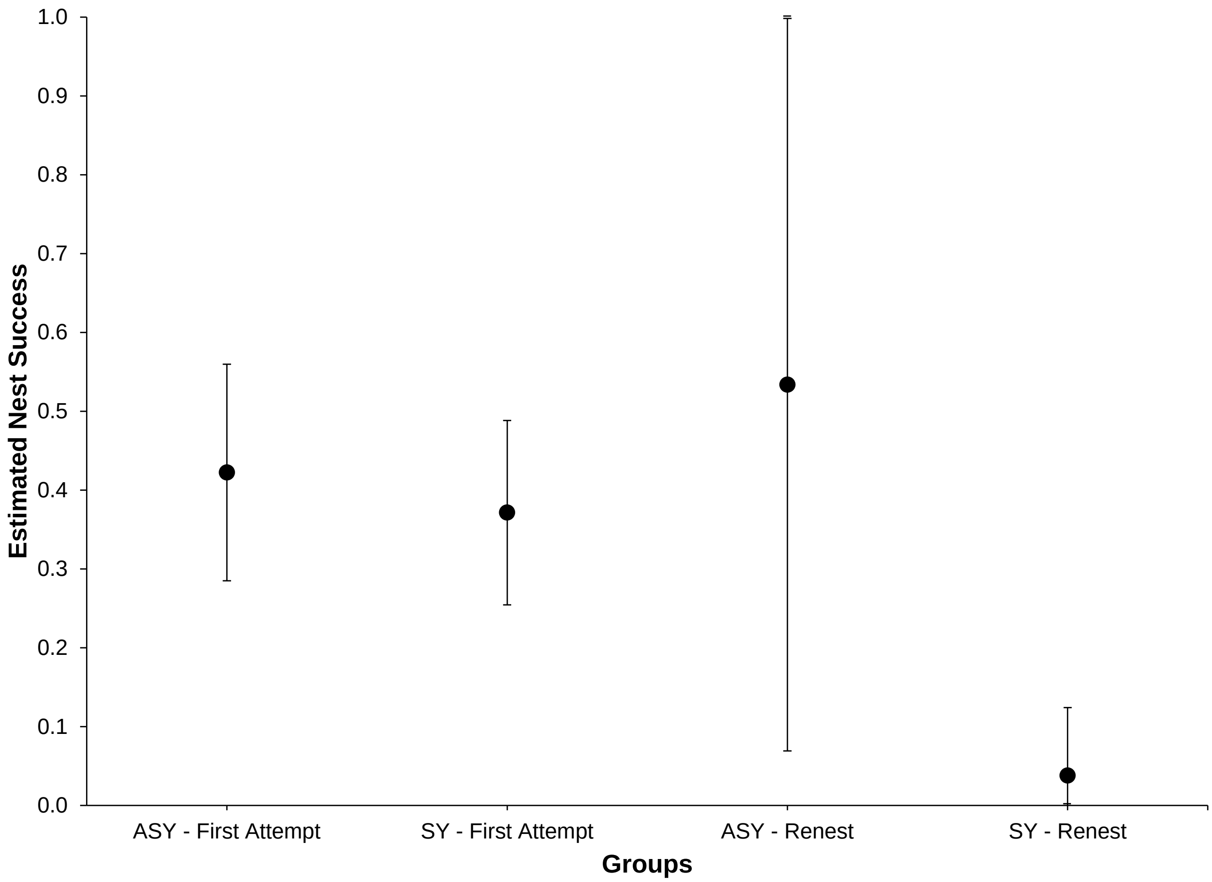

Figure 1.7 Nest survival estimates of lesser prairie-chickens translocated to the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020 in the Sand Sagebrush Prairie Ecoregion comparing groups containing age (SY = second-year, ASY = after-second-year) and nest attempt (First Attempt, Renest).

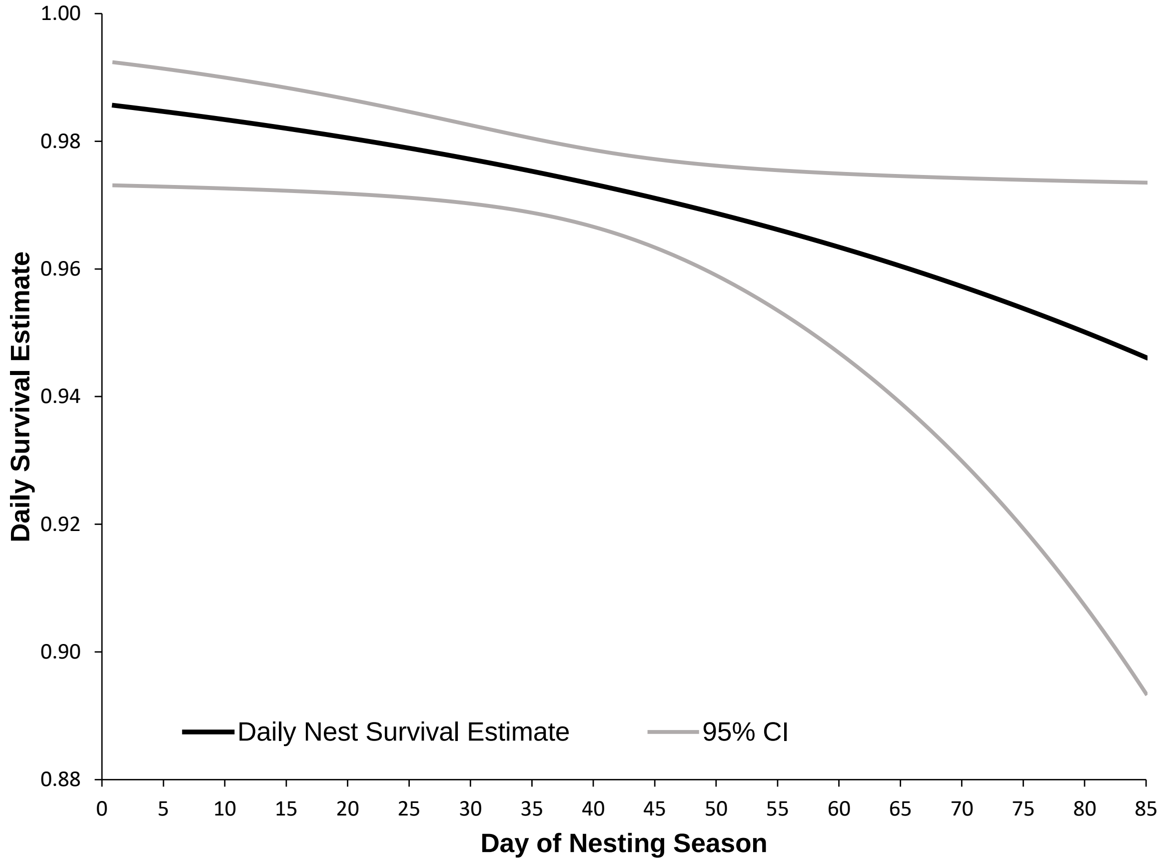

Figure 1.8 Daily survival estimates with 95% confidence intervals of nesting lesser prairie-chickens translocated to the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020 in the Sand Sagebrush Prairie Ecoregion across the 85-day nesting period encompassing multiple nesting attempts (Apr 25- Jul 19).

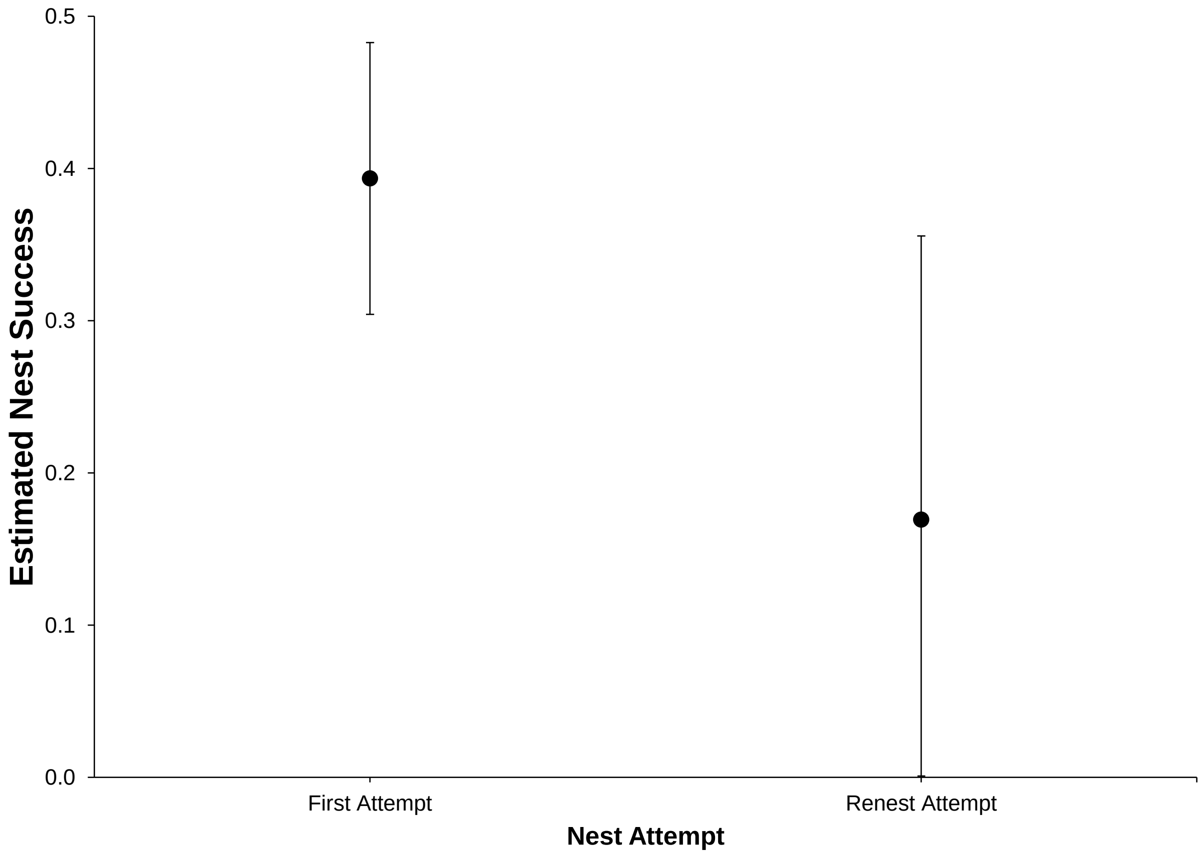

Figure 1.9 Nest success estimates with 95% confidence intervals of nesting lesser prairie-chickens translocated to the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas and Colorado, USA, respectively, in the Sand Sagebrush Prairie Ecoregion comparing first nest and renest attempts during 2017-2020.

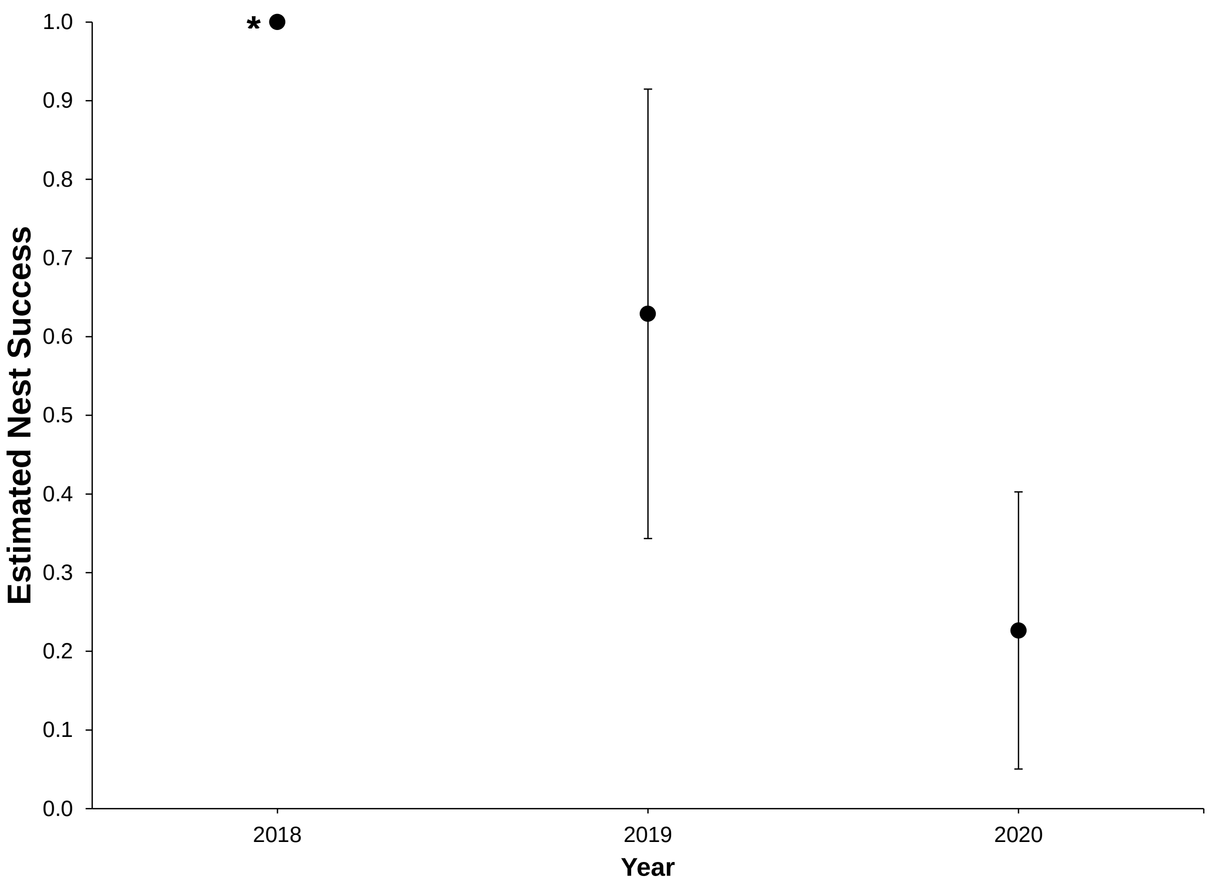

Figure 1.10 Annual nest success estimates with 95% confidence intervals of nesting lesser prairie-chickens translocated to the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020 in the Sand Sagebrush Prairie Ecoregion from 2018-2020 for individuals (*n* = 38) that nested in ≥1 year following year of release. *In 2018, all nests hatched successfully; therefore, confidence intervals could not be estimated.

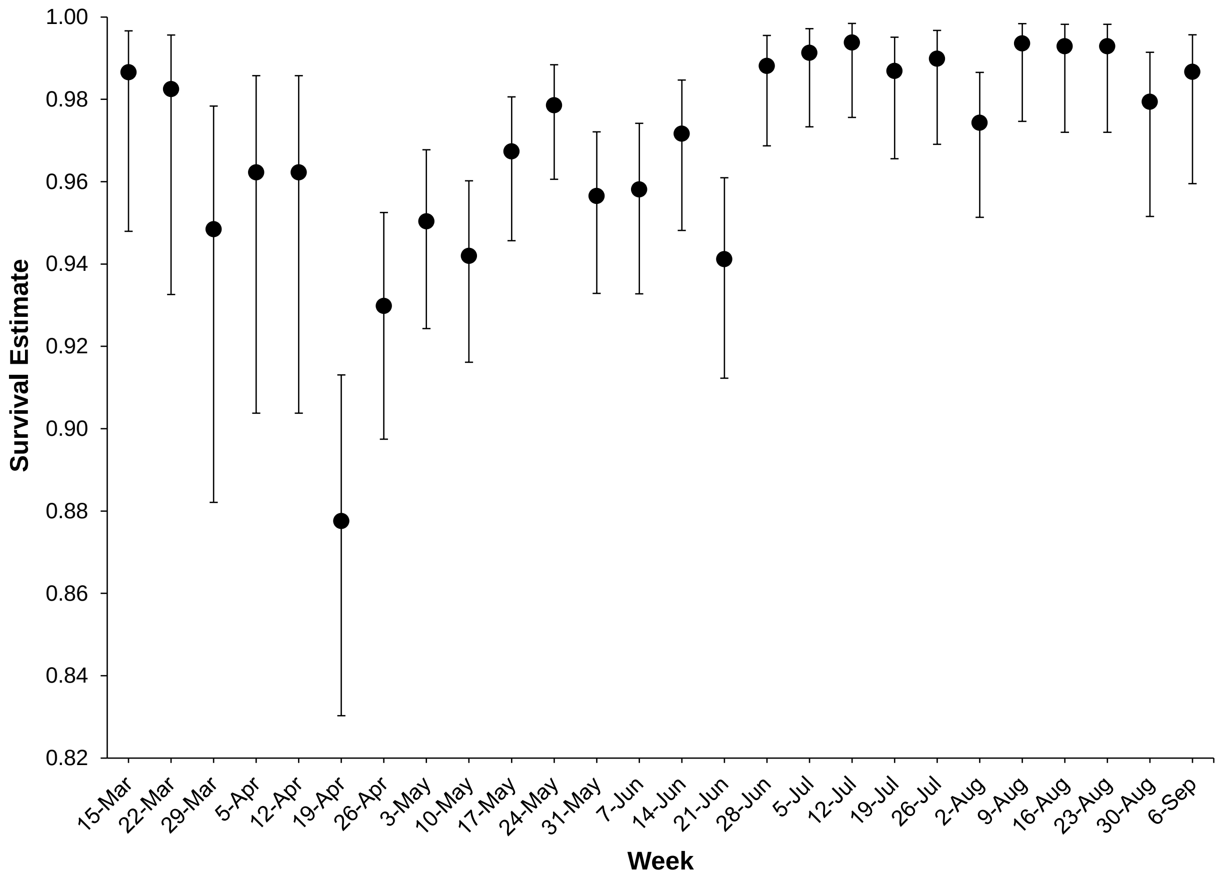

Figure 1.11 Estimated weekly survival estimates during the breeding season (15 Mar – 15 Sep) for male and female lesser prairie-chickens translocated to the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020 in the Sand Sagebrush Prairie Ecoregion.

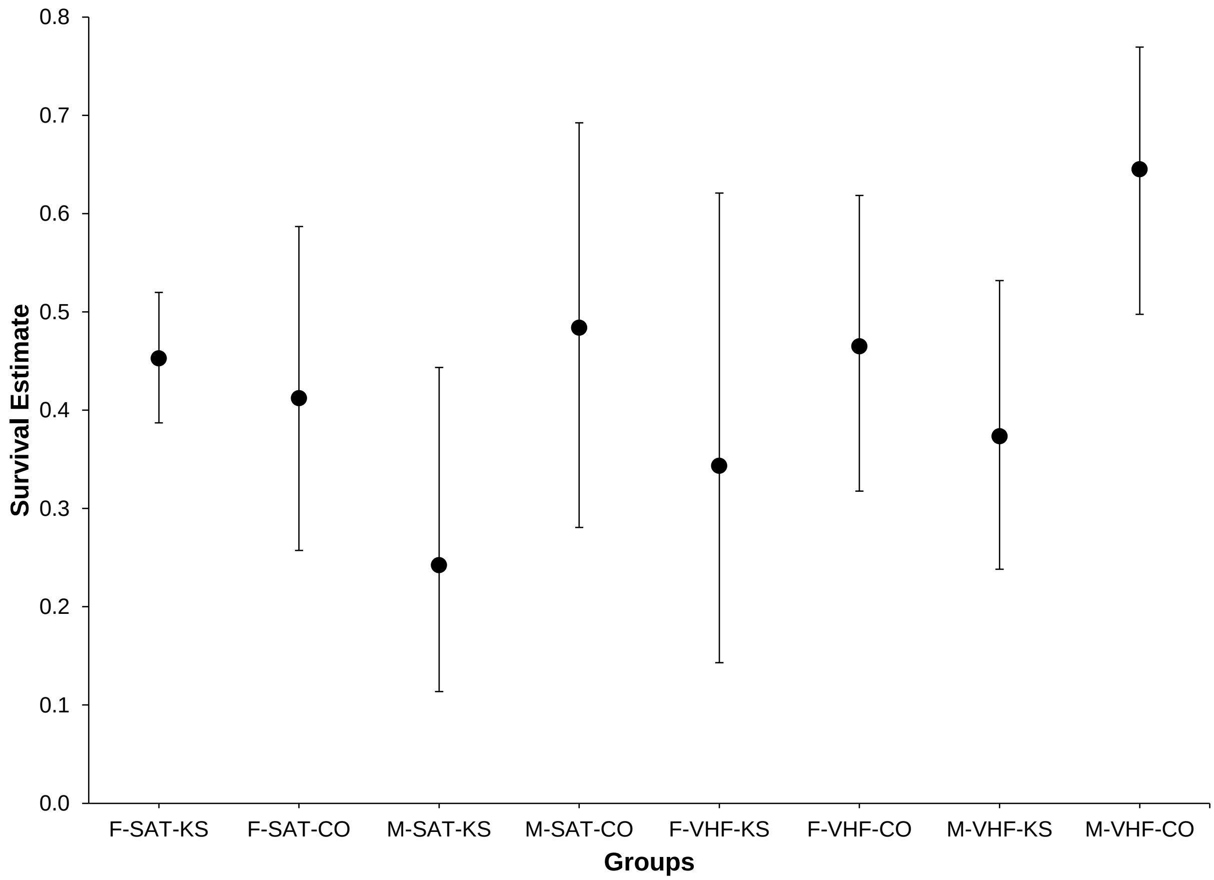

Figure 1.12 Estimates of breeding season (15 Mar – 15 Sep) survival of lesser prairie-chickens translocated to the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020 in the Sand Sagebrush Prairie Ecoregion for groups containing sex (F = Female, M = Male), transmitter type (GPS satellite [PTT-SAT], very-high-frequency [VHF]), and release site (Colorado [CO], Kansas [KS]).

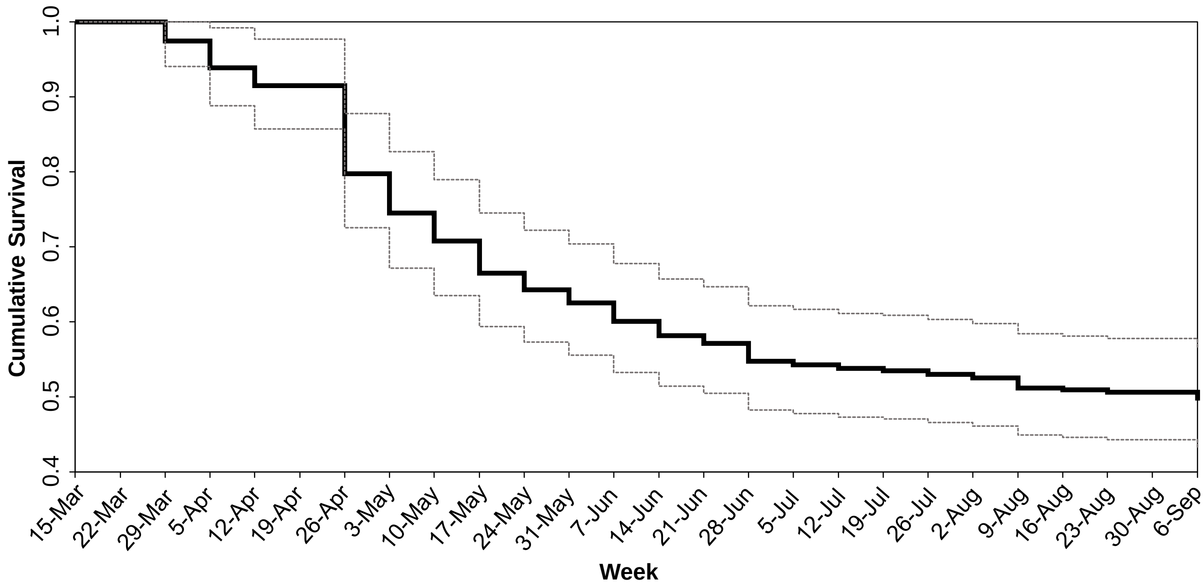

Figure 1.13 Cumulative weekly survival estimates during the breeding season (15 Mar – 15 Sep) using a Kaplan-Meier model of male and female lesser prairie-chickens translocated to the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020 in the Sand Sagebrush Prairie Ecoregion.

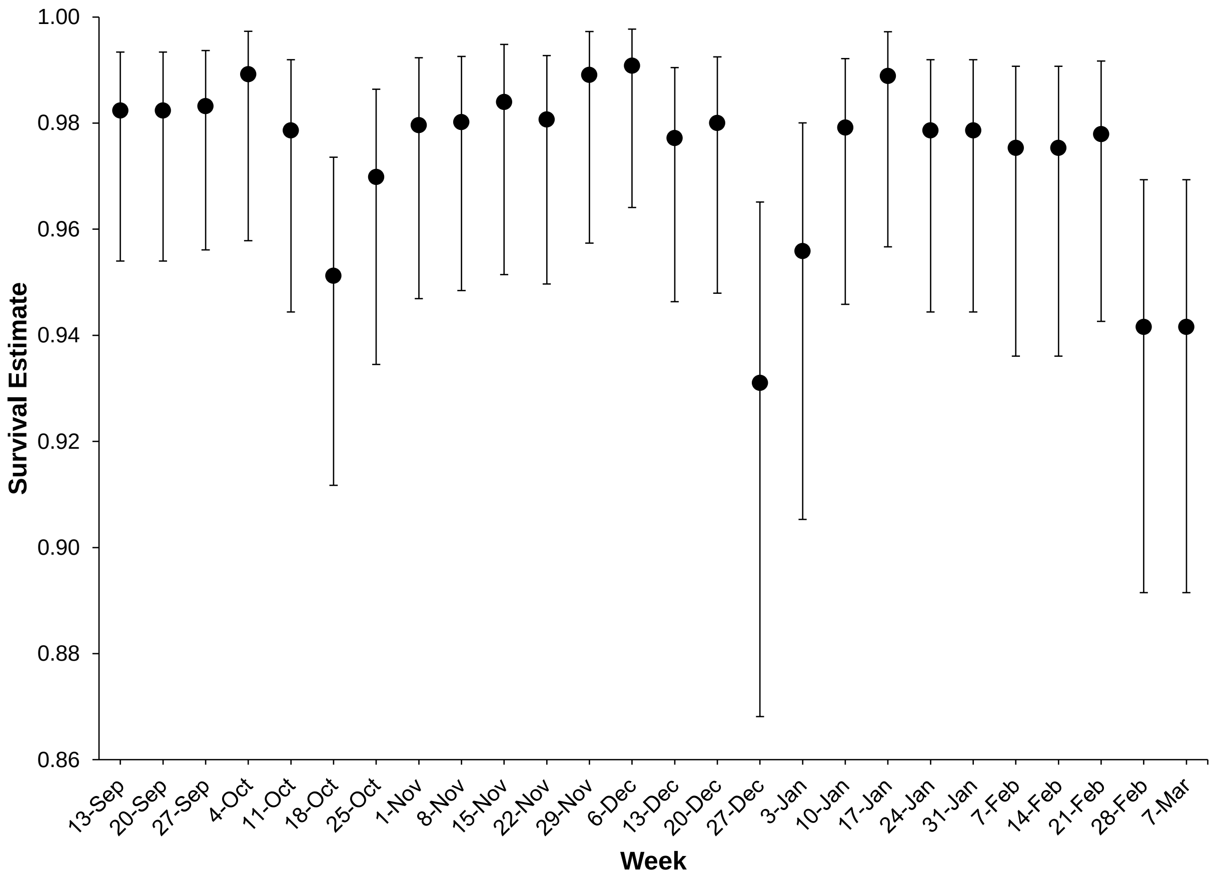

Figure 1.14 Estimated weekly survival estimates during the nonbreeding season (16 Sep – 14 Mar) for male and female lesser prairie-chickens translocated to the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020 in the Sand Sagebrush Prairie Ecoregion.

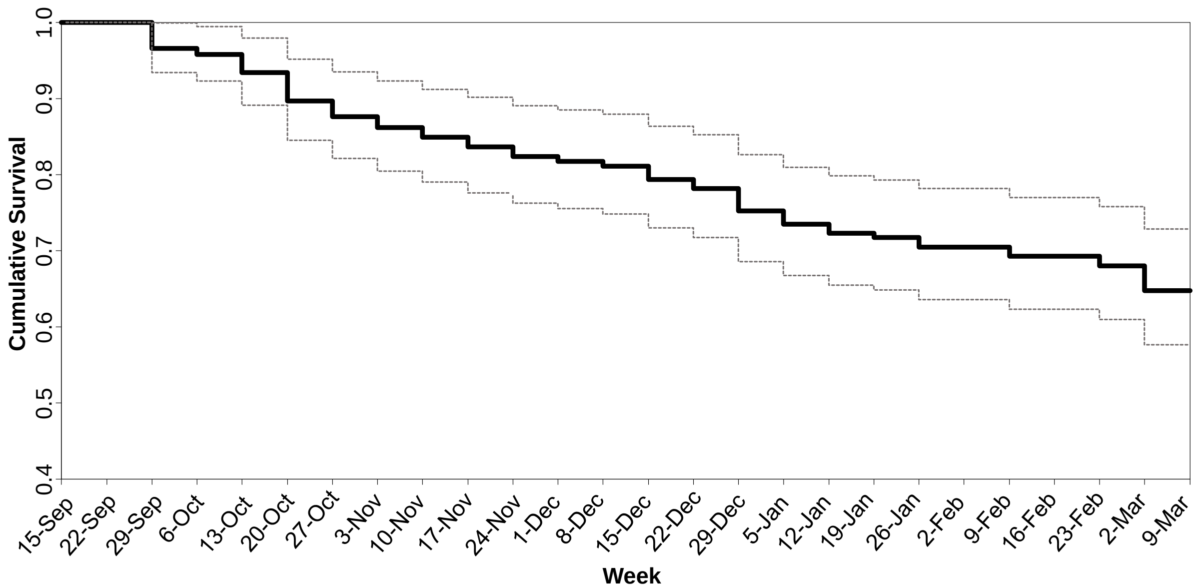

Figure 1.15 Cumulative weekly survival estimates during the nonbreeding season (16 Sep – 15 Mar) using a Kaplan-Meier model of male and female lesser prairie-chickens translocated to the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020 in the Sand Sagebrush Prairie Ecoregion.

Chapter 2 - Seasonal home range and space use of translocated lesser prairie-chickens

Introduction

Translocation is defined as the deliberate movement of organisms from one site to another where the main objective is a conservation benefit (IUCN/SSC 2013). Translocations are used frequently as a management tool to restore or augment wildlife populations, but are not novel approaches to wildlife conservation (Scott and Carpenter 1987). Historically, translocations have varying degrees of success as conservation strategies (Seddon et al. 2014, Hoffmann et al. 2015). Many species of wildlife have been either translocated or reintroduced into formally occupied range, including bighorn sheep (*Ovis canadensis*), muskrats (*Ondatra zibethicus*), greater sage-grouse (*Centrocercus urophasianus),* yellow-legged frogs (*Rana muscosa*), Canada geese (*Branta canadensis*), and western swamp turtle (*Pseudemydura umbrina*) among others (Reese and Connelly 1997, Mitchell et al. 2016, Werdel and Jenks 2018, Calatayud et al. 2020, Matykiewicz et al. 2021, Malanchuk et al. 2021). Often following translocation, when an animal is introduced to a novel environment, there are unexpected behavioral reactions or changes to normal behavior. However, it can be difficult to assess differences in expected behavior, space use, and resource selection among translocated individuals due to lack of comparative data or loss of the ability to research an individual animal in the wild when sourced from a captive-bred population. These common situations coupled with many poorly documented translocations following release can exacerbate the lack of understanding needed to assess behavior and space use in a novel landscape by translocated populations.

Several prairie grouse (*Tympanuchus* spp.) in North America have undergone translocations including greater prairie-chicken (*Tympanuchus cupido*), sharp-tailed grouse (*T. phasianellus*), and Attwater's prairie-chicken (*T. c. attwateri*); many of these species are either currently imperiled or extirpated from many areas of their historic ranges (Snyder et al. 1999). While other conservation strategies, such as habitat management, are being implemented for most populations of prairie grouse, translocation is often considered because of possible immediate and evident effects. However, prairie grouse have been among the most difficult groups to restore into historic range or augment low population abundance, in part because large numbers of birds, possibly >1,000, may be necessary to successfully restore or supplement populations (Toepfer et al. 1990). With such large numbers needed to establish a sustaining population, it is imperative that space use by translocated individuals and populations be studied to inform management decisions for the future.

Space use is an important component of understanding the distributions of animal populations and ultimately conservation of the animal. By using environmental and behavioral cues, animals distinguish between and select for habitat patches on the landscape to maximize their fitness (Fretwell and Lucas 1970, Block and Brennan 1993, Jones 2001). One of the most common factors affecting animal space use is the tendency for most animals to confine their activities to a particular area or home range (Burt 1943). Within a home range, animals often use certain habitats more than others (Horne et al. 2007). Where an animal spends a majority of its time and what habitat land cover types it is using can lead insight into differing demographic rates (Robinson et al. 2018), mating system dynamics (Conner et al. 1999, Gehrt et al. 2020, Aulicky 2020), and location of important resources (Powell 2000). These insights can then be used to inform management decisions to help conserve a single species or several species depending on a population's scope and scale of its space use (e.g., indicator species).

The lesser prairie-chicken (*T. pallidicinctus*) is found in the southwestern Great Plains of the United States and currently occupies four distinct ecoregions (Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, Sand Sagebrush Prairie, and Sand Shinnery Oak Prairie) across five states (Kansas, Colorado, Oklahoma, Texas, and New Mexico, USA; McDonald et al. 2014). These ecoregions are broadly described as semi-arid with abundant sandy soils and native shrubs including sand sagebrush *(Artemisia filifolia*) and sand shinnery oak (*Quercus havardii*) or mixed to tall grasses (Haukos and Zavaleta 2016, Spencer et al. 2017). Considered an indicator species of environmental conditions within each ecoregion, specific management strategies or objectives for lesser prairie-chickens have been proposed by ecoregion due to varying distribution and availability of habitat, land cover composition, land use, anthropogenic structures, and environmental conditions among ecoregions (Haukos and Boal 2016, Robinson et al. 2018*a*, Harryman et al. 2019, Hagen et al. 2020). Ecoregion-specific management strategies may increase local populations and should be considered prior to translocation, especially for translocations among ecoregions or between differing landscapes within ecoregions. Translocated populations may respond differently than native populations to ecoregion-specific conservation strategies due to introduction into a novel environment. Similarly natal habitat preference induction, where an animal is more likely to select a habitat that is comparable to one it experienced when young, may also negatively impact management strategies such as translocation (Davis and Stamps 2004).

Recent distribution estimates suggest that lesser prairie-chickens currently occupy ~15% of their estimated historical range (Boal and Haukos 2016, Rodgers 2016). Within their current occupied range, lesser prairie-chickens have been experiencing moderate to severe population declines (Hagen et al. 2017). Since a contemporary peak of an estimated 150,000 birds in the mid-1980s, populations have declined to current estimated population of 34,408 in 2020 (Nasman et al. 2020). This decline is attributed to loss of quality habitat through anthropogenic development, unmanaged grazing, invasive plant species, and extensive conversion of native prairie to row-crop agriculture causing fragmentation and degrading the quality of remaining habitat (Waddell and Hanzlick 1978, Haukos and Boal 2016). Population declines have been intensified by increasing frequency of severe droughts and extreme weather events (Ross et al. 2016). Increasing population decline and isolation have led to the enhanced probability of extirpations, which, coupled with loss of connectivity of among populations, has reduced the capacity of lesser prairie-chickens to occupy large areas of potential habitat (Garton et al. 2016, Hagen et al. 2017). Due to these on-going and intensifying threats, the lesser prairie-chicken has had a long history of legal status in consideration for listing as threatened or endangered species under the 1973 Endangered Species Act. Most recently (May 2021), a ruling has been proposed that would list lesser prairie-chicken as two distinct population segments, where the southern population segment (i.e., Sand Shinnery Oak Prairie Ecoregion) would be listed as endangered and the northern population segment (i.e., all other ecoregions) would be listed as threatened with a 4(d) rule that tailors protections for the species (U.S. Fish and Wildlife Service 2021).

The largest contemporary decline in population abundance and occupied range of lesser prairie-chickens is occurring in the Sand Sagebrush Prairie Ecoregion. Historically, the Sand Sagebrush Prairie Ecoregion was the epicenter of the lesser prairie-chicken range-wide population despite a large area of the ecoregion’s vegetation being decimated during the Dust Bowl of the 1930s. Jensen et al. (2000) reported an estimated high count of >86,000 birds in the ecoregion during the 1970s. More recently, a contemporary high count of ~75,000 was reported in the 1980s but, by the early 2000s, estimates dropped to ~25,000 birds (Garton et al. 2016, Hagen et al. 2017). This downward decline has continued with an estimate of only 1,479 birds in 2016 in the Sand Sagebrush Prairie Ecoregion (McDonald et al. 2016). Hagen et al. (2020) estimated a high probability of extirpation within five years for the Sand Sagebrush Prairie Ecoregion. No other ecoregion has experienced such a drastic population decline; thus, the Sand Sagebrush Prairie Ecoregion has relatively few remaining native lesser prairie-chickens and is a high priority for immediate conservation action to avoid ecoregion extinction. Conversely, >70% of the extant population occurs primarily in the nearby Short-Grass Prairie/CRP Mosaic and Mixed-Grass Prairie ecoregions of Kansas.

In response to the extreme population decline and estimated extinction risk for the lesser prairie-chicken population in the Sand Sagebrush Prairie Ecoregion, myself, along with the Kansas Department of Wildlife and Parks, Colorado Parks and Wildlife, and U.S. Forest Service translocated lesser prairie-chickens from the Short-Grass Prairie/CRP Mosaic Ecoregion in northwest Kansas, where lesser prairie-chickens are currently most abundant, to release sites in sand sagebrush prairie landscapes on the U.S. Forest Service, Cimarron and Comanche National Grasslands in southwestern Kansas and southeastern Colorado, respectively. Although lesser prairie-chickens were essentially extirpated from both National Grasslands by 2016 (Berigan 2019), a specific management plan developed in 2014 (US Forest Service 2014) and increased precipitation following the 2012-2013 intensive drought was thought to have enhanced habitat quality (i.e., improved vegetation composition and structure) on the National Grasslands sufficiently to support translocated birds. Although previous efforts to translocate lesser prairie-chickens and other prairie grouse have had mixed results (Duck and Fletcher 1943, Snyder et al

1999, Horton 2000, Hagen et al. 2004, Rodgers 2016), the extreme population decline and lack of immigration from other ecoregions make translocation one of the few remaining conservation options available to prevent local or, potentially, ecoregion extinction of lesser prairie-chickens in the Sand Sagebrush Prairie Ecoregion.

From 2016-2019, 411 lesser prairie-chickens were translocated from relatively stable populations in the Shortgrass Prairie/CRP Mosaic Ecoregion of northwestern Kansas to the Sand Sagebrush Prairie Ecoregion. This effort is the largest reported lesser prairie-chicken translocation (Snyder 1999, Giesen 2000). Translocated birds were monitored extensively from 2017–2021 to determine location and area of established home ranges and land cover composition within individual home ranges. My goal was to estimate home range area and evaluate composition of land cover types within estimated home ranges of translocated lesser prairie-chickens equipped with differing transmitter types by various biologically important seasons. I compared home range area estimates with previously published work of native lesser prairie-chickens in the northern extent of their range to assess space use decisions by translocated lesser prairie-chickens in a novel environment.

I evaluated the area and land cover composition of home ranges for translocated male and female lesser prairie-chickens following release in the Sand Sagebrush Prairie Ecoregion during biologically significant seasons. My objectives were to 1) compare estimates home range area of translocated lesser prairie-chickens between transmitter types, sexes, and states; 2) evaluate composition of land cover types within home ranges of translocated lesser prairie-chickens with comparison between transmitter types, sexes, and states within the study area, and 3) compare these results to previously published literature for native birds in the northern extent of lesser prairie-chicken range. I predicted home range area would be larger for translocated lesser-prairie chickens compared to their native counterparts due the novel environment and potential reduced availability of resources experienced by translocated lesser prairie-chickens. I predicted that land cover composition within home ranges of translocated lesser prairie-chickens would be similar to that reported for lesser prairie-chickens throughout their range (i.e., dominated by native grassland).

Study Area

Capture Study Area

I captured lesser prairie-chickens during fall 2016 and spring 2017–2019 in the Short-Grass Prairie/CRP Mosaic Ecoregion, which had the greatest contemporary density of lesser prairie-chickens across their range, in Gove, Lane, Ness, and Finney counties in Kansas (1,357,189 ha; Figure 2.1; Nasman et al. 2020). Land cover in these counties was a mixture of row-crop agriculture, Conservation Reserve Program grassland, and native short-grass prairie intermixed with remnant mixed-grass prairie (McDonald et al. 2014, Dahlgren et al. 2016, Robinson et al. 2018*a*). Historical (1901 to 2015) mean monthly temperatures ranged from -10.8° C to 29.9° C, and annual precipitation ranged from 23.0 to 84.3 cm ($\bar{x}$ = 50.1 cm) in Lane County, Kansas. During the study period (2016 to 2020) mean monthly temperatures ranged from -3.5° C to 26.4° C, and annual precipitation ranged from 44.0 to 60.6 cm (Lane County, Kansas; NOAA 2021).

Vegetation at the capture sites mostly reflected the composition of the native short-grass prairie, but also contains species of mixed-grass prairie (Sullins 2017, Berigan 2019). Most common grass species included little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), composite dropseed (*Sporobolus compositus*), western wheatgrass (*Pascopyrum smithii*), buffalograss (*Bouteloua dactyloides*), blue grama (*B. gracilis*), hairy grama (*B. hirsuta*), sand dropseed (*Sporobolus cryptandrus*), and inland saltgrass (*Distichlis spicata*). Forb species included slimflower scurfpea (*Psoralidium tenuiflorum*), winterfat (*Krascheninnikovia lanata*), western ragweed (*Ambrosia psilostachya*), broom snakeweed (*Gutierrezia sarothrae*), white heath aster (*Symphyotrichum ericoides*), common prickly pear (*Opuntia monacantha*), and field sagewort (*Artemisia campestris*; McGregor and Barkley 1986). Dominant shrub species were sand sagebrush (*Artemisia filifolia*) and four-wing saltbush (*Atriplex canescens*; Fields et al. 2006). Planted CRP grasslands in Kansas were seeded with a native grass-forb mixture since 1986. These grass species include little bluestem, sideoats grama, big bluestem, switchgrass, western wheatgrass, blue grama, buffalograss, and indiangrass (*Sorghastrum nutans*). Forb species include alfalfa (*Medicago sativa*), white sweet clover (*Melilotus alba*), yellow sweet clover (*Melilotus officinalis*), Maximillian sunflower (*Helianthus maximiliani*), prairie bundleflower (*Desmanthus illinoensis*), purple prairie clover (*Dalea purpurea*), and upright prairie coneflower (*Ratibida columnifera*; Fields et al. 2006).

Release Study Area

I released captured lesser prairie-chickens on either historic or current lek locations on the Comanche and Cimarron National Grasslands in Baca County, Colorado, and Morton County, Kansas, respectively (Figure 2.2). I then delineated the translocation study area boundaries by creating a minimum convex polygon around all points of transmittered birds after settling following dispersal events (movements >5 km) that occurred after release using the Minimum Bounding Geometry tool in ArcGIS 10.7.1 (ESRI, Redlands, CA, USA; Robinson et al. 2018*a*, Berigan 2019; Figure 2.3). The study site was 913,320 ha and comprised of 13% CRP, 10% National Grasslands, 29% private rangeland, 46% cropland, and 2% other land cover type (roads, water, etc.). Vegetation on the Comanche and Cimarron National Grasslands was sand sagebrush prairie with a gradient ranging from sparse to abundant densities of sand sagebrush. Vegetation composition and structure on the National Grasslands are largely dependent on soil type and grazing intensity. It includes both short- and mixed-grass prairie interspersed with tall grasses and sand sagebrush (Berigan 2019). Common grass species included sand dropseed, blue grama, buffalo grass, sand bluestem (*Andropogon hallii*). Forb species include yucca (*Yucca glauca*), blazing star (*Liatris* spp.), western ragweed, prairie sunflower (*Helianthus petiolaris*), annual sunflower (*H. annuus*), camphorweed (*Heterotheca subaxillaris*), fumewort (*Corydalis solida*), Indian blanket flower (*Gaillardia pulchella*), Russian thistle (*Salsola tragus*), pigweed (*Amaranthus hybridus*), tansy aster *(Machaeranthera tanacetifolia*), bush morning glory (*Ipomoea leptophylla*), evening primrose (*Calylophus serrulatus*), buffalo bur (*Solanum rostratum*), buffalo gourd (*Cucurbita foetidissima*), Texas croton (*Croton texensis*), and toothed spurge (*Euphorbia dentata*). The shrub community was dominated by sand sagebrush (Haukos and Zavaleta 2016). Vegetation in CRP fields was similar to the capture study area. Common animal species within the region included coyote (*Canis latrans*), white-tailed deer (*Odocoileus virginianus*), thirteen-lined ground-squirrel (*Ictidomys tridecemlineatus*), northern harrier (*Circus hudsonius*), meadowlarks (*Sturnella* spp.), grasshopper sparrow (*Ammodramus savannarum*), dickcissel (*Spiza americana*), gopher snake (*Pituophis catenifer*), and prairie rattlesnake (*Crotalus virdis*). Historical (1901 to 2015) mean monthly temperatures ranged from -7.3 to 29.6° C, and annual precipitation ranged from 21.9 to 70.5 cm ($\bar{x}$ = 42.8 cm) in Morton, Kansas. During the study period (2016 to 2020) mean monthly temperatures ranged from -0.17 to 26.8° C, and annual precipitation was above average during most years and ranged from 32.4 to 56.9 cm (Morton County, KS; NOAA 2021).

Methods

Capture and Monitoring

With private landowner permission, I captured lesser prairie-chickens during lekking activity in September-October (2016) and March-April (2017–2019). I used walk-in funnel traps and tension or magnetic drop nets for capture at lek sites (Haukos et al. 1990, Silvy et al. 1990). After capture, I fitted both male and female lesser prairie-chickens with either a 12- to 15-g bib-style very-high-frequency (VHF) transmitter (RI-2B Holohil Systems Ltd., Carp, Ontario, Canada or Series A3960, Advanced Telemetry System, Isanti, MN, USA) or rump-mounted 22-g Satellite Platform Transmitting Terminal GPS (SAT-PTT) transmitter (PTT-100, Microwave Telemetry, Columbia, MD, USA). Care was taken that transmitter type would not exceed 3% of the body mass of individual birds. I attached SAT-PTT transmitters using leg harnesses made of tubular Teflon® ribbon for durability and sewed in elastic for maneuverability (Bedrosian and Craighead, 2007, Dzialak et al. 2011). I determined sex of each bird from feather coloring and behavior on lek, aged birds as second-year (SY) or after-second-year (ASY) via the molt characteristics of the outer primary feathers (Ammann 1944). A few birds (<3%) had nondescript age characteristics or no age was recorded and were later labeled as after-hatch-year (AHY). I also took measurements of various morphometric data including eye comb length and height, head length, culmen length, pinnae length, tarsus length, tarsus with longest toe length, tail length, flatten wing cord, and mass of the bird (Aulicky 2020). Feathers from the breast and blood were also taken for genetic and disease analyses, respectively. I then marked individuals with a numbered aluminum leg band and a unique combination of plastic color bands for resighting (Coplin 1963).

During transportation to release sites, I minimized unnecessary stressors such as sounds, stops, and kept vehicle temperatures cool to reduce stress on the birds. I released birds within 11 hours after capture on the Cimarron or the Comanche National Grasslands. Chosen release sites were either historic lek locations or visually assessed for nesting habitat and reviewed annually (Figure 2.3). This research was conducted in accordance with guidelines on the use of wild birds in research and in compliance with state and federal regulations (Fair et al. 2010). All handling and capture protocols were completed and approved by the Kansas State University Institutional Animal Care and Use Committee Permit #3703, Kansas Scientific Wildlife Permits SC-024-2018 and SC-015-2019, and Colorado Scientific Wildlife Permits SC-128-2016, SC-079-2017, SC-076-2018, and SC-077-2019.

I monitored male and female lesser prairie-chickens during the breeding (Mar 15–Sep 15) and nonbreeding seasons (Sep 16 – Mar 14) from April 2017 – August 2020. I attempted to locate birds fitted with a VHF transmitter ≥3 times per week using triangulation from 3-5 observer locations via handheld three-piece Yagi antennas and radio receivers (R4000, R410; Advanced Telemetry System, Isanti, MN, USA, or R1000; Communications Specialists, Orange, CA, USA). Triangulation consisted of compass bearings taken at each location ≥15 degrees apart and within 20 min to decrease error from bird movement. Recorded location and associate error was estimated with the Location Of A Signal software (LOAS; Ecological Software Solutions, Hegymagas, Hungary). If an individual could not be triangulated (out of receiver range, flew away, etc.), a second attempt was attempted at another time during the day or the following day. Fixed-wing aircraft was used to locate individuals with VHF transmitters that had dispersed and could not be found by ground scanning. Birds fitted with SAT-PTT transmitters had 8 to 10 GPS locations in 2-hour intervals recorded per day between 0600 and 2200 (18-m accuracy). Locations were uploaded to the Argos satellite system every 3 days and downloaded weekly.

Estimating Home Range Area

I used similar methods for estimating home range area as described by Verheijen et al. (2021) to have directly comparable results. I estimated home range area of translocated lesser prairie-chickens with either kernel density estimators (VHF birds) or biased random bridge movement models (SAT-PTT birds) using the adehabitatHR package in Program R (Worton 1989, Seaman and Powell 1996, Calenge 2006, Benhamou and Cornelis 2010, Benhamou 2011, R Core Team 2020). I estimated home range area for three time periods: the breeding season (Mar 15 – Sep 15), nonbreeding season (Sep 16 – Mar 14), and the entire study duration (2017-2020). I estimated home range area for the entire duration of the study to include birds that did not have sufficient locations (≥30) in either the breeding or nonbreeding season, but enough locations overall to estimate a home range. I excluded locations that were >5 km from the center of the home range for both VHF and SAT-PTT transmitters. Such movements are exploratory or indicate a dispersal event and not generally considered as within home range movements (Earl et al. 2016, Robinson et al. 2018*b*). For each VHF-equipped bird, I obtained at least 30 unique locations over the entire duration of the study and during specific breeding seasons necessary to estimate unbiased home range area (Worton 1989, Seaman et al. 1999, Leonard et al. 2008, Patten et al. 2011, Robinson et al. 2018*b*, Verheijen et al. 2021). I only used VHF locations that had an associated error polygon of ≤0.1 ha for accuracy and consistency with other studies (Robinson et al. 2018*b*, Verheijen et al. 2021). I estimated 95% isopleths of the utilization distribution calculated with a kernel density estimator. An appropriate smoothing parameter is critical when using kernel density estimation because it contains the area over which locations are affecting the utilization distribution and therefore, affecting overall home range area of an individual (Silverman 1986, Hemson et al. 2005, Fieberg 2007, Leonard et al. 2008). Therefore, I estimated a smoothing parameter with least-squares cross-validation (LSCV), which is generally recommended for animal space use and home range studies (Seaman et al. 1999, Horne and Garton 2006). When LSCV failed to converge for VHF birds (n = 104 of 119), I averaged the smoothing parameter of remaining birds (Robinson et al. 2018*b*, Verheijen et al. 2021).

For translocated birds equipped with SAT-PTT transmitters, I estimated a home range area as the 95% isopleth of the utilization distribution calculated with biased random bridge movement models in adehabitatHR package in R. Only birds with at least 100 unique locations over the entire duration of the study or during specific breeding seasons were used, as at least of 100 unique locations is needed to obtain an unbiased estimate of home range area with these movement models (Girard et al. 2002, Robinson et al. 2018*b*, Plumb et al. 2019, Verheijen et al. 2021). I set a minimum smoothing parameter to 6 m, which is the standard deviation of the accuracy of the SAT-PTT transmitters and determined the diffusion coefficient (D) with the maximum likelihood approach (Verheijen et al. 2021).

Statistical Analyses

To assess differences in home range area, I first log-transformed home range area to approximate a normal distribution, then used a two-way analysis of variance (ANOVA, $\alpha = 0.05$) to assess differences between transmitter type and time periods (breeding season, nonbreeding season, and duration of the study). If there was a significant difference between time periods, transmitter type, or an interaction of transmitter and time period then transmitter type and time periods would be separated for further analyses. Within time periods or transmitter types, I then used two-way ANOVA ($\alpha = 0.05$) to test for differences in home range area between sexes and states.

I calculated the composition of land cover types within home range by estimating percent of native non-CRP/grass pasture (private rangeland), CRP, cropland, U.S. Forest Service (public land), and developed open space (roads) area using a cover map comprised of U.S. Department of Agriculture's Cropland Data Layer (USDA-NASS 2019) and a 2014 shapefile provided by the U.S. Farm Service Agency to determine CRP locations. I ground truthed categorization of these patches within 2 km of known leks and determined these data to be accurate. I used Kruskal-Wallis (K-W) tests to assess differences in the percent of each land cover within the home range between transmitter types and time periods. If there was a significant difference between time periods, transmitter type, or an interaction of transmitter and time period then transmitter type and time periods I separated categories for further analyses. Within time periods or transmitter types, I then would use Kruskal-Wallis to test for differences in percent composition of cover types within home range between sexes and states using groups categorized as Colorado males (MCO), Colorado females (FCO), Kansas males (MKS), Kansas females (FKS), and lastly Oklahoma females (FOK). If a main effect was identified ($P < 0.05$), I used Mann-Whitney U tests to identify differences of percent land cover within the home range between groups described above.

Results

Home Range Area

I estimated 128 home ranges in the breeding season (42 = Male, 86 = Female), 55 home ranges in the nonbreeding season (27 = Male, 28 = Females), and 160 home ranges over the entire duration of the study (64 = Male, 96 = Female) that met the criteria for minimum number of locations to estimate a home range upon settling after dispersal events associated with release (VHF: 30 locations, GPS: 100 locations; Tables 2.1, 2.2). Dispersal on average lasted 1-2 months for all translocated birds following release and also an estimate of 55% (n = 227) of translocated birds crossed at least one state line throughout the study period (Berigan 2019; C. Aulicky, unpublished data). Overall, centers of home ranges were placed on average 2.82 km (range: 0.43 m – 32.89 km) from a known lek by the end of the study and 18.37 km (range: 66.63 m – 78.93 km) from the release site for each bird. There was an interaction between time period and transmitter type for home range area ($F_{2,337} = 5.56$, $P < 0.001$; Figure 2.4). Estimated home range area differed between transmitter types ($F_{1,337} = 226.81$, $P < 0.0001$), with SAT-PTT home ranges averaging ~4.0 times larger than VHF home ranges (Figure 2.5). Therefore, time periods and transmitter types were analyzed separately.

Breeding Season

There was no interaction for home range area between sexes and state in which the home range was established for lesser prairie-chickens marked with VHF transmitters ($F_{1,36} = 1.74$, P = 0.19). Home range area differed between sexes for VHF-marked birds, with male area averaging ~1.4 times larger than females ($F_{1,36} = 10.22$, $P = 0.003$; Figure 2.6). Home range area in Kansas averaged ~1.4 times larger than home range area in Colorado ($F_{1,36} = 4.62$, $P = 0.04$; Figure 2.7) for VHF-marked birds. The average breeding season home range area of VHF-marked lesser prairie-chickens pooled across states and sexes was 59.0 ha ± 20.3 (SE 3.8; 95% CI = 17.6 – 111.2). The smoothing parameter (h) estimate of 48.87 was used for the 95% isopleth Kernel Density Estimators. For SAT-PTT marked lesser prairie-chickens there was no interaction for home range area between sexes and state in which the home range was established ($F_{1,83} = 0.44$, $P = 0.51$). Home range area of SAT-PTT lesser prairie-chickens did not differ between sexes

($F_{1,83}$ = 0.003, P = 0.95) or states ($F_{2,83}$ = 1.24, P = 0.30) during the breeding season (Figure 2.8). The average breeding season home range area of SAT-PTT-marked lesser prairie-chickens pooled across states and sexes was 406.6 ha ± 20.3 (SE 40.9; 95% CI = 27.4 – 1975.1). Overall breeding season VHF home ranges were ~6.8 times smaller than SAT-PTT estimated home ranges.

Nonbreeding Season

Unfortunately, I was unable to compare home range area between sexes or states for VHF-marked lesser prairie-chickens during the nonbreeding season due to lack of overall sufficient number of locations to estimate several home ranges for females (n = 2) and birds in Colorado (n = 2; Table 2.1). The average nonbreeding season home range area of VHF-marked lesser prairie-chickens pooled across states and sexes was 95.2 ha ± 20.3 (SE 20.3; 95% CI = 55.41 - 134.99). Home range area did not differ between sexes ($F_{1,83}$ = 2.29, P = 0.14) or states ($F_{2,83}$ = 0.39, P = 0.68) for translocated lesser prairie-chickens marked with SAT-PTT transmitters during the nonbreeding season. A range of smoothing parameter (h) estimates from 50.92 – 117.9 was used for the 95% isopleth Kernel Density Estimators. The average nonbreeding season home range area of SAT-PTT-marked lesser prairie-chickens pooled across states and sexes was 338.7 ha ± 20.3 (SE 36.0; 95% CI = 26.1 – 968.8). Overall SAT-PTT marked lesser prairie chickens nonbreeding season home range were on average ~3.6 times larger than VHF marked birds.

Study Period Duration

Over the duration of the study period, home range area did not differ between sexes ($F_{1,60}$ = 0.40, P = 0.53) or states in which the home range was established ($F_{2,60}$ = 0.55, P = 0.58) for VHF-marked lesser prairie-chickens. Similarly, there was no interaction for home range area difference estimated by sexes or states in which the home range was established for VHF marked birds ($F_{1,60}$ = 1.23, P = 0.27). The average home range area of VHF-marked lesser prairie-chickens pooled across states and sexes was 127.6 ha ± 20.3 (SE 9.9; 95% CI = 26.4 – 571.6) over the duration of the study period. A range of smoothing parameter (*h*) estimates from 33.1 – 125.6 was used for the 95% isopleth Kernel Density Estimators. For SAT-PTT-marked lesser prairie-chickens over the duration of the study, home range area did not differ between sexes ($F_{1,60}$ = 0.55, P = 0.46) or states in which the home range was established ($F_{2,90}$ = 0.97, P = 0.39). Similarly, there was no interaction for home range area estimated over the duration of the study period between sexes or states in which the home range was established ($F_{1,90}$ = 0.006, P = 0.94). The average home range area of SAT-PTT-marked lesser prairie-chickens pooled across states and sexes was 436.2 ha ± 20.3 (SE 38.1; 95% CI = 26.0 – 1975.1) over the duration of the study period. Over the entire duration of the study period, on average SAT-PTT home ranges were estimated to be ~3.4 times larger than VHF home ranges.

Home Range Land Cover Composition

Of all the home ranges estimated (n = 344), 93% of home ranges included CRP, 59% of home ranges included U.S. Forest Service National Grassland within, 77% of home ranges included non-CRP grassland, 89% of home ranges included crop within, and 50% of home ranges included developed/open land; however, there was variation among sexes and states (Table 2.3). Average land cover composition in home ranges across all translocated birds was 44.8% CRP (range: 0% – 100%), 25.03% U.S. Forest Service National Grassland (range: 0% – 100%), 8.0% non-CRP grassland (Private rangeland; range: 0% – 100%), 22.0% crop (range: 0% – 93.5%), and lastly 0.24% developed/open land (roads or buildings; range: 0% – 3.6%). Average home range composition in the breeding season across all birds was 41.7% CRP (range:

0% – 100%), 28.6% U.S. Forest Service National Grassland (range: 0% – 100%), 7.7% non-CRP grassland (Private rangeland; range: 0% – 100%), 21.0% crop (range: 0% – 93.5%), and lastly, 0.24% developed/open land (roads or buildings; range: 0% – 3.6%; Table 2.4). Average home range composition in the nonbreeding season across all birds was 49.7% CRP (range: 0% – 97.5%), 16.9% U.S. Forest Service National Grassland (range: 0% – 99.5%), 9.3% non-CRP grassland (Private rangeland; range: 0% – 89.9%), 23.9% crop (range: 0% – 92.8%), and lastly 0.28% developed/open land (roads or buildings; range: 0% – 2.9%; Table 2.5) Average home range composition duration of the study period across all birds was 45.6% CRP (range: 0% – 100%), 25.02% U.S. Forest Service National Grassland (range: 0% – 100%), 7.7% non-CRP grassland (Private rangeland; range: 0% – 100%), 21.5% crop (range: 0% – 93.5%), and lastly 0.23% developed/open land (roads or buildings; range: 0% – 3.1%; Table 2.6).

Because the developed/open land category made up such a low percent of land cover composition, it was not used in additional analyses. Overall percent cover within home ranges did not differ among time periods (breeding or nonbreeding season or the duration of the study) for CRP, U.S. Forest Service land, non-CRP grassland, and crop categories ($H = 2.75$, $P = 0.25$; $H = 3.96$, $P = 0.14$; $H = 0.13$, $P = 0.94$; $H = 1.49$, $P = 0.48$, respectively). Therefore, home ranges in all different time periods (breeding, nonbreeding, duration of the study period) were pooled for further analysis. Average percent cover of CRP, non-CRP grassland, and crop within home ranges varied between VHF and SAT-PTT marked birds ($H = 30.67$, $P < 0.0001$; $H = 33.49$, $P < 0.0001$; $H = 34.08$, $P < 0.0001$, respectively). However, percent land cover of U.S. Forest Service land within home range did not vary between transmitter types ($H = 0.99$, $P = 0.32$); however, due to management importance of the U.S. Forest Service land it was still analyzed separately among transmitters (Figure 2.9).

VHF – Home Range Composition

Percent land cover of non-CRP grassland within home ranges of VHF-marked lesser prairie-chickens difference between states (H = 23.82, P < 0.0001), with birds in Kansas ($\bar{x}$ = 4.0, SE = 0.9) having ~2.7 times more non-CRP grassland within home ranges than Colorado ($\bar{x}$ = 1.5, SE = 0.6). Percent of crop also differed between females in Colorado ($\bar{x}$ = 9.7, SE = 1.5) and males in Kansas ($\bar{x}$ = 18.4, SE = 2.0) with males in Kansas using ~ 1.8 more crop than females in Colorado (H = 16.82, P < 0.05; FCO vs MKS, P < 0.05). Percent cover of U.S. Forest Service land (H = 6.77, P = 0.15) or CRP (H = 5.31, P = 0.26) did not differ between states and sexes of translocated lesser prairie-chickens (Table 2.4; Table 2.5; Table 2.6).

SAT-PTT – Home Range Composition

Percent land cover of CRP within home ranges differed (H = 21.01, P < 0.001) for SAT-PTT-equipped translocated lesser prairie-chickens by sex and state. Male translocated lesser prairie-chickens in Kansas had a range of 1.5-2.1 times greater percent of CRP in their home ranges ($\bar{x}$ = 42.1, SE = 2.8) than other sexes in other states (Figure 2.10). Similarly, females and males in Colorado had differing amounts of CRP within the home range with females on average having ~2.1 times more CRP ($\bar{x}$ = 42.2, SE = 5.05) in their home range than males ($\bar{x}$ = 20.0, SE = 5.9; MCO vs. FCO, P < 0.05). This pattern continues in Colorado with females and males having differing amounts of U.S. Forest Service land within the home range with males ($\bar{x}$ = 45.2, SE = 8.0) on average with ~1.7 times more than females ($\bar{x}$ = 26.1, SE = 5.7; H = 19.06, P < 0.0001; FCO vs MCO, P < 0.05; Figure 2.11). Also, Oklahoma females did not use U.S. Forest Service land while all other birds on average had 26% (SE = 2.4) U.S. Forest Service land within their home ranges (H = 19.06, P < 0.0001). Conversely, Oklahoma females used a range of 6.9 times more non-CRP grassland ($\bar{x}$ = 56.4, SE = 10.2) than all other birds combined ($\bar{x}$ = 8.2, SE

= 1.1; $H = 32.16$, $P < 0.0001$; Figure 2.12). Lastly, there was no significant difference in percent land cover of cropland within home ranges of SAT-PTT equipped translocated lesser prairie-chickens ($H = 6.80$, $P = 0.15$). All other combinations unless stated above were not significant between sexes or states.

Overall CRP percent was 1.5 times greater in VHF home ranges ($\bar{x} = 56.5$, SE = 2.9) than SAT-PTT ($\bar{x} = 38.5$, SE = 1.8). Non-CRP grassland percent was 3.4 times greater in SAT-PTT ($\bar{x} = 10.6$, SE = 1.3) than in VHF home ranges ($\bar{x} = 3.1$, SE = 0.6). Crop cover percent was 1.7 times greater in SAT-PTT home ranges ($\bar{x} = 25.9$, SE = 1.2) than in VHF home ranges ($\bar{x} = 14.6$, SE = 1.1). Lastly, U.S. Forest Service land percentage was similar in SAT-PTT home ranges ($\bar{x} = 24.7$, SE = 2.4) and VHF home ranges ($\bar{x} = 25.6$, SE = 3.1).

Discussion

Home Range Area

Home ranges are important aspects of an animal's behavior and distribution on the landscape. Knowing an animal's home range area can provide knowledge of food choices, limiting resources, and important components of habitat (Powell 2000). Estimating home ranges can lead to further understanding of animal behavior when introduced to a novel environment. Addressing this knowledge gap is important in understanding spatial needs for lesser prairie-chicken populations. Space use in the novel environment may be fundamentally different than it would be in a native environment because of differences in activity relative to available resources and limitations in space use that could be implicit. Therefore assessing space use in translocated lesser prairie-chickens is vital to ultimately understanding how to conserve the overall population.

I found that home range area in translocated lesser prairie-chickens does not vary like their native counter parts during biologically relevant seasons. Generally, home ranges were larger in the breeding season and smaller in the nonbreeding season compared to native populations (Robinson et al. 2018*b*, Verheijen et al. 2021). As expected, VHF-marked birds had smaller home ranges than SAT-PTT birds. Consistently, CRP was found to be translocated lesser prairie-chicken home ranges at greater percentages than other cover types including U.S. Forest Service National Grasslands, non-CRP private working grasslands, and cropland. Interestingly, there was a few considerable differences in home range composition between states, sexes, and transmitter types, but not during biological time periods. On average, home ranges of VHF-marked lesser prairie-chickens included 1.5 times more CRP than SAT-PTT home ranges, but SAT-PTT home ranges included 3.4 and 1.7 times more non-CRP grasslands and crop, respectively, than VHF-marked birds. Among states, non-CRP grasslands home range composition was ~2.7 times larger in Kansas than in Colorado among VHF-marked birds and SAT-PTT birds in Oklahoma used 6.9 times more non-CRP grasslands and used no amount of U.S. Forest Service National Grasslands compared to birds in Kansas and Colorado. Between sexes, males in Kansas had the largest percent CRP composition in their home ranges compared to other sex-state groups. Lastly, female and male home ranges in Colorado varied in composition, with males having 1.7 times more U.S. Forest Service National Grasslands and females having 2.1 times more CRP. This indicates the importance of estimating home ranges between sexes and release locations as it can lead insight into differing space use and ultimately resource utilization among groups. With this information, more specific and informed management decisions can be made for the conservation of lesser prairie-chickens.

No difference in home range area was found among time periods of interest (i.e., breeding season, nonbreeding season, and the total duration of the study) even though there was large variation in home range area among individuals. This finding contrasts with reports that home ranges for native lesser prairie-chickens are generally smaller in the breeding season than during the nonbreeding season (Taylor and Guthery 1980, Merchant 1982, Riley et al. 1994, Jamison 2000, Hagen 2003, Haukos and Zavaleta 2016). This seasonal space use difference is often attributed to variation in availability of resources needed during a lesser prairie chickens life-cycle including differing habitat vegetation and structure for food and cover (Haukos and Zavaleta 2016).

Prairie grouse studies have found that estimates of home range area can vary by transmitter type (Berger et al. 1991, Robinson et al. 2018*b*, Verheijen et al. 2021). I found that birds marked with SAT-PTT transmitters had on average a range of ~3.4-6.8 times than greater home range area of birds marked with VHF transmitters. Breeding season home ranges from a recent study that occurred across the lesser prairie-chicken northern range using the same transmitter types, reported home range areas ranged from 17.7 – 2448.1 ha with an average 283.6 ha for females equipped with SAT-PTT (Verheijen et al. 2021). Translocated females marked with SAT-PTT had 53% larger home ranges with an average of 435.1 ha and a range of 27.3 – 1975.1 ha. This is likely due to translocated birds being unfamiliar with the novel location and continuing to search for high quality habitats even once they settled and established a home range following the initial dispersal after release. Such on-going assessment of habitat quality and availability on the landscape results in larger home ranges.

While home ranges estimated from VHF-marked birds have been found to be smaller in area (Robinson et al. 2018*b*, Verheijen et al. 2021), I found that the VHF-marked translocated birds have much smaller home ranges during the breeding season and were considerably smaller ($\bar{x}$ = 59.0 ha; range = 17.6 – 111.2 ha) compared to other estimates of 190.4 ha – 233.0 ha across the range (Merchant 1982, Toole 2005, Leonard 2008, Borsdorf 2013, Winder et al. 2015, Verheijen et al. 2021). With the study by Verheijen et al. (2021) finding a breeding season home range size of females lesser prairie-chickens with VHF transmitters in the northern distribution of their range to be 190.4 ha using very similar methods. However with other studies, different home range estimation methodologies, such as exclusion of dispersal location, which is not mentioned in other studies, and more leniency around location error may account for some of the disparity leading to the smaller estimates (Merchant 1982, Toole 2005, Leonard 2008, Borsdorf 2013, Winder et al. 2015, Robinson et al. 2018*b*, Verheijen et al. 2021). However, the large difference in estimated home range area between my study and other studies could also be related to the sheer size of the study area and number of VHF-marked birds (n = 279). Relatively few birds (31%) had sufficient locations with an error of <0.1 ha necessary to estimate an unbiased home range area. Further, long-distance dispersal by birds following release limited capacity for tracking lesser prairie-chickens marked with VHF radio transmitters. These issues may have led to variation in location and triangulation effort as reflected in the difference in home range area between VHF males and females and VHF birds between Kansas and Colorado as the same pattern was not present in the SAT-PTT-marked birds.

It is not surprising then, that I found a difference in home range area between transmitter types with estimated areas of SAT-PTT home ranges averaging ~4.0 times larger than VHF home ranges. Other studies have found similar results of SAT-PTT home ranges being 1.5 - >3 times larger than VHF-marked lesser prairie-chickens (Robinson et al. 2018*b*, Verheijen et al. 2021).

Although home range area of translocated lesser prairie-chickens did not differ between breeding and nonbreeding seasons, many studies analyze them separately because it has been shown that nonbreeding season home ranges are larger, birds have greater movements, and space use differs from the breeding season; most of these these studies were in the southern portion of the range (Candelaria 1979, Jones 2009, Lyons et al. 2009, Kukal 2010, Pirius et al. 2013). In a large lesser prairie-chicken study in the northern three ecoregions, home range area was estimated to be 237 ha for the breeding season and 286 ha during the nonbreeding season for females across VHF and SAT-PTT transmitters (Robinson et al. 2018*b*, Verheijen et al. 2021). Home range area of SAT-PTT-marked translocated lesser prairie-chickens averaged 338.7 ha (range 26.1 – 968.8) during the nonbreeding season, which is smaller compared to the estimate from another study where nonbreeding season home range area estimate was 997 ha for both male and female lesser-prairie chickens equipped with SAT-PTT in the northern part of the lesser prairie-chicken range (Robinson et al. 2018*b*). This could indicate that there is less available quality habitat in the Sand Sagebrush Prairie Ecoregion available for translocated birds, effectively limiting movements once the bird establishes a home range. It appears that translocated birds have larger home ranges overall because of the distribution of quality habitat may be more fragmented on the landscape.

Home range area of nonbreeding lesser prairie-chickens marked with VHF transmitters averaged 95.2 ha (range: 24.5 – 263.4). which, similar to SAT-PTT-marked birds, is on the low end of the range reported in other studies (62 ha – 1, 946 ha); however, there is considerable variation in the time period defined as nonbreeding in these other studies (i.e., 1 month - 6 months) and considerable variation in home range estimation methodologies among studies (Taylor 1978, Candelaria 1979, Jamison 2000, Toole 2005, Pirius et al. 2013, Robinson et al.

2018*b*). However, I found nonbreeding season home ranges to be much less than breeding season home range area. This is likely due to birds becoming familiar with the lek landscape and their need to fly farther to reach leks in a novel environment while, conversely, during the nonbreeding season strictly using spaces with known resources to negate possible negative demographic consequences of expending large amounts of energy needed to find more resources in an unknown environment.

In an effort to include more birds in the home range analyses, I estimated home range area for all translocated lesser prairie-chickens that met location criteria over the entire duration of the study period (i.e., either their entire life span or from release until August 2020). Using bird locations that span both the nonbreeding and breeding seasons to estimate overall home ranges could provide knowledge of whether the amount of space used increases or remains consistent in comparison relative to the breeding and nonbreeding seasons. Using all locations of individual birds for an entire study period to estimate home range area is rare; thus, little is known about home range estimates over the course of an entire study. Average home range area of translocated lesser prairie-chickens for the duration of the study was 127.6 ha (range: 26.4 – 571.6 ha) for VHF-marked birds over the entire study period and 436.2 ha (range: 26.0 – 1975.1 ha) for SAT-PTT-marked birds, indicating that inclusion of birds that could not have estimated home ranges in either breeding or the nonbreeding season are likely using a similar area of space as birds that has sufficient locations to estimate separate breeding and nonbreeding season home range area.

I found no difference in home range area between sexes or states for birds marked with SAT-PTT transmitters. While VHF home ranges differed during the breeding season, this may due to methodology of collecting data and is likely not entirely representative of the translocated birds as a whole. Home range area estimates of SAT-PTT-marked birds are likely more accurate given consistent availability of locations (8-10 per day). The lack of a difference in home range area between sexes and states is likely due to release into a novel environment and availability of quality habitat at release sites (Berigan et al., *in review*). Ultimately, home range area is often driven by movements geared toward securing resources necessary to maximize individual fitness and therefore, correspond to availability of quality habitat for lesser prairie-chickens (Haukos and Zavaleta 2016).

Home Range Composition

Interestingly, composition of land cover types within estimated home ranges did not vary among breeding season, nonbreeding season, or over the duration of the study. There is evidence suggesting that lesser prairie-chickens use different resources during different times of the year by shifting home ranges and altering relatively composition of land cover types within their home range; for example, possibly using more cropland in the winter as birds feed on waste grain (Crawford and Bolen 1976). However, that was not the case in this study. Furthermore, it was not surprising that composition varied by transmitter type as SAT-PTT-transmitter home range area was ~4.0 times larger than VHF-transmitter home range area, providing opportunity for additional variety in percent land cover.

Lesser prairie-chickens marked with VHF transmitters in Kansas used non-CRP grassland ~2.7 times more than birds in Colorado. This may be due to differences in landscape composition and land use within the study area between the two states. Colorado has more public grazing opportunity because more U.S. Forest Service Comanche National Grassland tracts available throughout much of the study area compared to the amalgamated essentially contiguous Cimarron National Grassland in Kansas. Therefore, private land is more likely to be used by lesser prairie-chickens following dispersal from release sites on the Cimarron National Grassland. Interestingly, I found no difference in percent cover of CRP within home ranges between states and sexes for birds marked with VHF transmitters; however, VHF-marked birds used 1.5 times more CRP than SAT-PTT marked birds. This indicates that CRP provides important habitat for translocated lesser prairie-chickens in both states as CRP was consistently the greatest percent land cover type in all home ranges for VHF-marked birds.

There was greater variation of percent composition of non-CRP grassland within home range area among SAT-PTT-marked birds than their VHF counterparts. Not surprisingly, females in Oklahoma use no U.S. Forest Service land at all and conversely used 6.9 times more non-CRP grassland than birds in other states. There was no U.S. Forest Service land within the study area in Oklahoma; therefore, females used non-CRP grassland. Interestingly, males in Colorado had 1.7 times more area of U.S. Forest Service land within their home range than females in Colorado. This may be caused by a greater percent of leks in Colorado being on tracts of the Comanche National Grasslands compared to leks in Kansas on the Cimarron National Grasslands and males incorporating those areas into their home ranges (Figure 1.5). This indicates that home range composition can significantly differ between sexes and only considering a single sex may bias statements of generalized habitat use by lesser prairie-chickens. Males are often more visible on leks and while females may be nearby, they may not be utilizing habitat types at the same frequencies as males. Therefore, characterizing habitat use by populations of lesser prairie-chickens based on lek locations may not recognize differential habitat use by females and lead to misleading management recommendations. As female lesser prairie-chickens provide uniparental care for young and are drivers of population growth, it is important to recognize habitat differences among sexes for conservation success.

Similar to VHF-marked lesser prairie-chickens, CRP was consistently the largest percentage of home range area of any other cover type within home ranges of SAT-PTT-marked birds. Male lesser prairie-chickens marked with SAT-PTT transmitters in Kansas had a range of 1.5-2.1 more CRP within their home ranges than all other birds. Unexpectedly, females in Colorado had ~2.1 greater percent CRP within their home ranges than Colorado males. Other studies have shown that CRP is increasingly quality habitat for this grassland-obligate grouse in semi-arid regions of its range (Sullins et al. 2018). Indeed, the majority of the entire lesser prairie-chicken population resides in the Short-Grass Prairie/CRP Ecoregion in northwest Kansas (Nasman 2020). Prior to the establishment of the CRP in Kansas, lesser prairie-chickens were not detected in northwest Kansas (Rodgers 2016). Recently, a study in Texas found that lesser prairie-chickens used native-planted CRP year-round by both sexes (Harryman et al. 2019). Lesser prairie-chickens are thought to use CRP because of vegetation structural heterogeneity and abundant food resources (Hagen et al. 2004, 2013). However, an investigation of the demographic effects of CRP on lesser prairie-chickens showed strong evidence that birds are selecting CRP because of its reproductive output and overall success (Sullins et al. 2018).

It is important to note that the birds in this study were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion where CRP is abundant and may be choosing land cover types similar to their landscape of capture. This phenomenon is termed natal habitat preference induction and predicts translocated birds would select CRP grasslands surrounding the release site over sand sagebrush prairie of comparable habitat quality (Davis and Stamps 2004, Stamps and Swaisgood 2007). However, data from SAT-PTT-marked native birds during 2011-2013 on Cimarron National Grassland also selected for CRP (E. Teige, unpublished data) and vegetation sampling results from this study showed that CRP supported quality nesting habitat for lesser-prairie chickens more consistently compared to other cover types in the study area (L. Berigan, unpublished data). Furthermore, to fully test this prediction, lesser prairie-chickens would need to be translocated from other areas within the Sand Sagebrush Prairie ecoregion to determine if habitat selection and home range composition is similar or different to these results from the translocated Short-Grass Prairie/CRP Mosaic Ecoregion birds.

Summary

Home range area of translocated lesser prairie-chickens did not differ among breeding season, nonbreeding season, and the duration of the study period, but there was a considerable difference in estimated home range area of lesser prairie-chickens between VHF and SAT-PTT transmitters. Furthermore, translocated birds had larger breeding season and smaller nonbreeding season home ranges than native counterparts across the species' range. This is likely due to the novel nature of the study area to translocated birds, physical isolation once a home range was established, and quality/availability of resources. Translocated lesser prairie-chicken had greater percent cover of CRP within their home ranges than any other land cover type including U.S. Forest Service land and non-CRP grassland. Interestingly females in Colorado have more CRP within their home range while males in Colorado have more U.S. Forest Service land. This may indicate that CRP is a more critical and demographically important land cover type as females provide uniparental care and generally considered more important for population recruitment. As several studies have indicated CRP as an important cover type on the landscape for lesser prairie-chickens in semi-arid portion of their range (Sullins et al. 2018, Harryman et al. 2019, Hagen et al. 2020), it is important to note that populations in the Sand Sagebrush Prairie Ecoregion have declined at a greater rate than other ecoregions after CRP was implemented in 1986. While several causes for this decline have been proposed, such as habitat conversion to pivot irrigated row crop agriculture, extreme weather events including drought and blizzards, changing vegetation composition, and degradation of habitat quality, conclusive identification of reasons for the relatively extreme population decline of lesser prairie-chickens in this ecoregion has not been achieved. However, currently estimates of lesser prairie-chicken population abundance in the Sand Sagebrush Prairie Ecoregion are so low that extirpation is likely from a stochastic weather event or the lack of effective habitat conservation. Continued investment into CRP may be a more helpful conservation strategy than translocation in the future for the entire lesser prairie-chicken population in the Sand Sagebrush Prairie Ecoregion.

Management Implications

Translocated birds collectively had an average breeding season home range area of 406.6 ha and incorporated CRP fields more than other cover types in the study area. Also translocated lesser prairie-chickens consistently used CRP as habitat throughout the year, between states, and for both sexes. Importantly, my results show that while males in Colorado incorporated more U.S. Forest Service National Grasslands in their home ranges, females in Colorado conversely used more CRP within their home ranges. This finding stresses the importance of assessing habitat beyond immediate lek site areas where males are most often seen due to survey methods. Research has shown that management should be at a scale of 5 km around a lek to support lesser prairie-chicken population growth (Gehrt et al. 2020). My nest success estimates and additional recent research results have also shown CRP to be beneficial for reproductive output, which would be ideal in an ecoregion where population is declining. Finally, re-enrolling or keeping CRP fields in grasses after contract expiration will help to ensure long-term conservation benefits (Sullins et al. 2021).

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Tables

Table 2.1 Average 95% isopleth of home range area (ha) using Kernel Density Estimates of for male and female lesser prairie-chickens marked with very-high-frequency (VHF) transmitters and translocated to the U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020. Estimates are stratified by sex (Male, Female), season (Breeding, Nonbreeding, Total Study Period) and states (CO, KS, OK), but pooled across years.

Season	State	Sex	*n*	$\bar{x}$	SE	Range
Breeding	CO	F	18	45.3	4.2	17.6 – 85.6
		M	2	79.1	13.4	65.7, 92.4
		Combined	20	48.7	4.6	17.6 – 92.4
	KS	F	11	65.9	8.7	28.4 – 111.2
		M	9	73.7	4.4	54.4 – 94.2
		Combined	20	69.4	5.1	28.4 – 111.2
	Study Area	F	29	53.1	4.5	17.6 – 111.2
		M	11	74.7	4.0	54.4 – 94.2
		Combined	40	59.0	3.8	17.6 – 111.2
Nonbreeding	CO	F	1	95.3*	-	-
		M	1	73.2*	-	-
		Combined	2	84.2	11.1	73.2 – 95.3
	KS	F	1	113.8*	-	-
		M	11	95.5	26.0	24.5 – 263.4
		Combined	12	97.1	23.8	24.5 – 263.4
	Study Area	F	2	104.6	9.3	95.3, 113.8
		M	12	93.7	23.8	24.5 – 263.4
		Combined	14	95.2	20.3	24.5 – 263.4
Total Study Period	CO	F	22	107.1	8.4	29.9 – 187.8
		M	7	140.7	17.8	97.6 – 235.3
		Combined	29	115.2	8.0	29.9 – 235.3
	KS	F	12	131.1	18.2	52.0 – 245.5
		M	23	144.1	24.3	26.4 – 571.6
		Combined	35	139.7	17.0	26.4 – 571.6
	OK	F	1	65.0*	-	-
	Study Area	F	35	114.2	8.4	30.0 – 245.5
		M	30	143.3	18.9	26.4 – 571.6
		Combined	65	127.6	9.9	26.4 – 571.6

*Only a single birds in category – unable to estimate mean, SE, or range

Table 2.2 Average 95% isopleth of Biased Random Bridge Movement Model home range (ha) of SAT-PTT equipped male and female translocated lesser prairie-chickens to the U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020. Estimates are stratified by sex (Male, Female), season (Breeding, Nonbreeding, Total Study Period) and states (CO, KS, OK), but pooled across years.

Season	State	Sex	*n*	$\bar{x}$	SE	Range
Breeding	CO	F	19	322.8	74.1	98.3 – 1339.3
		M	11	375.1	108.5	68.5 – 1409.4
		Combined	30	342.0	60.6	68.5 – 1409.4
	KS	F	33	478.1	83.2	27.4 – 1975.1
		M	20	342.8	48.3	96.9 – 770.0
		Combined	53	427.0	55.3	27.4 – 1975.1
	OK	F	5	577.5	214.7	189.2 – 1415.1
	Study Area	F	57	435.1	57.4	27.3 – 1975.1
		M	31	354.3	48.5	68.5 – 1409.4
		Combined	88	406.6	40.9	27.4 – 1975.1
Nonbreeding	CO	F	8	213.8	57.2	26.1 – 489.0
		M	3	464.2	110.9	253.9 – 630.3
		Combined	11	282.1	59.8	26.1 – 630.3
	KS	F	17	314.7	48.1	37.2 – 672.1
		M	12	4328	84.6	29.6 – 968.8
		Combined	29	363.6	45.4	29.6 – 968.8
	OK	F	1	242.8*	-	-
	Study Area	F	26	280.9	36.6	26.1 – 672.1
		M	15	439.1	69.7	29.6 – 968.8
		Combined	41	338.7	36.0	26.1 – 968.8
Total Study Period	CO	F	20	424.0	99.8	26.0 – 1751.3
		M	11	429.6	109.8	68.5 – 1409.4
		Combined	31	425.9	74.1	26.0 – 1781.3
	KS	F	36	433.5	65.7	27.4 – 1975.1
		M	23	416.4	53.3	98.5 – 873.2
		Combined	59	426.8	44.8	27.4 – 1975.1
	OK	F	5	610.4	202.4	327.0 – 1415.1
	Study Area	F	61	444.8	52.8	26.0 – 1975.1
		M	34	420.6	49.6	68.5 – 1409.4
		Combined	95	436.2	38.1	26.0 – 1975.1

*Only a single birds in category – unable to estimate mean, SE, or range

Table 2.3 Percent of estimated home ranges delineated by sex (M, F), state (KS, CO, OK), and overall that contain an individual cover type. Home ranges are from lesser prairie-chickens marked with very-high-frequency (VHF) and SAT-PTT transmitters and translocation to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019. Cover types include, cropland, Conservation Reserve Program (CRP), non-CRP grassland (private rangeland), U.S. Forest Service (public land), and other (developed land [i.e., roads]).

Group	***n***	Cover Type				
		CRP	**USFS**	**Non-CRP Grassland**	**Crop**	**Other**
Overall	344	93	59	79	89	50
Sex						
F	210	85	53	73	89	37
M	133	95	32	82	99	34
State						
KS	208	93	66	83	93	40
CO	123	85	52	64	93	72
OK	8	75	0	100	88	0

Table 2.4 Breeding season (Mar 15 – Sep 15) average percent cover of cropland, Conservation Reserve Program (CRP), non-CRP grassland (private rangeland), U.S. Forest Service (public land) and other (developed land [i.e., roads]) within home ranges estimated for male, female, and combined lesser prairie-chickens marked with very-high-frequency (VHF) and SAT-PTT transmitters and translocation to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2020.

				% CRP	% USFS	% Non-CRP Grassland	% Crop	% Other
Transmitter	**State**	**Sex**	***n***	$\bar{x}$ **± SE**	$\bar{x}$ **± SE**	$\bar{x}$ **± SE**	$\bar{x}$ **± SE**	$\bar{x}$ **± SE**
VHF	CO	F	18	54.0 ± 8.8	37.2 ± 9.6	2.2 ± 1.3	6.4 ± 1.7	0.3 ± 0.2
		M	2	0	89.9 ± 4.9	0	10.1 ± 4.9	0
		Combined	20	48.6 ± 8.7	42.5 ± 9.4	2.0 ± 1.2	6.7 ± 1.6	0.3 ± 0.2
	KS	F	11	54.5 ± 8.9	25.2 ± 9.6	3.7 ± 1.2	16.4 ± 3.6	0.3 ± 0.3
		M	9	63.4 ± 7.2	13.8 ± 5.0	2.7 ± 0.9	20.1 ± 4.7	0
		Combined	20	58.5 ± 5.8	20.0 ± 5.8	3.2 ± 0.8	18.1 ± 2.8	0.1 ± 0.1
	Study Area	F	29	54.1 ± 6.3	32.6 ± 6.9	2.8 ± 0.9	10.2 ± 1.9	0.3 ± 0.2
		M	11	51.9 ± 9.7	27.6 ± 10.2	2.2 ± 0.8	18.3 ± 4.0	0
		Combined	40	53.5 ± 5.2	31.2 ± 5.7	2.6 ± 0.7	12.4 ± 1.8	0.2 ± 0.1
SAT-PTT	CO	F	19	42.9 ± 8.0	27.4 ± 8.8	3.8 ± 1.2	25.6 ± 4.1	0.2 ± 0.1
		M	11	19.2 ± 8.8	43.1 ± 11.9	6.9 ± 2.8	30.7 ± 8.1	0.1 ± 0.02
		Combined	30	34.2 ± 6.3	33.2 ± 7.1	5.0 ± 1.3	27.5 ± 3.9	0.1 ± 0.1
	KS	F	33	34.3 ± 4.4	32.5 ± 7.2	10.2 ± 3.7	22.6 ± 3.2	0.3 ± 0.1
		M	20	45.8 ± 4.1	16.9 ± 5.9	4.6 ± 0.9	32.5 ± 3.9	0.3 ± 0.1
		Combined	53	38.7 ± 3.2	26.6 ± 5.1	8.1 ± 2.4	26.3 ± 2.5	0.3 ± 0.1
	OK	F	5	23.3 ± 14.5	0	62.0 ± 14.6	14.4 ± 5.5	0.3 ± 0.2
	Study Area	F	57	36.2 ± 3.9	28.0 ± 5.2	12.6 ± 3.2	22.9 ± 2.3	0.3 ± 0.1
		M	31	36.3 ± 4.6	26.2 ± 6.0	5.4 ± 1.1	31.9 ± 3.7	0.2 ± 0.1
		Combined	88	36.3 ± 3.0	27.3 ± 3.9	10.1 ± 2.2	26.1 ± 2.0	0.3 ± 0.1

*Only a single birds in category – unable to estimate mean or SE

Table 2.5 Nonbreeding season (Sep 16 – Mar 14) average percent cover of cropland, Conservation Reserve Program (CRP), non-CRP grassland (private rangeland), U.S. Forest Service (public land) and other (developed land [i.e., roads]) within home ranges estimated for male, female, and combined lesser prairie-chickens marked with very-high-frequency (VHF) and SAT-PTT transmitters and translocation to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2020.

				% CRP	% USFS	% Non-CRP Grassland	% Crop	% Other
Transmitter	**State**	**Sex**	***n***	**$\bar{x}$ ± SE**	**$\bar{x}$ ± SE**	**$\bar{x}$ ± SE**	**$\bar{x}$ ± SE**	**$\bar{x}$ ± SE**
VHF	CO	F	1	58.5*	0*	0.2*	41.2*	0*
		M	1	85.7*	0*	0*	14.3*	0*
		Combined	2	72.1 ± 13.6	0	0.1 ± 0.1	27.8 ± 13.5	0
	KS	F	1	38.5*	42.7*	1.8*	38.5*	0*
		M	11	67.4 ± 7.4	11.4 ± 4.5	0.7 ± 0.4	20.3 ± 4.1	0.3 ± 0.2
		Combined	12	63.2 ± 7.9	14.0 ± 4.9	0.8 ± 0.4	21.8 ± 4.1	0.3 ± 0.2
	Study Area	F	2	37.7 ± 20.8	21.4 ± 21.4	1.0 ± 0.8	39.9 ± 1.4	0
		M	12	68.9 ± 6.9	10.4 ± 4.25	0.6 ± 0.4	19.8 ± 3.8	0.3 ± 0.2
		Combined	14	64.5 ± 7.0	12.0 ± 4.4	0.7 ± 0.3	22.6 ± 3.8	0.2 ± 0.2
SAT-PTT	CO	F	8	38.8 ± 14.2	22.7 ± 14.9	10.0 ± 9.8	28.6 ± 10.2	0
		M	3	26.7 ± 26.3	58.8 ± 29.4	0.2 ± 0.1	14.4 ± 3.3	0
		Combined	11	35.5 ± 12.0	32.5 ± 13.7	7.3 ± 7.1	24.7 ± 7.6	0
	KS	F	17	42.0 ± 4.7	13.9 ± 5.6	20.1 ± 6.0	23.5 ± 4.0	0.5 ± 0.2
		M	12	56.3 ± 3.7	13.7 ± 5.0	6.2 ± 3.3	23.5 ± 3.0	0.3 ± 0.1
		Combined	29	47.9 ± 3.4	13.9 ± 3.8	14.3 ± 3.9	23.5 ± 2.6	0.4 ± 0.1
	OK	F	1	49.3*	0*	7.2*	43.5*	0*
	Study Area	F	26	41.3 ± 5.2	16.1 ± 5.8	16.5 ± 4.9	25.8 ± 4.0	0.3 ± 0.1
		M	15	50.4 ± 6.2	22.7 ± 8.0	5.0 ± 2.7	21.7 ± 2.6	0.2 ± 0.1
		Combined	41	44.6 ± 4.0	18.5 ± 4.7	12.3 ± 3.4	24.3 ± 2.7	0.3 ± 0.1

*Only a single birds in category – unable to estimate mean or SE

Table 2.6 Total study period (2017 – 2020) average percent cover of cropland, Conservation Reserve Program (CRP), non-CRP grassland (private rangeland), U.S. Forest Service (public land) and other (developed land [i.e., roads]) within home ranges estimated for male, female, and combined lesser prairie-chickens marked with very-high-frequency (VHF) and SAT-PTT transmitters and translocation to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2020.

				% CRP	% USFS	% Non-CRP Grassland	% Crop	% Other
Transmitter	**State**	**Sex**	***n***	**$\bar{x}$ ± SE**	**$\bar{x}$ ± SE**	**$\bar{x}$ ± SE**	**$\bar{x}$ ± SE**	**$\bar{x}$ ± SE**
VHF	CO	F	22	49.9 ± 7.9	37.6 ± 8.6	1.6 ± 0.8	10.6 ± 2.1	0.3 ± 0.2
		M	7	46.64 ± 16.7	40.1 ± 18.4	0.1 ± 0.02	13.2 ± 3.2	0.1 ± 0.1
		Combined	29	49.1 ± 7.1	38.2 ± 7.7	1.2 ± 1.0	11.3 ± 1.8	0.2 ± 0.1
	KS	F	12	51.0 ± 8.5	23.7 ± 8.3	7.5 ± 3.8	17.5 ± 4.0	0.2 ± 0.2
		M	23	68.3 ± 4.2	10.3 ± 3.1	4.4 ± 1.3	16.9 ± 2.6	0.1 ± 0.1
		Combined	35	62.4 ± 4.2	14.9 ± 3.6	5.5 ± 1.6	17.1 ± 2.2	0.1 ± 0.1
	OK	F	1	71.8*	0*	28.2*	0*	0*
	Study Area	F	35	50.9 ± 5.7	31.8 ± 6.2	4.4 ± 1.6	12.7 ± 2.0	0.2 ± 0.1
		M	30	63.3 ± 5.2	17.2 ± 5.2	3.4 ± 1.1	16.0 ± 2.1	0.1 ± 0.05
		Combined	65	56.6 ± 3.9	25.1 ± 4.2	3.9 ± 1.0	14.2 ± 1.5	0.2 ± 0.1
SAT-PTT	CO	F	20	42.9 ± 7.5	26.3 ± 8.5	3.7 ± 1.2	26.9 ± 4.1	0.3 ± 0.1
		M	11	18.9 ± 8.7	43.6 ± 12.4	6.14 ± 2.8	31.3 ± 7.9	0
		Combined	31	34.4 ± 6.0	32.4 ± 7.1	4.6 ± 1.2	28.4 ± 3.8	0.2 ± 0.1
	KS	F	36	36.3 ± 4.0	28.4 ± 6.5	11.2 ± 3.4	23.7 ± 2.9	0.3 ± 0.1
		M	23	49.2 ± 3.5	15.0 ± 5.2	5.7 ± 1.7	29.8 ± 3.3	0.3 ± 0.1
		Combined	59	41.3 ± 2.9	23.2 ± 4.5	9.1 ± 2.2	26.1 ± 2.2	0.3 ± 0.1
	OK	F	5	21.4 ± 11.9	0	60.6 ± 15.2	17.8 ± 6.3	0.3 ± 0.2
	Study Area	F	61	37.2 ± 3.5	25.4 ± 4.8	12.8 ± 3.0	24.3 ± 2.2	0.3 ± 0.1
		M	34	39.4 ± 4.4	24.3 ± 5.7	5.8 ± 1.4	30.3 ± 3.3	0.2 ± 0.1
		Combined	95	38.0 ± 2.7	25.0 ± 3.7	10.3 ± 2.02	26.4 ± 1.9	0.3 ± 0.1

*Only a single birds in category – unable to estimate mean or SE

Figures

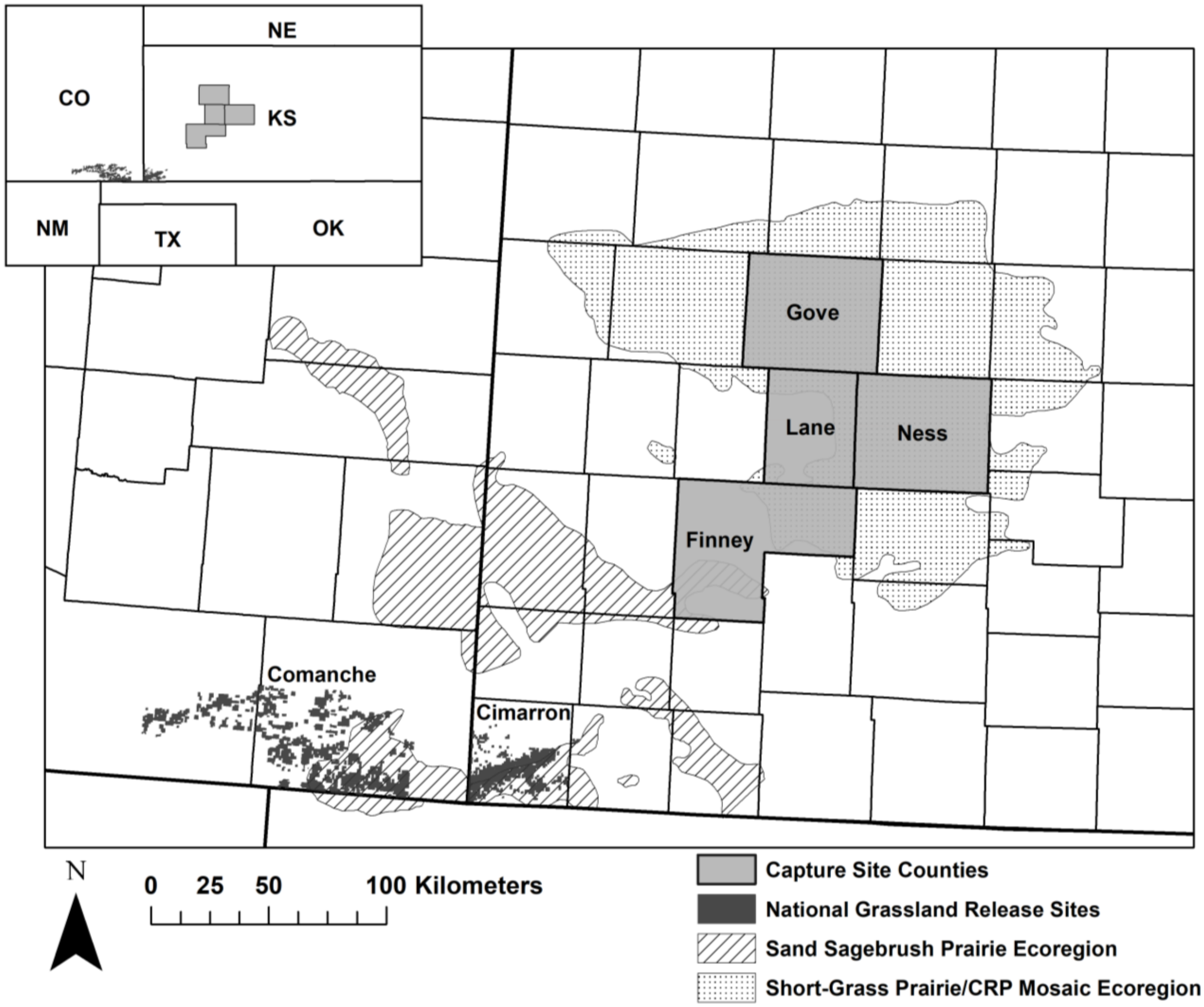

Figure 2.1 Locations of four capture counties (Gove, Lane, Ness, and Finney) in Kansas, USA, where lesser prairie-chickens were trapped on leks and released on the U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019, shown in dark gray. The capture site leks were in the Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion and release sites were in the Sand Sagebrush Prairie Ecoregion of the lesser prairie-chicken range.

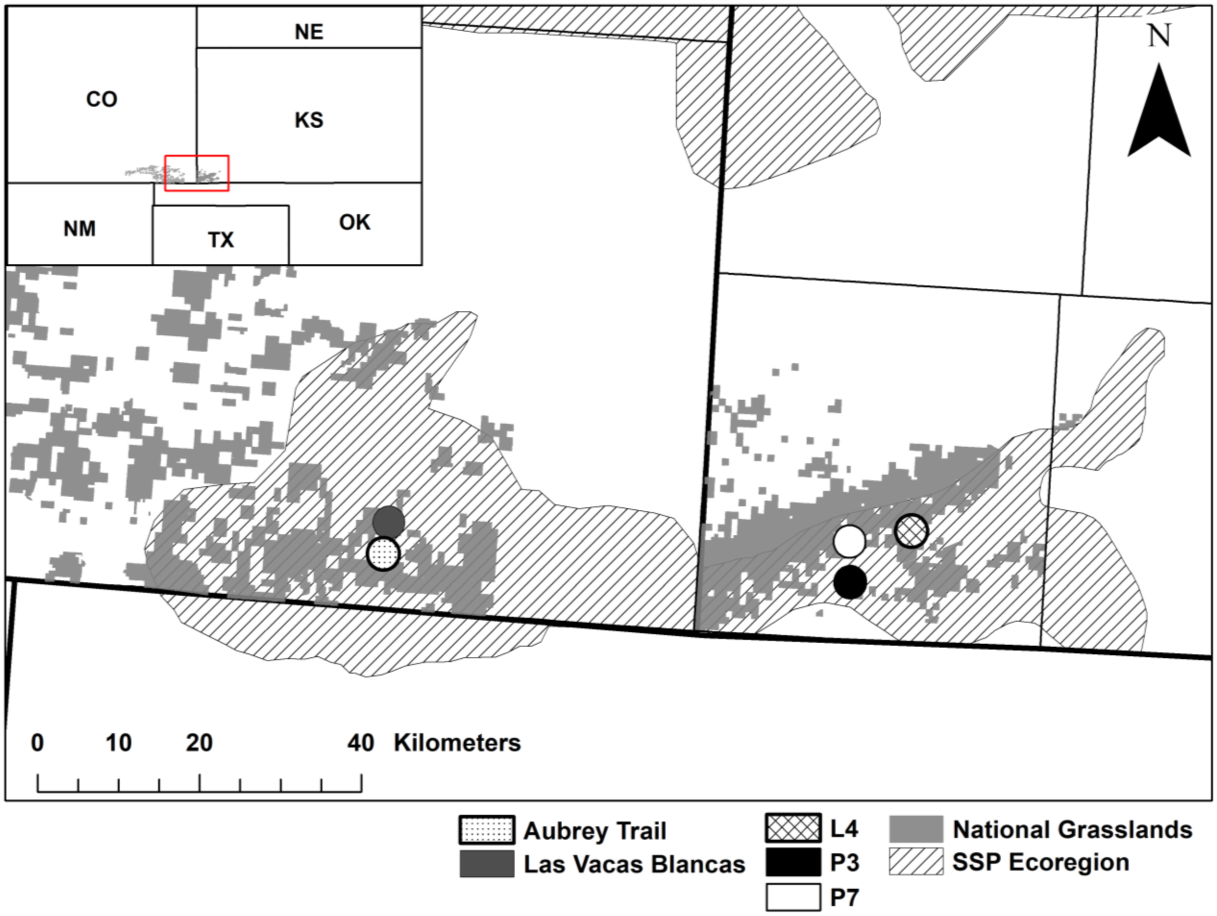

Figure 2.2 Locations of release sites (either active or historic leks) on the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas (KS) and Colorado (CO), USA, respectively, during 2016-2019 in the Sand Sagebrush Prairie Ecoregion (SSP). Release sites were utilized as follows: CO Aubrey Trail (2016-2017) and Las Vacas Blancas (2018-2019); KS L4 (2019), P3 (2016-2018), and L7 (2018). Locations are buffered by a 2-km radius.

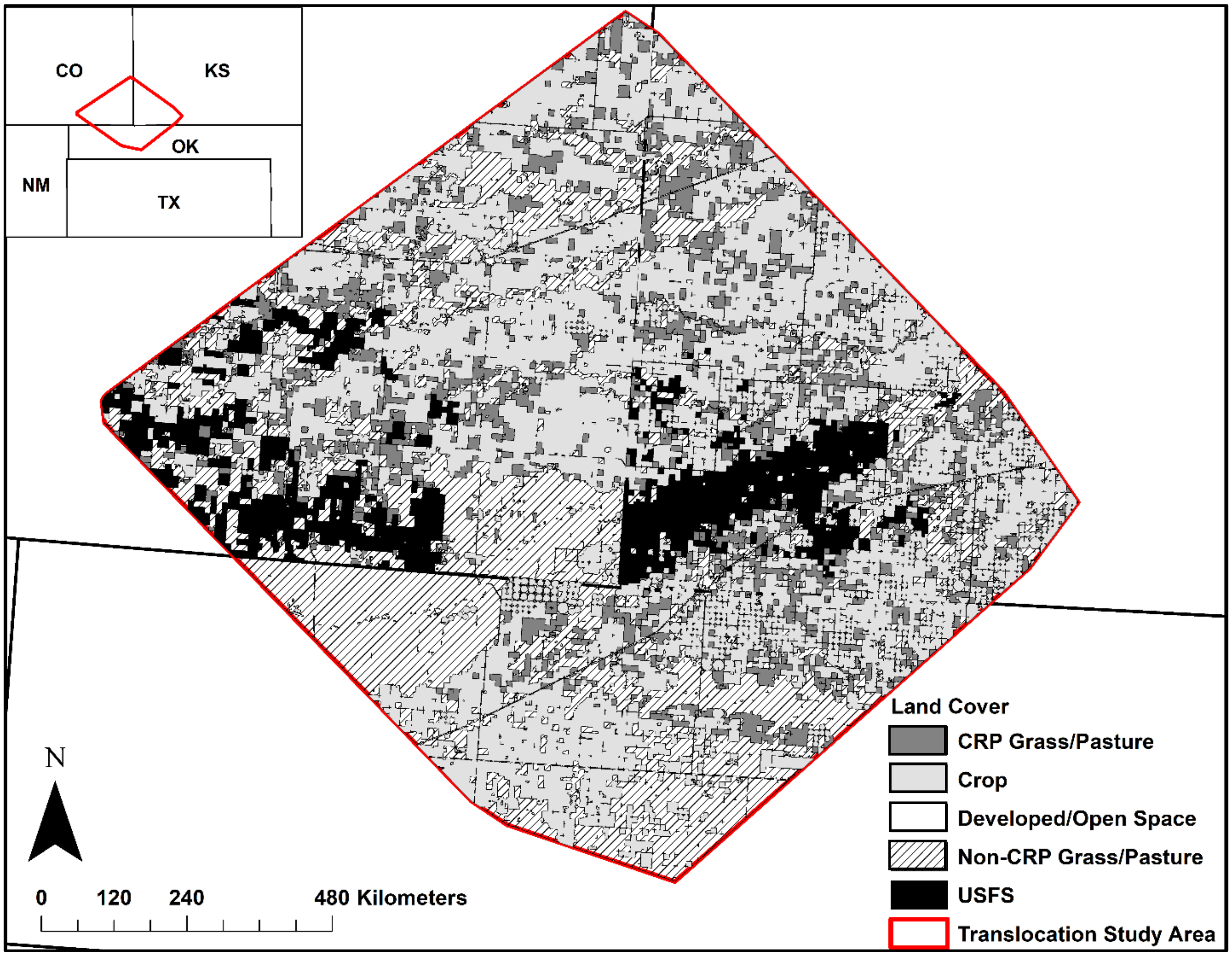

Figure 2.3 The study area in Kansas, Colorado, and Oklahoma, USA, detailing the extent of dominant land cover types encountered by dispersing and settling lesser prairie-chickens translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2021. Cover types include CRP Grass/Pasture (Conservation Reserve Program fields), crop, developed/open space (urban, water, wooded, etc.), Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO).

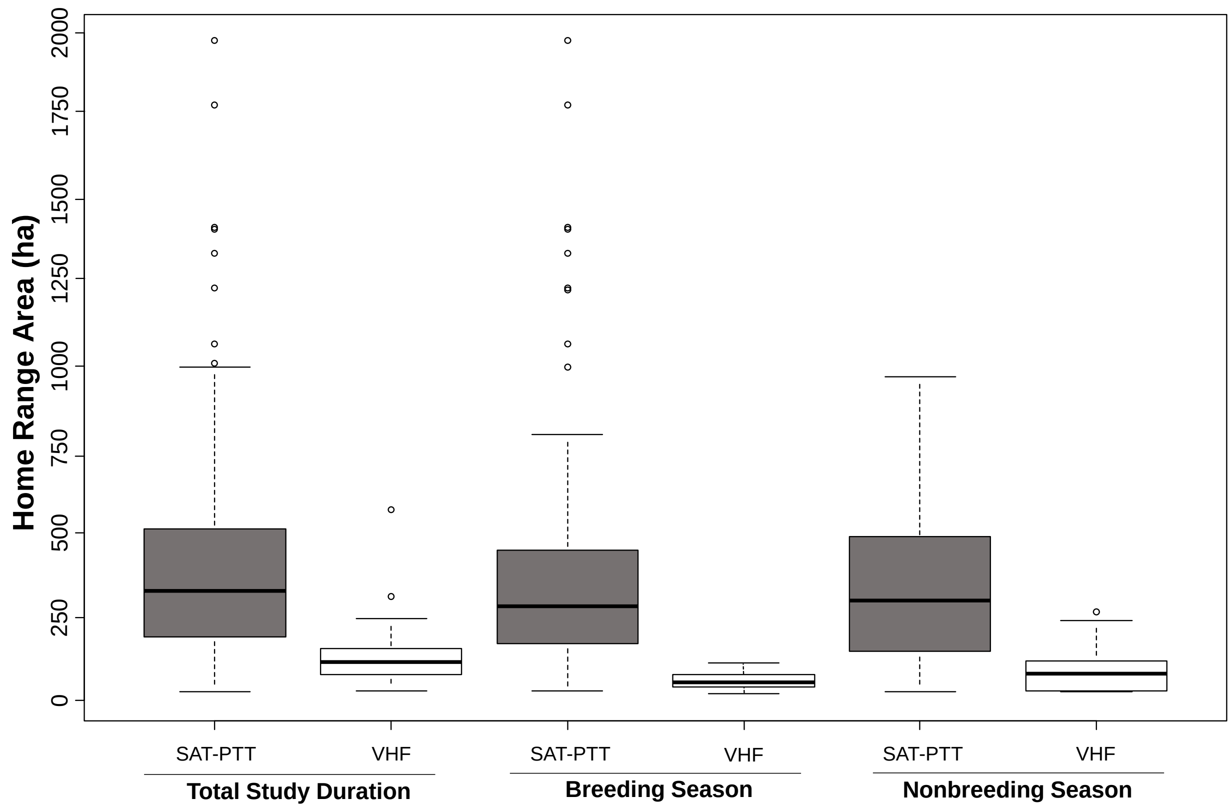

Figure 2.4 Boxplot depicting the variation of home range sizes (ha) by transmitter type (VHF, SAT-PTT) and time period (Breeding, Nonbreeding, Total Study Duration) for translocated lesser prairie-chickens released on the U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020. Dark solid horizontal line = median, box outline = 25%-75% interquartile range, dashed line whiskers = min and max, and small circles = outliers.

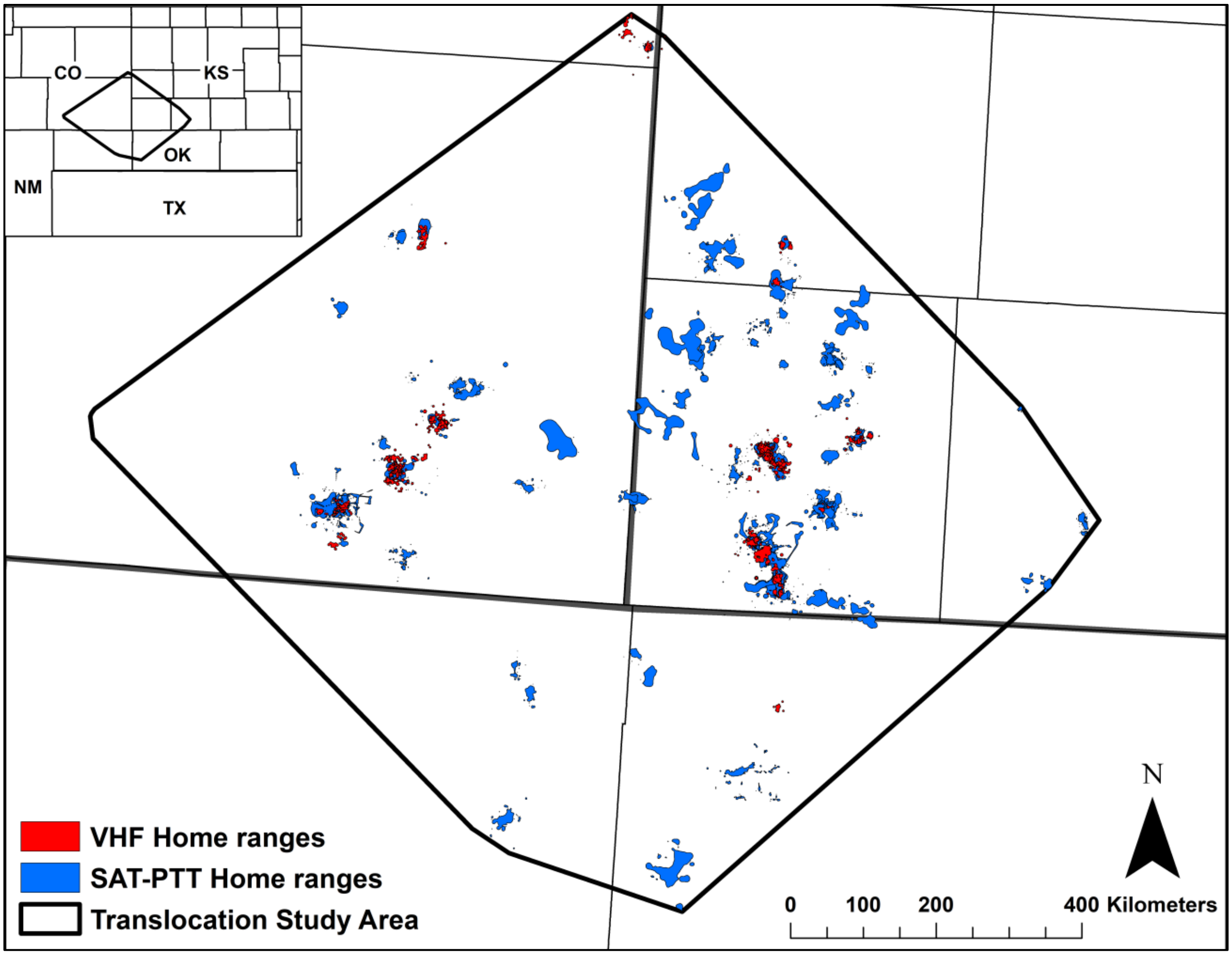

Figure 2.5 The study area in Kansas, Colorado, and Oklahoma, USA, detailing the extent of home ranges by VHF and SAT-PTT marked lesser prairie-chickens translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2017-2020.

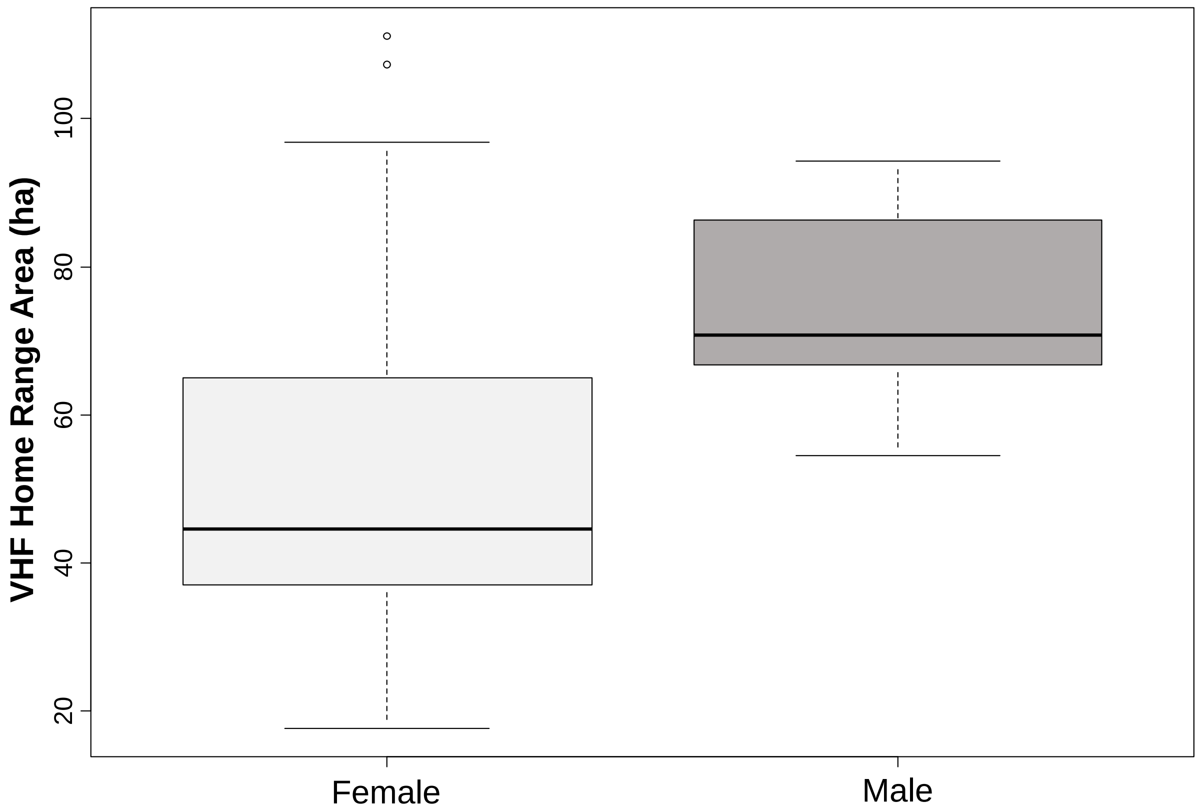

Figure 2.6 Boxplot depicting the variation of breeding season home range sizes (ha) of VHF- marked female (n = 29) and male (n = 11) translocated lesser prairie-chickens released on the U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020. Dark solid horizontal line = median, box outline = 25%-75% interquartile range, dashed line whiskers = min and max, and small circles = outliers.

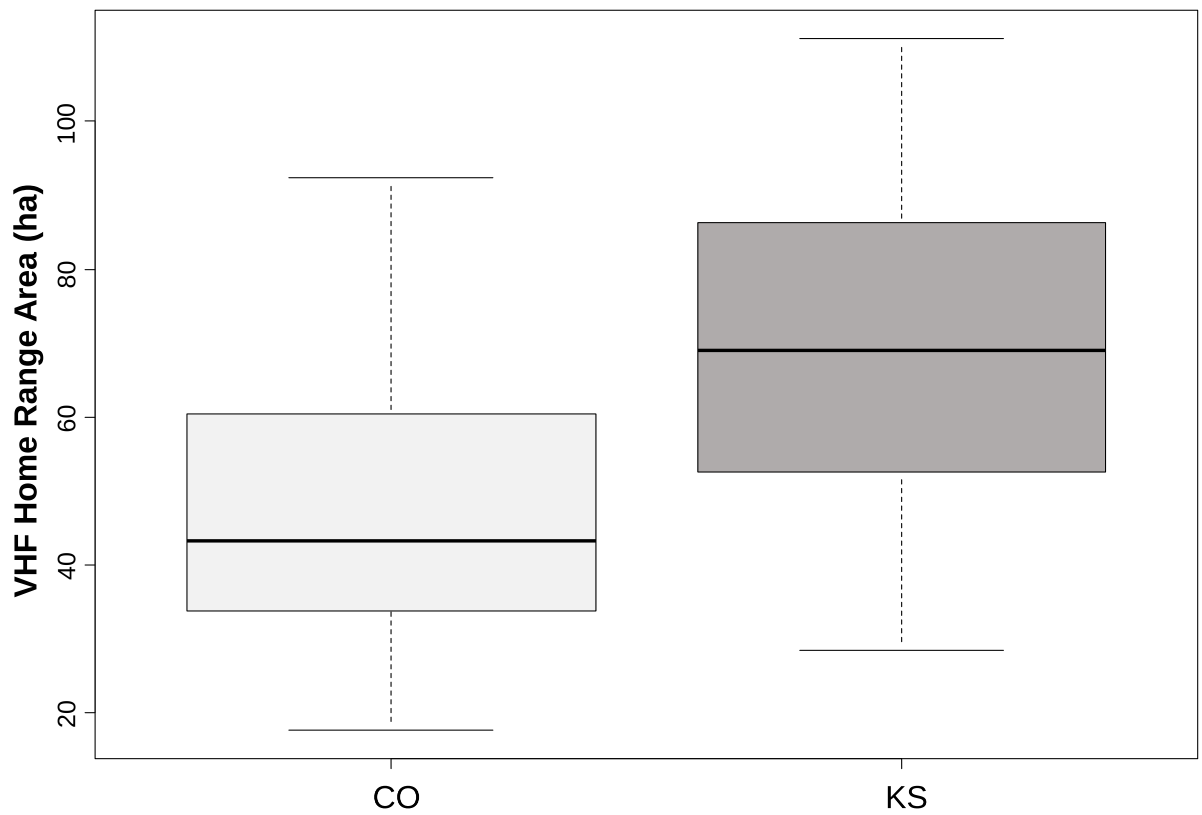

Figure 2.7 Boxplot depicting the variation of breeding season home range sizes (ha) of VHF- marked translocated lesser prairie-chickens between Colorado (CO; n = 20) and Kansas (KS; n = 20) released on the U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020. Dark solid horizontal line = median, box outline = 25%-75% interquartile range, dashed line whiskers = min and max, and small circles = outliers.

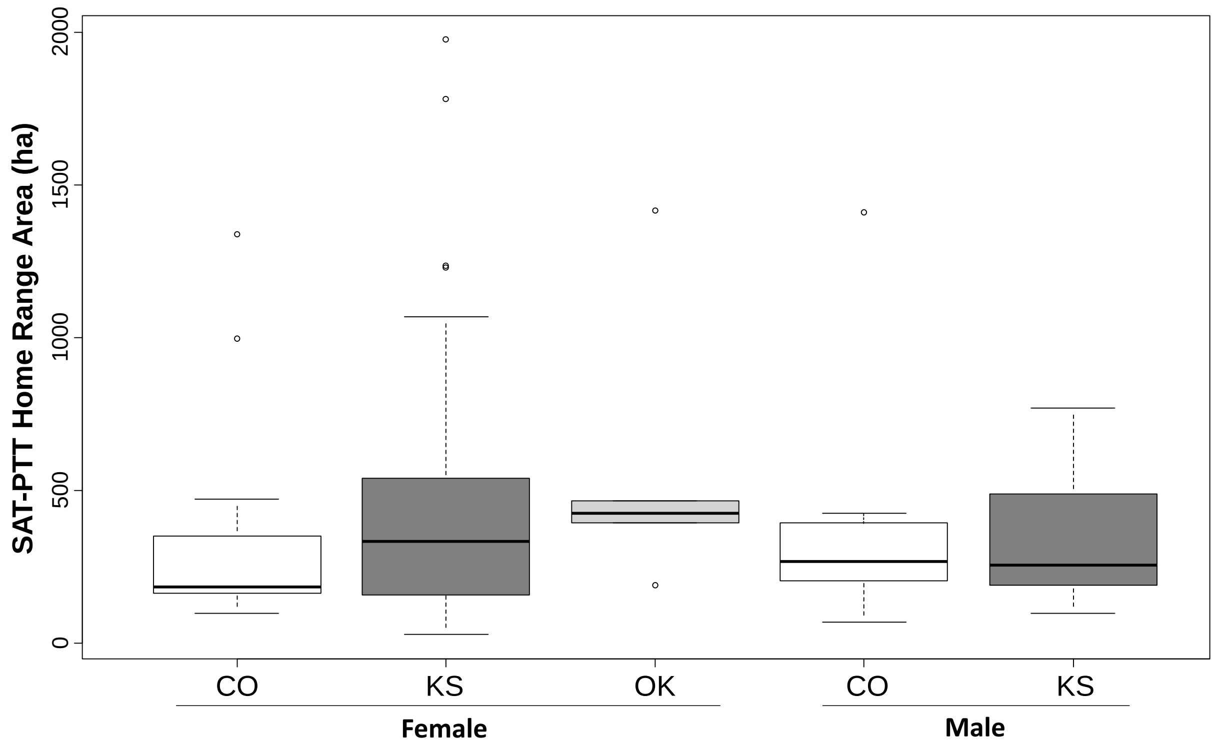

Figure 2.8 Boxplot depicting the variation of breeding season home range area (ha) of SAT-PTT-marked translocated male and female lesser prairie-chickens between Colorado (CO), Kansas (KS), and Oklahoma released on the U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2017-2020. Note there were no male breeding season home ranges in Oklahoma. Dark solid horizontal line = median, box outline = 25%-75% interquartile range, dashed line whiskers = min and max, and small circles = outliers.

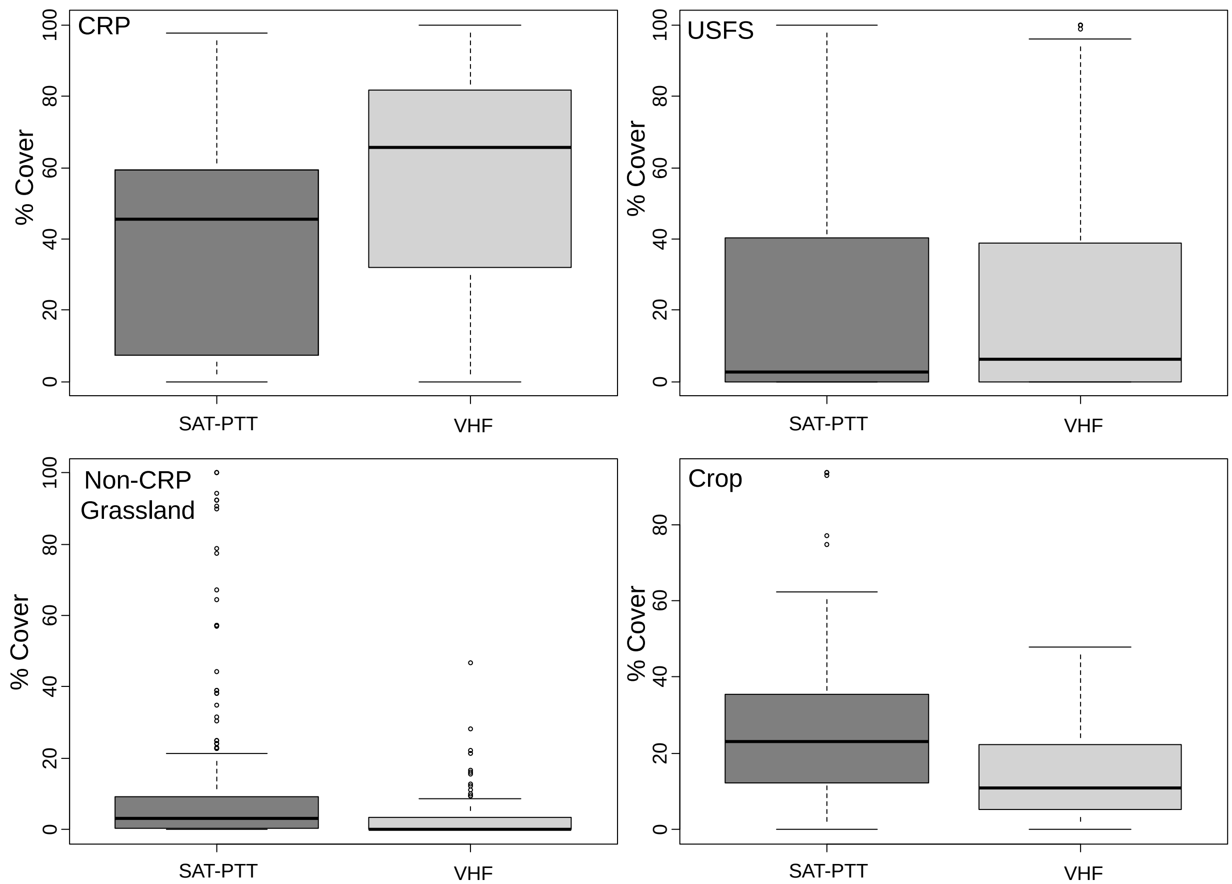

Figure 2.9 Boxplots depicting the variation of all within-home range percent land cover type of SAT-PTT and VHF-marked translocated lesser prairie-chickens released on the U.S. Forest Service, Cimarron and Comanche National Grasslands in Kansas and Colorado, USA, respectively, from 2017-2020. Land cover types are Conservation Reserve Program (CRP), U.S. Forest Service public land (USFS), Non-CRP grassland (private land), and cropland (Crop). Dark solid horizontal line = median, box outline = 25%-75% interquartile range, dashed line whiskers = min and max, and small circles = outliers.

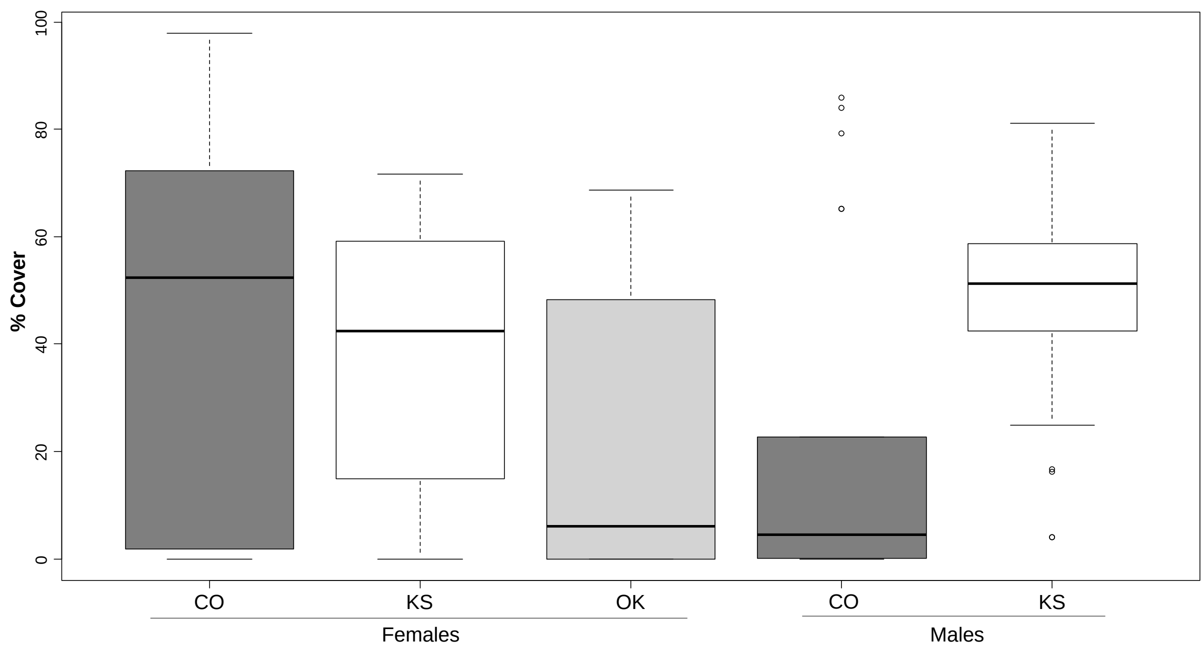

Figure 2.10 Boxplot depicting the variation of within-home range percent CRP (Conservation Reserve Program) of SAT-PTT-marked translocated lesser prairie-chickens between states (CO, KS, OK) and sexes (Male , Female) released on the U.S. Forest Service, Cimarron and Comanche National Grasslands in Kansas and Colorado, USA, respectively, during 2016-2019. Males in Kansas had significantly more CRP in their home ranges on average than other groups. Percent CRP in their home ranges differed between sexes in Colorado. Note: No males established home ranges in Oklahoma. Dark solid horizontal line = median, box outline = 25%-75% interquartile range, dashed line whiskers = min and max, and small circles = outliers.

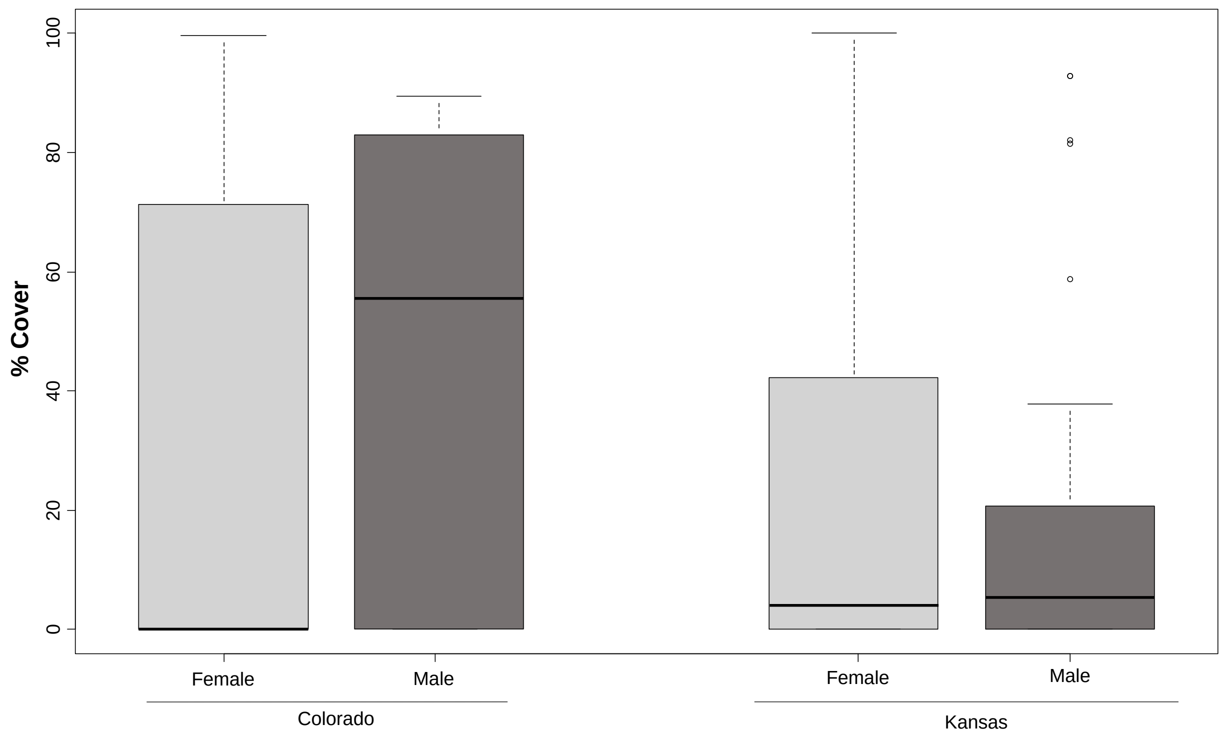

Figure 2.11 Boxplot depicting the variation of within home range percent U.S. Forest Service land of female and male SAT-PTT-marked translocated lesser prairie-chickens in Colorado that were released on the U.S. Forest Service, Cimarron and Comanche National Grasslands in Kansas and Colorado, USA, respectively, during 2016-2019. Females and Males in Colorado had significantly different percent of U.S. Forest Service land in their home ranges. Dark solid horizontal line = median, box outline = 25%-75% interquartile range, dashed line whiskers = min and max, and small circles = outliers.

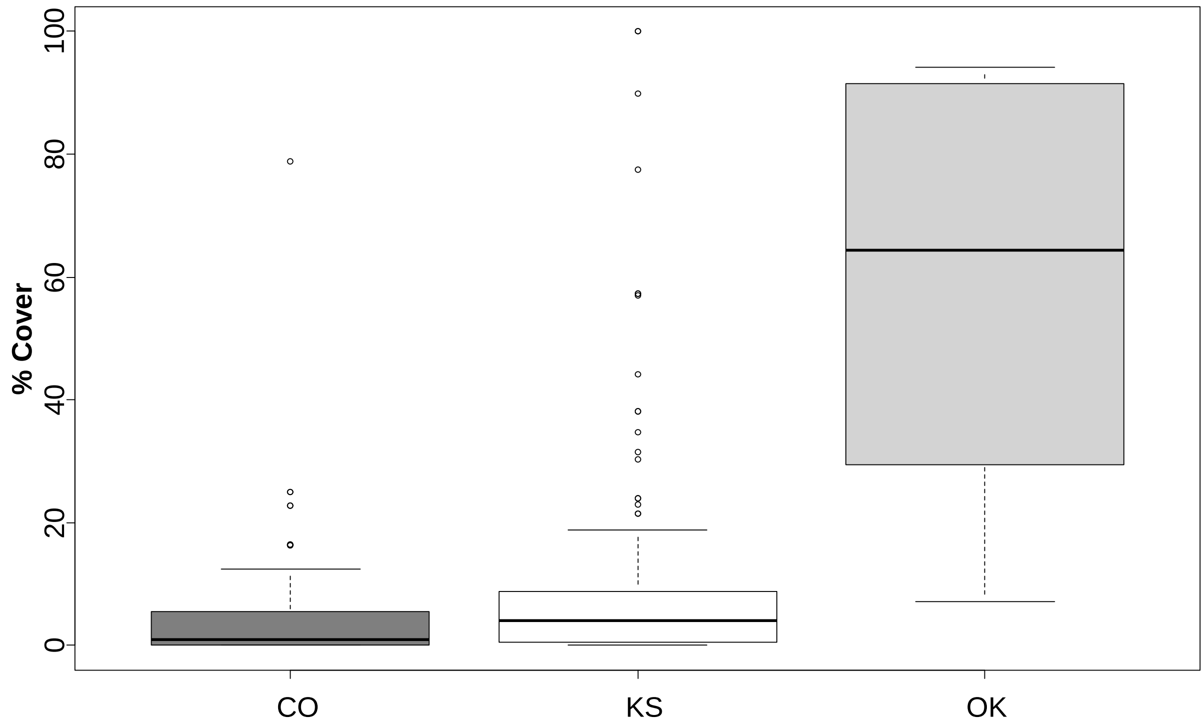

Figure 2.12 Boxplot depicting the variation of within home range percent Non-CRP grassland (private land) of SAT-PTT-marked translocated lesser prairie-chickens among states (CO, KS, OK) that were released on the U.S. Forest Service, Cimarron and Comanche National Grasslands in Kansas and Colorado, USA, respectively, during 2016-2019. Dark solid horizontal line = median, box outline = 25%-75% interquartile range, dashed line whiskers = min and max, and small circles = outliers.

Chapter 3 - Translocated lesser prairie-chicken vegetation characteristic resource selection within local and landscape scales

Introduction

The study of habitat use and selection has been on ongoing area of study in the wildlife field for over a century (Grinnell 1917, Kendeigh 1945, Svärdson 1949, Hildén 1965, Block and Brennan 1993). Resource selection is an important tool for understanding population dynamics and species distributions. Animals distinguish among patches to minimize risk of predation and select for key resources to maximize their fitness (Fretwell and Lucas 1970, Whitham 1980 Block and Brennan 1993, Jones 2001). Resources selected by individuals within a landscape are often used as an index of habitat quality (Cody 1985, Johnson 2007). Although resource selection can be a useful tool for identifying and conserving high-quality habitat, it depends on a variety of intrinsic and extrinsic factors. Intrinsic features such as sex, breeding status, or age also determine resource needs of individuals (Dorbney and Fredrickson 1979, Thurfjell et al. 2017, Zurrell et al. 2018, Yang et al. 2021). Extrinsic factors such as precipitation, temperature, duration of growing seasons, landscape composition and configuration, and anthropogenic effects can all directly affect the availability of resources to an animal (Brown et al. 1994, Igl and Johnson 1999, Street et al. 2015, Plumb et al. 2019, Sullins et al. 2019, Parker et al. 2021). Variation in habitat quality then influences persistence and densities of local populations (Pidgeon et al. 2006, Doherty et al. 2010). Therefore, resource selection is especially important for species in a novel landscape. As an individual moves into a new environment, through dispersal movements, immigration, or by management intervention, they are forced to undertake rapid and usually uniformed decisions regarding space use. As such translocation, provides a unique opportunity to examine factors that influence habitat selection by species in a new area.

Translocation is the deliberate movement of organisms from one site to another where the main objective is a conservation benefit (IUCN/SSC 2013).Translocations are used frequently as a management tool to restore or augment wildlife populations, but are not novel approaches to wildlife conservation (Scott and Carpenter 1987). Historically, translocations have varying degrees of success as conservation strategies (Seddon et al. 2014, Hoffmann et al. 2015). Many species of wildlife have been either translocated or reintroduced into formally occupied range, including bighorn sheep (*Ovis canadensis*), muskrats (*Ondatra zibethicus*), greater sage-grouse (*Centrocercus urophasianus)*, yellow-legged frogs (*Rana muscosa*), Canada geese (*Branta canadensis*), and western swamp turtle (*Pseudemydura umbrina*) among others (Reese and Connelly 1997, Mitchell et al. 2016, Werdel and Jenks 2018, Calatayud et al. 2020, Matykiewicz et al. 2021, Malanchuk et al. 2021). Often following translocation, when an animal is introduced to a novel environment, there are unexpected changes to habitat use. However, it can be difficult to assess differences in expected habitat use and resource selection among translocated individuals due to lack of comparative data among natal origins and post-translocation release. Especially when translocations are sourced from captive-bred populations. These common translocation source population limitations, coupled with many poorly documented translocations following release can exacerbate the lack of understanding needed to assess resource selection in a novel landscape by translocated populations.

To understand resource selection following a translocation effort, it is necessary to use a hierarchal approach to understand how selection at multiple scales influences where animals settle following translocation. At a landscape scale, it is important to document relative use of available habitat patches that determines where home ranges are established and how that structures distribution of translocated individuals in the novel landscape (2^{nd} order selection;

Johnson 1980). Within cover types comprising home ranges, it is necessary to understand factors influencing selection of frequently used habitat types or patches and areas within these patches by testing for selection of finer-scale resources and physical characteristics that may make patches quality habitat (3^{rd} and 4^{th} order selection; Johnson 1980). Translocations are often undertaken for species of conservation concern to augment low density populations of, so it is necessary to examine multiple levels of resource selection to ensure detection of factors that could operate at broad or fine-scales to influence translocation success (Griffith et al. 1989, Wolf et al. 1996, Stamps and Swaisgood 2007, Le Gouar et al. 2012). Understanding differing levels of selection is important for determining how individual animals and populations use a novel landscape as it may lack the presence of conspecifics and other known cues that can influence selection (Ahlering and Faaborg 2006, Aulicky 2020). Knowledge of selection at broad and local scales may help in explaining the success or failure of a translocation, and give managers valuable insights about what habitat types may be lacking on the landscape or need to be improved.

The lesser prairie-chicken (*Tympanuchus pallidicintus*) is a prairie grouse that has been translocated several times in past. The first and previously largest published lesser prairie-chicken translocation took place in 1933, when 300 birds from Ellis County, Oklahoma, were translocated to 15 sites within the state (Duck and Fletcher 1943, Horton 2000). However, none of these translocations were successful in establishing a lesser prairie-chicken population. Since then, there have been at least 10 attempts to translocate lesser prairie-chickens, and only one was noted to be successful (Rodgers 2016). Factors influencing translocation success include animal behavior, habitat quality, and the ability to accurately monitor translocated individuals (Berger-Tal et al. 2020). While previous lesser-prairie chicken translocations may not have considered all these factors, following this strategy will be key to a successful translocation for lesser prairie-chickens.

The lesser prairie-chicken is found in the southwestern Great Plains of the United States and currently occurs in four distinct ecoregions (Short-Grass Prairie/CRP Mosaic, Mixed-Grass Prairie, Sand Sagebrush Prairie, and Sand Shinnery Oak Prairie) across five states (Kansas, Colorado, Oklahoma, Texas, and New Mexico, USA; McDonald et al. 2014; Figure 1.1). Occupied areas within these ecoregions are broadly described as semi-arid with abundant sandy soils and native shrubs including sand sagebrush *(Artemisia filifolia*) and sand shinnery oak (*Quercus havardii*) or mixed to tall grasses (Haukos and Zavaleta 2016, Spencer et al. 2017). Lesser prairie-chickens breed on areas defined as leks where males gather from March - May, display, and often defend territories to attract females for mating. Females then initiate nests, incubate a clutch, and then provide uniparental care for any hatched chicks.

Recent estimates suggest that the lesser prairie-chicken currently occupies only ~15% of their estimated historical range (Boal and Haukos 2016, Rodgers 2016). Within the current occupied range, lesser prairie-chickens have been experiencing moderate to severe population declines (Hagen et al. 2017). Since an estimated contemporary peak of 150,000 birds in the mid-1980s, populations have declined with current estimated population of 34,408 in 2020 (Hagen et al. 2017, Nasman 2020). This decline is attributed to loss of quality habitat through anthropogenic development, unmanaged grazing, invasive plant species, and extensive conversion of native prairie to row-crop agriculture causing loss, fragmentation, and degradation of the quality of remaining habitat (Waddell and Hanzlick 1978). Population declines have been intensified by increasing frequency of severe droughts and extreme weather events (Ross et al. 2016). This has led to the enhanced probability of extirpation, which, coupled with loss of connectivity of among populations, has reduced the capacity of lesser prairie-chickens to occupy large areas of potential habitat (Garton et al. 2016, Hagen et al. 2017). Due to these continued threats, the lesser prairie-chicken has had a history of legal status in consideration for listing as a threatened or endangered species under the 1973 Endangered Species Act. Most recently (May 2021), a ruling has been proposed that would list lesser prairie-chicken as two distinct population segments, where the southern population segment (i.e., Sand Shinnery Oak Prairie Ecoregion) would be listed as endangered and the northern population segment (i.e., other ecoregions) would be listed as threatened with a 4(d) rule that tailors protections for the species (U.S. Fish and Wildlife Service 2021).

The largest contemporary decline in lesser prairie-chicken population abundance and occupied range is occurring in the Sand Sagebrush Prairie Ecoregion. Historically, the Sand Sagebrush Prairie Ecoregion was the epicenter of the lesser prairie-chicken population despite a large amount of the ecoregion's vegetation being decimated during the Dust Bowl of the 1930s. Jensen et al. (2000) reported an estimated high count of >86,000 birds in the ecoregion during the 1970s. More recently, a contemporary high count of ~75,000 was reported in the 1980s, but estimates dropped to ~25,000 birds by the early 2000s (Garton et al. 2016, Hagen et al. 2017). This downward decline has continued with an estimate of only 171 birds in 2020 in the Sand Sagebrush Prairie Ecoregion (Nasman et al. 2020). Hagen et al. (2020) found a high probability of extirpation within five years for the Sand Sagebrush Prairie Ecoregion. However, other ecoregions have not experienced such drastic declines and currently >70% of the extant population occurs primarily in the Short-Grass Prairie/CRP Mosaic and Mixed-Grass Prairie ecoregions of Kansas (Nasman et al. 2020).

In response to the extreme population decline and estimated extinction risk for the lesser prairie-chicken population in the Sand Sagebrush Prairie Ecoregion, myself, along with the Kansas Department of Wildlife and Parks, Colorado Parks and Wildlife, and U.S. Forest Service translocated lesser prairie-chickens from the Short-Grass Prairie/CRP Mosaic Ecoregion in northwest Kansas, where lesser prairie-chickens are currently most abundant, to release sites in sand sagebrush prairie landscapes on the U.S. Forest Service Cimarron and Comanche National Grasslands in southwestern Kansas and southeastern Colorado, respectively. Lesser prairie-chickens were essentially extirpated from both National Grasslands by 2016 (Berigan 2019), a specific management plan developed in 2014 (US Forest Service 2014) and increased precipitation following the 2012-2013 intensive drought was thought to have improved habitat quality (i.e., improved vegetation composition and structure) on the National Grasslands sufficiently to support translocated birds. Although previous efforts to translocate lesser prairie-chickens and other prairie grouse have had mixed results (Duck and Fletcher 1943, Snyder et al 1999, Horton 2000, Hagen et al. 2004, Rodgers 2016), the extreme population decline and lack of immigration from other ecoregions make translocation one of the few remaining conservation options available to prevent extirpation in the Sand Sagebrush Prairie Ecoregion.

From 2016-2019, I, in conjunction with Kansas Department of Wildlife and Parks and Colorado Parks and Wildlife, translocated 411 lesser prairie-chickens. This effort is the largest known lesser prairie-chicken translocation effort (Snyder 1999, Giesen 2000). Translocated birds were monitored extensively during 2017 – 2021 to determine resource selection at various orders and scales. My goal was to evaluate resource selection by translocated lesser prairie-chickens and compare them with previously published work to assess if resources were selected differentially for birds introduced into a novel landscape. I evaluated resource selection by land cover type, landscape-scale vegetation characteristics, and local, scale (25 m^2) vegetation characteristics for insights into the hierarchical decision process by lesser prairie-chickens structuring home range placement and use of habitat types or patches within established home ranges. My objectives were to 1) determine relative use of different cover types by translocated lesser prairie-chickens following release, 2) test for resource selection at various scales by translocated lesser prairie-chickens released into a novel environment, and 3) compare patterns of resource selection by translocated lesser prairie-chickens to native birds in the Sand Sagebrush Prairie Ecoregion and throughout their range. I predicted that resource selection by translocated lesser prairie-chickens resource selection would be more pronounced at larger scales in a novel landscape, but less prominent at smaller scales within the novel environment (e.g., within patch). Finally, I predicted that use of habitat types by translocated lesser prairie-chickens would differ from native birds and between sexes given the novel environment and different physiological needs by each sex at the time of release.

Study Area

Capture Study Area

I captured lesser prairie-chickens during fall 2016 and spring 2017-2019 in the Short-Grass Prairie/CRP Mosaic Ecoregion, which had the greatest contemporary density of lesser prairie-chickens across their range (Nasman et al. 2020). I captured lesser prairie-chickens, with landowners' permission, on short- and mixed-grass prairie and cropland landscapes in Gove, Lane, Ness, and Finney counties in Kansas (1,357,189 ha; Figure 3.1). Land cover in these counties was a mixture of row-crop agriculture, U.S. Department of Agriculture Conservation Reserve Program (CRP) grassland, and native short-grass prairie intermixed with remnant mixed-grass prairie (McDonald et al. 2014, Dahlgren et al. 2016, Robinson et al. 2018).

Historical (1901 to 2015) mean monthly temperatures ranged from -10.8° C to 29.9° C, and annual precipitation ranged from 23.0 to 84.3 cm ($\bar{x}$ = 50.1 cm) in Lane County, Kansas. During the study period (2016 to 2020) mean monthly temperatures ranged from -3.5° C to 26.4° C, and annual precipitation ranged from 44.0 to 60.6 cm (Lane County, Kansas; NOAA 2021).

Vegetation at the capture sites mostly reflected the composition of the native short-grass prairie, but also contains species of mixed-grass prairie (Sullins 2017, Berigan 2019). Most common grass species included little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), composite dropseed (*Sporobolus compositus*), western wheatgrass (*Pascopyrum smithii*), buffalograss *(Bouteloua dactyloides*), blue grama (*B. gracilis*), hairy grama (*B. hirsuta*), sand dropseed (*Sporobolus cryptandrus*), and inland saltgrass (*Distichlis spicata*). Forb species included slimflower scurfpea (*Psoralidium tenuiflorum*), winterfat (*Krascheninnikovia lanata*), western ragweed (*Ambrosia psilostachya*), broom snakeweed *(Gutierrezia sarothrae*), white heath aster *(Symphyotrichum ericoides*), common prickly pear (*Opuntia monacantha*), and field sagewort (*Artemisia campestris*; McGregor and Barkley 1986). Dominant shrub species were sand sagebrush (*Artemisia filifolia*) and four-wing saltbush (*Atriplex canescens*; Fields et al. 2006). The planted CRP grasslands in Kansas were seeded with a native grass-forb mixture since 1986. These grass species included little bluestem, sideoats grama, big bluestem, switchgrass, western wheatgrass, blue grama, buffalograss, and indiangrass (*Sorghastrum nutans*). Forb species include alfalfa (*Medicago sativa*), white sweet clover (*Melilotus alba*), yellow sweet clover (*M. officinalis*), Maximillian sunflower (*Helianthus maximiliani*), prairie bundleflower (*Desmanthus illinoensis*), purple prairie clover (*Dalea purpurea*), and upright prairie coneflower (*Ratibida columnifera*; Fields et al. 2006).

Release Study Area

I released captured lesser prairie-chickens on either historic or current lek locations on the Comanche and Cimarron National Grasslands in Baca County, Colorado, and Morton County, Kansas, respectively (Figure 3.2). I then delineated the translocation study area boundaries by creating a minimum convex polygon around all points for released birds marked with radio transmitters once initial dispersal ended and they were settled. Therefore, I excluded >5-km one-way movements after individuals established a home range (Robinson et al. 2018; Chapter 2), using the Minimum Bounding Geometry tool in ArcGIS 10.7.1 (ESRI, Redlands, CA, USA; Figure 3.3). The translocation study site was 913,320 ha and comprised of 13% CRP, 10% National Grasslands, 29% private rangeland, 46% cropland, and 2% of other land cover type (roads, water, etc.). Vegetation on the Comanche and Cimarron National Grasslands was sand-sagebrush prairie with a gradient ranging from sparse to abundant densities of sand sagebrush. Vegetation composition and structure on the National Grasslands was largely dependent on soil type and grazing intensity. Composition included both short- and mixed-grass prairie interspersed with tall grasses, and sand sagebrush prairie. Common grass species included sand dropseed, blue grama, buffalo grass, and sand bluestem (*Andropogon hallii*). Forb species included yucca (*Yucca glauca*), blazing star (*Liatris* spp.), western ragweed, prairie sunflower (*Helianthus petiolaris*), annual sunflower (*H. annuus*), camphorweed (*Heterotheca subaxillaris*), fumewort (*Corydalis solida*), Indian blanket flower (*Gaillardia pulchella*), Russian thistle (*Salsola tragus*), pigweed (*Amaranthus hybridus*), tansy aster *(Machaeranthera tanacetifolia*), bush morning glory (*Ipomoea leptophylla*), evening primrose (*Calylophus serrulatus*), buffalo bur (*Solanum rostratum*), buffalo gourd (*Cucurbita foetidissima*), Texas croton (*Croton texensis*), and toothed spurge (*Euphorbia dentata*). The shrub community was dominated by sand sagebrush (Haukos et al. 2016). Vegetation in CRP fields surrounding the National Grasslands was similar to the capture study area. Common animal species within the region included coyote (*Canis latrans*), white-tailed deer (*Odocoileus virginianus*), thirteen-lined ground-squirrel (*Ictidomys tridecemlineatus*), northern harrier (*Circus hudsonius*), meadowlarks (*Sturnella* spp.), grasshopper sparrow (*Ammodramus savannarum*), dickcissel (*Spiza americana*), gopher snake (*Pituophis catenifer*), and prairie rattlesnake (*Crotalus virdis*). Historical (1901 to 2015) mean monthly temperatures ranged from -7.3 to 29.6º C, and annual precipitation ranged from 21.9 to 70.5 cm ($\bar{x}$ = 42.8 cm) in Morton County, Kansas. During the study period (2016 to 2020) mean monthly temperatures ranged from -0.17 to 26.8º C, and annual precipitation was above average most years and ranged from 32.4 to 56.9 cm (Morton County, Kansas; NOAA 2021).

Methods

Capture and Monitoring

With private landowner permission, I captured lesser prairie-chickens during lekking activity in September-October (2016) and March-April (2017-2019) in four northwestern Kansas counties within the Short-Grass Prairie/CRP Mosaic Ecoregion (Figure 3.1). I used walk-in funnel traps and tension or magnetic drop nets for capture at lek sites (Haukos et al. 1990, Silvy et al. 1990). After capture, I fitted both male and female lesser prairie-chickens with either a 12- to 15-g bib-style very-high-frequency (VHF) transmitter (RI-2B Holohil Systems Ltd., Carp, Ontario, Canada or Series A3960, Advanced Telemetry System, Isanti, MN, USA) or rump-mounted 22-g Satellite Platform Transmitting Terminal GPS (SAT-PTT) transmitter (PTT-100, Microwave Telemetry, Columbia, MD, USA). Care was taken that transmitter type would not exceed 3% of an individual birds body mass. I attached SAT-PTT transmitters using leg harnesses made of tubular Teflon® ribbon for durability and sewed in elastic for maneuverability

(Bedrosian and Craighead, 2007, Dzialak et al. 2011). I determined sex of each bird from feather coloring and behavior on lek, and aged birds as second-year (SY) or after-second-year (ASY) via the molt characteristics of the outer primary feathers (Ammann 1944). A few birds (<3%) had nondescript age characteristics or no age was recorded and was later labeled as after-hatch-year (AHY). I also took measurements of various morphometric data including eye comb length and height, head length, culmen length, pinnae length, tarsus length, tarsus with longest toe length, tail length, flatten wing cord, and mass of the bird (Aulicky 2020). Feathers from the breast and blood were also taken for genetic and disease analyses, respectively. I then marked individuals with a numbered aluminum leg band and a unique combination of plastic color bands for resighting (Coplin 1963).

During transportation to release sites, I minimized unnecessary stressors such as sounds, stops, and kept vehicle temperatures cool to reduce stress on the birds. I released birds within 11 hours after capture on the Cimarron or the Comanche National Grasslands. Chosen release sites were either historic lek locations or visually assessed for nesting habitat and reviewed annually (Figure 3.2). This research was conducted in accordance with guidelines on the use of wild birds in research and in compliance with state and federal regulations (Fair et al. 2010). All handling and capture protocols were completed and approved by the Kansas State University Institutional Animal Care and Use Committee Permit #3703, Kansas Scientific Wildlife Permits SC-024-2018 and SC-015-2019, and Colorado Scientific Wildlife Permits SC-128-2016, SC-079-2017, SC-076-2018, and SC-077-2019.

I monitored male and female lesser prairie-chickens during the breeding (Mar 15 – Sep 15) and nonbreeding seasons (Sep 16 – Mar 14) from April 2017 – August 2020. I attempted to locate birds fitted with a VHF transmitter ≥3 times per week using triangulation from 3-5 observer locations via handheld three-piece Yagi antennas and radio receivers (R4000, R410; Advanced Telemetry System, Isanti, MN, USA, or R1000; Communications Specialists, Orange, CA, USA). Triangulation consisted of compass bearings taken at each location ≥15 degrees apart and within 20 min to decrease error from bird movement. Recorded location and associated error was estimated with the Location Of A Signal software (LOAS; Ecological Software Solutions, Hegymagas, Hungary). If an individual could not be triangulated (out of receiver range, flew away, etc.), a second attempt was attempted at another time during the day or the following day. Fixed-wing aircraft was used to locate individuals with VHF transmitters that had dispersed and could not be found by ground scanning. Birds fitted with SAT-PTT transmitters had 8 to 10 GPS locations in 2-hour intervals recorded per day between 0600 and 2200 (18-m accuracy). Locations were uploaded to the Argos satellite system every 3 days and downloaded weekly.

Vegetation Surveys

I conducted vegetation surveys at points used by SAT-PTT-marked translocated lesser prairie-chickens in the breeding and nonbreeding seasons. I limited my collection to SAT-PTT-marked individuals to maintain a manageable subset of locations for vegetation surveys and because of the consistent accuracy of the SAT-PTT transmitters locations would result in more accurate location vegetation measurements. I randomly selected two locations per week for lesser prairie-chickens captured and outfitted with a SAT-PTT transmitter and collected vegetation data at those locations. Then I randomly generated a paired available location up to 300 m away from the original point to make inferences about vegetation selection at the local or within patch scale. This resulted in 2 used locations and 2 paired locations for every SAT-PTT-marked translocated bird weekly throughout the duration of the study. In a similar manner, I also conducted vegetation surveys at nest locations shortly after the nest fate was determined

(Chapter 1) and a randomly paired available location up to 300 m away. This resulted in 1 nest location and 1 paired location per nest throughout the duration of the study. Lastly, I conducted vegetation surveys at randomly generated points throughout the study area in various habitat patches to determine vegetation availability at the landscape scale (Figure 3.4). These points were not paired with any other vegetation survey points. Patches were delineated based on property ownership, grazing allotment (U.S. Forest Service National Grasslands), and soil type boundaries (Berigan 2019). Within each patch, I conducted up to 10 point-vegetation surveys (rate of 1 per 4 ha). Patches were sampled during the breeding season and again in the nonbreeding season from 2018-2020. All points were generated randomly among seasons and years to avoid sampling one location several times within a patch.

At each point (used, paired available, nest, random [not paired]), I measured vegetation following protocols established in the lesser prairie-chicken literature (Sullins et al. 2018, Lautenbach et al. 2019, Gehrt et al. 2020). I measured 100%, 75%, 50%, 25%, and 0% visual obstruction reading (VOR; dm) in each cardinal direction using a Robel pole placed at point center (Robel et al. 1970). I used a modified Daubenmire frame (60 x 60 cm) to estimate percent cover of grasses, forbs, litter, bare ground, and shrubs at the point center, as well as at locations 4 m from the point center in each cardinal direction. I also measured vegetation height at each of these 5 locations. Litter depth (cm) was measured every 0.5 m along 4-m transects in each cardinal direction from point center. As litter depth heterogeneity has been found to be important for nesting lesser prairie-chickens (Lautenbach 2015, Sullins 2017), I also calculated the standard deviation of litter depth measurements as a metric of litter heterogeneity. Within the 4-m radius circle surrounding each point, I visually estimated percentage of the top three most abundant plant species.

Analysis

Cover Type Selection

I categorized cover types as CRP Grass / Pasture (Conservation Reserve Program fields), Crop, Developed/Open Space (urban, water, wooded, etc.), Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). I calculated the area of each cover type available to the translocated lesser prairie-chickens across the translocation study area (Figure 3.3). Given the dispersal capability of released lesser prairie-chickens, I used the entire study area to estimate available cover types for analyses of resource selection among transmitter types, breeding seasons, and nest sites (Thomas and Taylor 2006). For analysis comparing resource selection among states, I divided the study area into 3 separate areas delineated by state boundaries and estimated available cover types by state (CO, KS, and OK). These study areas included areas that lesser prairie-chickens could reasonably access; however, due to the low percent of developed/open land cover type overall (2%), relatively low number of locations found within the cover type ($n < 200$ of >125,000 locations), and that developed/ open land (urban, roads, oil pads, water, wooded, etc.) is generally considered a cover type avoided by lesser prairie-chickens (Lautenbach et al. 2017, Plumb et al. 2018, Patten et al. 2021), I excluded the cover type from the analyses (Aebischer et al. 1993, Buskirk and Millspaugh 2006). To quantify cover type use, I summed the number of locations in each cover type of established home ranges by each cohort of lesser prairie-chickens (Chapter 2). I evaluated variation of cover type use by sex within state, transmitter type, and breeding or nonbreeding season groups. To test cover type selection among groups, I calculated selection ratios using the proportion of each cover type available in the respective study area and the number of locations found in each cover type for that group using the adehabitatHS package in program R (Calenge 2006). For my analysis I did not distinguish between individual birds and use and availability was measured at the population level (design I data type; Manly et al. 2003).

Landscape-Scale Vegetation Characteristic Selection

For landscape-scale resource selection, I used logistic regression to assess selected vegetation at used locations of SAT-PTT-marked birds and random vegetation points throughout the translocation study area (Manly et al. 2002, Boyce et al. 2002). I conducted separate model sets for used and random vegetation points during the breeding and nonbreeding seasons, in Kansas and Colorado, and all used locations throughout the study area and duration. For each model set group, I developed 25 vegetation composition models that tested linear and quadratic version of each composition covariate and a null model. These covariates included averaged percent cover of bare ground, forb, grass, litter, and shrub; averaged VOR at 0%, 25%, 50%, 75%, and 100%; and averaged litter depth and standard deviation of each litter depth. I ranked and selected the most parsimonious model based AICc and informative beta coefficients (Burnham and Anderson 2002). Model weight (w_i), untransformed beta coefficients (β) that differed from zero at the 95% confidence interval (CI) were evaluated for models where ΔAICc ≤ 2 was considered competitive.

Local Scale Vegetation Characteristic Selection

I used a paired Hotelling T^2 test to examine multivariate differences in vegetation characteristics at the used and nest locations and their paired available counterparts from 2018-2020 (i.e., within patch, 4^{th} order selection). I evaluated points sampled by season (breeding or nonbreeding), sex (male or female), and state in which the points were taken (CO or KS). Once a multivariate difference was detected from the Hotelling T^2 test ($P < 0.05$), I used paired *t*-tests with a Bonferroni correction ($P < 0.0038$; 0.05/13 vegetation characteristics) to examine changes in the mean of each vegetation characteristic between the various time periods, sexes and states.

Results

Cover Type Selection

Using selection ratios, I found that overall, translocated lesser prairie-chickens selected for CRP in the study area. A total of 81,757 and 43,615 used locations were recorded for all translocated lesser prairie-chickens during the breeding and nonbreeding seasons, respectively (Table 3.1). Specifically, CRP and U.S. Forest Service tracts were selected more than what was available on the landscape for both the breeding and nonbreeding season, although the selection ratio for CRP was ~2.7 times greater than for U.S. Forest Service land (Figure 3.5, Figure 3.6). Conversely, non-CRP Grasslands and Cropland were avoided compared to what was available on the landscape and the selection ratio was similar among the two cover types. A total of 3,952 and 121,420 used locations were recorded for VHF and SAT-PTT-marked birds, respectively (Table 3.2). Similar to seasonal selection, VHF and SAT-PTT-marked birds selected for CRP and U.S. Forest Service land more than what was available on the landscape with CRP having a selection ratio ~2.7 times greater than for U.S. Forest Service land (Figure 3.7, Figure 3.8). Also, the selection ratio for VHF-marked birds was ~1.3 times greater for CRP than SAT-PTT-marked birds. For birds sorted by state and sex, totals of 29,944, 88,200, and 7,092 used locations were recorded for Colorado, Kansas, and Oklahoma, respectively; a total of 73,380 and 51,856 used locations were recorded for female and males, respectively (Table 3.3). Females and males in Colorado selected for both CRP and U.S. Forest Service cover types and avoided non-CRP Grasslands and Cropland (Figure 3.9, Figure 3.10). However, the selection ratio for females in Colorado was ~1.4 times greater for CRP than for males. Males in Colorado had a selection ratio for U.S. Forest Service land that was ~1.3 times greater than females. Females and males in Kansas both selected for CRP and avoided U.S. Forest Service land and Cropland tracts. Males in Kansas had a selection ratio that was ~1.13 times greater than females for CRP; however, U.S. Forest Service land and Cropland were avoided with similar selection ratios. Notably, females in Kansas selected for non-CRP Grasslands in Kansas verses males avoiding the cover type (Figure 3.11, Figure 3.12). Females in Oklahoma selected for CRP and non-CRP Grasslands and avoided Cropland (Figure 3.13). Lastly, nest-site selection throughout the study area occurred in CRP and U.S. Forest Service tracts; however, selection was most prominent in CRP with a selection ratio that was 2.0 times greater than U.S. Forest Service land (Table 3.4.). Females avoided selecting nest sites in non-CRP Grasslands and Cropland (Figure 3.14).

Landscape-Scale Vegetation Characteristic Selection

I tested 25 models containing various vegetation metrics for resource selection at used locations for translocated lesser prairie-chickens separated into groups including all birds across the study site, breeding season locations, nonbreeding season locations, and separate sexes in each state. Among all individuals, translocated birds selected for 25% VOR ($\beta_{25\%VOR}$ = 0.15, SE = 0.014, 95% CI = 0.12 – 0.18; Table 3.5; Figure 3.15). While my top model was a quadratic relationship with 25% VOR, ($\beta_{25\%VOR}$ = 0.21, SE = 0.041, 95% CI = 0.13 – 0.29; $\beta_{25\%VOR\hat{}2}$ = -0.005, SE = 0.003, 95% CI = -0.011 – 0.001) and was not as informative as the single variable model of 25% VOR. These were the only two competitive models (ΔAICc $\leq$ 2). Similarly, in the breeding season, translocated birds selected for 25% VOR, as it was the top model ($\beta_{25\%VOR}$ = 0.15, SE = 0.018, 95% CI = 0.12 – 0.18; Table 3.6; Figure 3.16). The other competitive model (ΔAICc $\leq$ 2) was a quadratic relationship with 25% VOR ($\beta_{25\%VOR}$ = 0.17, SE = 0.053, 95% CI = 0.07 – 0.27; $\beta_{25\%VOR\hat{}2}$ = -0.002, SE = 0.004, 95% CI = -0.01 – 0.006). In the nonbreeding season however, translocated birds selected for a quadratic covariate of 75% VOR ($\beta_{75\%VOR}$ = 0.91, SE = 0.157, 95% CI = 0.6 – 1.22; $\beta_{75\%VOR\text{^}2}$ = -0.104, SE = 0.038, 95% CI = -0.030 – -0.178; Table 3.7; Figure 3.17). This model was 20.84 times more likely than the next model and the only competitive model (ΔAICc $\leq$ 2).

Next, I evaluated 25 models *a priori* (12 single variable, 12 quadratic variables) within model sets differentiated by sex and state. Males in Colorado selected for areas with less litter depth ($\beta_{\text{littler depth}}$ = - 1.74, SE = 0.303, 95% CI = -2.34 – -1.14; Table 3.8; Figure 3.18). Males also selected for locations that had lower 50% VOR ($\beta_{50\%VOR}$ = -1.22, SE = 0.20, 95% CI = -0.83 – -1.61; $\beta_{50\%VOR\text{^}2}$ = 0.13, SE = 0.031, 95% CI = -0.069 – 0.19; Figure 3.19). These two models were competitive (ΔAICc $\leq$ 2) as was a third model with a quadratic covariate of litter depth but the associated confidence interval overlapped zero ($\beta_{\text{litter depth}}$ = -1.92, SE = 0.35, 95% CI = -1.92 – -1.23; $\beta_{\text{litter depth\text{^}2}}$ = 0.081, SE = 0.061, 95% CI = -0.040 – 0.201). For females in Colorado, the top-ranked model was a quadratic covariate of percent grass cover ($\beta_{\text{\% grass cover}}$ = 0.08, SE = 0.019, 95% CI = 0.04 – 0.12; $\beta_{\text{\% grass cover\text{^}2}}$ = -0.0009, SE = 0.0002, 95% CI = -0.0007 – -0.0013; Table 3.9; Figure 3.20). This model was 14.55 times more likely than the next model and the only competitive model (ΔAICc $\leq$ 2). The model set for the males in Kansas had two competing models. There was a linear effect of 25% VOR ($\beta_{25\%\ VOR}$ = 0.24, SE = 0.020, 95% CI = 0.20 – 0.28; Table 3.10; Figure 3.21) and a quadratic effect of 25% VOR ($\beta_{25\%\ VOR}$ = 0.304, SE = 0.058, 95% CI = 0.19 – 0.42; $\beta_{25\%\ VOR\text{^}2}$ = -0.0047, SE = 0.004, 95% CI = -0.013 – 0.0013; Figure 3.22). No other models were competitive in the model set (ΔAICc $\leq$ 2). For females in Kansas, the top-ranked model was a quadratic covariate of 50% VOR ($\beta_{50\%VOR}$ = 0.876, SE = 0.125, 95% CI = 0.631 – 1.00; $\beta_{50\%VOR\text{^}2}$ = -0.126, SE = 0.024, 95% CI = -0.08 – -0.173; Table 3.11; Figure

3.23). This model was 697.41 times more likely than the next model and the only competitive model (ΔAICc ≤ 2).

Local Scale Vegetation Characteristic Selection

I found no difference in vegetation characteristics for all locations pooled across sex and state between used and paired-random locations at the 300-m local scale (Hotelling's $T^2 = 1.32$, $P = 0.19$; Table 3.12). Similarly, there were no differences in vegetation characteristics between used and paired-random locations for the breeding season (Hotelling's $T^2 = 1.32$, $P = 0.20$; Table 3.13); female used locations only (Hotelling's $T^2 = 0.75$, $P = 0.71$; Table 3.14); male locations only (Hotelling's $T^2 = 1.20$, $P = 0.28$; Table 3.15); locations of birds only in Colorado (Hotelling's $T^2 = 1.01$, $P = 0.45$; Table 3.16); and locations from birds only in Kansas (Hotelling's $T^2 = 1.54$, $P = 0.10$; Table 3.17). However, there was a difference in vegetation characteristics between used and paired-random locations during the nonbreeding season (Hotelling's $T^2 = 2.01$, $P = 0.02$; Table 3.18). Lesser prairie-chickens used 2.74 less percent cover of bare ground on average at used locations than what was available at 300 m within local scale during the nonbreeding season ($t_{224} = -2.93$, $P = 0.004$).

Available paired-random vegetation locations for nests in Colorado were limited and therefore, only nests in Kansas were used for this analysis. There was a difference of vegetation structure at nests than what was available at the 300-m local scale (Hotelling's $T^2 = 2.01$, $P = 0.034$; Table 3.19). Lesser prairie-chickens nested in areas where 75% VOR was 5.9 cm taller on average than what was available at the 300-m local scale ($t_{56} = 3.79$, $P = 0.004$).

Discussion

Although, my study area was vast (913,320 ha) with potential variation of available resources throughout, patterns of selection were relatively consistent across space, time, and sexes. I observed that translocated lesser prairie-chickens selected the CRP cover type within their home range and for nesting more intensely and consistently than any other cover typed. The second most used cover type was U.S. Forest Service land but at much less intensity of selection than CRP andthe magnitude of use varied among different groups of lesser prairie-chickens. Males in Colorado indeed used U.S. Forest Service land more than what was available on the landscape at a magnitude larger than CRP, but all other groups used CRP at a much greater selection ratio than U.S. Forest Service land. This highlights the importance of evaluating resource selection between sexes and across spatial scales when assessing translocation of wildlife. I also found that vegetation selection at the within-patch scale varied among most groups delineated by sex, state, and seasons. The most frequent top-ranked models had a metric of VOR, which is a surrogate for vegetation thickness (i.e., vertical cover). My results indicated that taller, thicker vegetation is indeed a major factor for resource selection by lesser prairie-chickens in the novel landscape. This finding coupled with the finding that most translocated birds strongly selected for the CRP cover type indicated that areas of grass-dominated landscapes with denser herbaceous cover are selected most often by translocated lesser prairie-chickens. Landscapes with CRP grasslands and grasslands with abundant cover should continue as the focus for management, conservation, and acquisition as my results also showed little difference in selection at the local scale (i.e., within patch). However, nest sites and nonbreeding season locations differed at the within-patch scale, with selection for greater VOR. Therefore, demonstrating the hierarchical importance of quality and quantity of grassland habitat on a landscape scale that may be needed prior to future translocation or reintroduction of lesser prairie-chickens.

Cover Type Selection

I found that translocated lesser-prairie chickens selected for CRP at a frequency much greater than what was available on the landscape. There are several studies that highlight the importance of CRP planted with native grasses and forbs for lesser prairie-chicken population demography (Sullins et al. 2018), space use (Fields 2004), and resource selection (Harryman et al. 2019) throughout most of their range, but of greatest value in semi-arid regions (Sullins et al. 2018). However, select groups of translocated lesser prairie-chickens did use to some degree the two other native cover types of non-CRP grassland and U.S. Forest Service National Grasslands. Selection and relative number of birds (e.g., birds that settled in Oklahoma) in these cover types were low, which is likely due to the quality of vegetation structure within those patches (L. Berigan, *in review*). This is evident by avoidance of the Cimarron National Grasslands by female birds in Kansas where they selected for CRP with a selection ratio that was 7.2 times greater than the U.S. Forest Service land. Further evidence of the importance of CRP was the strongest selection and nest success for nest sites in CRP (Chapter 1). Careful adaptive management that responds to ecological pressures, such as drought or grazing, of the other native cover types could improve vegetation structure and likely improve selection probability of cover types other than CRP among translocated lesser prairie chickens.

Landscape-Scale Vegetation Characteristic Selection

For all translocated birds over the course of the entire study (2018-2021), the breeding season, and the smaller group of males in Kansas, the metric of 25% VOR was the top-ranked selection model. It is important to note the 25% VOR was often recorded as any vegetation, even as little as a blade grass counted as 25% VOR. Thus, 25% VOR is likely more of an index of vegetation height than vegetation thickness. Therefore, lesser prairie-chickens in these groups and time frames were selecting areas with taller vegetation. Taller vegetation has been shown in other studies of lesser prairie-chickens to act as needed cover in the semi-arid region of the range (Haukos and Zavaleta 2016). These top-ranked models indicate the birds were selecting for areas supporting generally taller and thicker grasses. This is not unexpected for lesser prairie-chickens in the northern distribution of its range (Van Pelt et al. 2013, Haukos and Zavaleta 2016), but other studies in the Sand Sagebrush Prairie Ecoregion have emphasized the importance of shrub cover and density for lesser prairie-chickens (Hagen et al. 2013, Haukos and Zavaleta 2016). On average, vegetation at nest locations for translocated birds had an average shrub cover of 2.53%, whereas other studies have shown 12.53% shrub cover at nest locations and recommendations for shrub cover are currently at 15 – 30% (Hagen et al. 2013, Van Pelt et al. 2013). I did not detect strong selection for shrub vegetation by translocated lesser prairie-chickens. This may be due to changes in the ecoregion natural landscape via prolonged droughts, grazing practices, and land conversion to row-crop agriculture changing the landscape over time. Shrub density may become too great in areas of intensive grazing pressure (Haukos and Zavaleta 2016); consequently leaving little remaining grass heterogeneity causing avoidance by lesser prairie-chickens. However, landscape changes within the ecoregion, especially in regards to shrub cover and density, since the contemporary population peak in the 1980s, is unknown and should be investigated due to the severe population declines in the Sand Sagebrush Prairie Ecoregion.

Translocated birds in Colorado exhibited different patterns for selection of vegetation characteristics at the landscape scale between males and females. Top-ranked models for males included a model of litter depth whereas females in Colorado had a top ranked model of percent grass cover. Males had highest probability of use in areas with little accumulated litter and females had the highest probability of use when percent grass cover was ~50%. These differences are likely caused by the differences in cover type use between the two sexes in the state where males selected for the U.S. Forest Service National Grasslands and females overwhelmingly selected for CRP. The U.S. Forest Service National Grasslands is grazed and therefore have areas of shorter grass and more bare ground leading to shorter litter depths overall. Whereas, the CRP tracts selected by females will have greater percent grass cover over all.

Local Scale Vegetation Characteristic Selection

Selection of vegetation at the within-patch scale was evident for nest-site selection by translocated lesser prairie chickens. Selected nest sites had taller and thicker vegetation than available locations. This was likely due to the needed residual vegetation for cover for concealment when lesser prairie-chickens are nesting (Haukos and Zavaleta 2016, Lautenbach et al. 2019). There was local-scale avoidance of percent bare ground cover during the nonbreeding season and this was likely due to vegetation dormancy/die off during winter creating more litter accumulation and selection for thermal cover.

Summary

I have presented evidence that female and male translocated lesser prairie-chickens consistently select for CRP grasslands at broad scales. Selection of vegetation characteristics varied among groups at a landscape scale but was consistently related to the taller and thicker vegetation of grass cover. Nest-site selection was evident at finer spatial scales where females selected for areas with tall thick residual cover for concealment. With the decline of lesser prairie-chickens throughout most of its range, translocations could be more seriously considered in the future. My findings indicate how translocated lesser prairie-chickens assess and use a novel landscape and that assessing quality habitat via active field data collection of vegetation characteristic across a large scale before a translocation is conducted is critical for translocation success.

Management Implications

Translocation of lesser prairie-chickens is costly and may not yield lasting long-tern effects, especially if quality habitat is lacking in the release area. My findings show that CRP is consistently selected by most translocated lesser prairie-chickens and apparently represents high quality habitat in the Sand Sagebrush Prairie Ecoregion. To sustain this high quality habitat, maintaining and expanding CRP, via community outreach and competitive financial incentives, is necessary in the Sand Sagebrush Prairie Ecoregion. Along with expanding CRP, there is also a need to improve private non-CRP working rangelands in the ecoregion as translocated birds consistently avoided that cover type. Adaptive grazing management will likely improve sustainable levels of grass cover for lesser-prairie chickens on these private lands. This may lead to heterogeneous vegetation structure across landscapes with relatively high density of CRP that is ideal for lesser prairie-chickens. Similar grazing intensities through rotational grazing or mixed management such as patch-burn grazing should be implemented to support grass cover and thickness for lesser prairie-chicken conservation.

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Tables

Table 3.1 Resource selection ratios of translocated lesser prairie-chickens (Use: Availability; Manly et al. 2002) of four cover types among breeding (Mar 15-Sep 15) and nonbreeding (Sep 16-Mar14) seasons. Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

Season	Cover Type	Locations *n*	Used Proportion	Selection ratio $\hat{w}$	Standardized index B
Breeding					
	CRP	39,046	0.478	3.674	0.601
	USFS	11,568	0.141	1.415	0.232
	Non-CRP Grassland	15,164	0.185	0.598	0.098
	Cropland	15,979	0.195	0.425	0.070
Nonbreeding					
	CRP	23,705	0.544	4.181	0.646
	USFS	6,565	0.151	1.505	0.233
	Non-CRP Grassland	5,076	0.116	0.375	0.058
	Cropland	8,269	0.190	0.412	0.064

Table 3.2 Resource selection ratios of translocated lesser prairie-chickens (Use: Availability; Manly et al. 2002) of four main cover types between transmitter types (VHF and SAT-PTT). Ratios >1.0 and <1.0 indicate positive selection and negative selection avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

Season	Cover Type	Locations *n*	Used Proportion	Selection ratio $\hat{w}$	Standardized index B
VHF					
	CRP	2,558	0.647	4.979	0.693
	USFS	689	0.174	1.743	0.243
	Non-CRP Grassland	271	0.069	0.221	0.031
	Cropland	434	0.11	0.239	0.033
SAT-PTT					
	CRP	60,193	0.496	3.813	0.614
	USFS	17,444	0.144	1.437	0.231
	Non-CRP Grassland	19,969	0.164	0.531	0.085
	Cropland	23,814	0.196	0.426	0.069

Table 3.3 Resource selection ratios of translocated lesser prairie-chickens (Use: Availability; Manly et al. 2002) of four main cover types between sexes (Male, Female) in three states (CO, KS, OK). Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

Group	Cover Type	Locations *n*	Used Proportion	Selection ratio $\hat{w}$	Standardized index B
CO Females					
	CRP	8,076	0.434	3.340	0.499
	USFS	7,051	0.379	2.916	0.436
	Non-CRP Grassland	213	0.011	0.038	0.006
	Cropland	3,260	0.175	0.398	0.060
CO Males					
	CRP	3,599	0.317	2.44	0.361
	USFS	5,761	0.508	3.907	0.578
	Non-CRP Grassland	119	0.01	0.035	0.005
	Cropland	1,865	0.164	0.374	0.055
KS Females					
	CRP	25,278	0.530	3.118	0.607
	USFS	2,929	0.061	0.439	0.085
	Non-CRP Grassland	11,133	0.233	1.229	0.239
	Cropland	8,348	0.175	0.350	0.068
KS Males					
	CRP	24,131	0.596	3.504	0.706
	USFS	2,392	0.059	0.422	0.085
	Non-CRP Grassland	4,300	0.106	0.559	0.113
	Cropland	9,689	0.239	0.478	0.096
OK Females					
	CRP	1,594	0.225	2.497	0.602
	USFS*	-	-	-	-
	Non-CRP Grassland	4,474	0.631	1.314	0.317
	Cropland	1,024	0.144	0.336	0.081

* No U.S. Forest Service land in the study area in Oklahoma

Table 3.4 Resource selection ratios of translocated lesser prairie-chicken nests (Use: Availability; Manly et al. 2002) of four main cover types. Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

Cover Type	Nest Locations n	Used Proportion	Selection ratio $\hat{w}$	Standardized index B
CRP	90	0.652	5.017	0.644
USFS	35	0.254	2.536	0.326
Non-CRP Grassland	4	0.029	0.094	0.012
Cropland	9	0.065	0.142	0.018

Table 3.5 ***A priori*** **candidate models used to estimate landscape-scale selection of vegetation metrics by SAT-PTT-marked lesser prairie-chickens translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019, but locations and vegetation were collected from 2018-2020. Models include covariates included averaged, percent cover of; bare ground, forb, grass, litter, and shrub; averaged visual obstruction reading (VOR) at 0%, 25%, 50%, 75%, and 100%; averaged litter depth and standard deviation of averaged littler depth, a quadratic term of each covariate, and a null model.**

Model	K[a]	Δ AICc[c]	AICc[b]	w_i[d]	Deviance[e]
25% VOR^2	3	0.00	4632.04	0.57	4626.04
25% VOR	2	0.53	4632.57	0.43	4628.56
0% VOR	2	12.47	4644.51	0.00	4640.50
0% VOR^2	3	14.21	4646.25	0.00	4640.24
% Grass Cover^2	3	53.85	4685.89	0.00	4679.88
75 % VOR^2	3	53.90	4685.94	0.00	4679.94
% Litter Cover^2	3	56.32	4688.36	0.00	4682.36
% Littler Cover	2	56.48	4688.52	0.00	4684.52
50% VOR^2	3	59.34	4691.38	0.00	4685.38
50% VOR	2	73.27	4705.31	0.00	4701.32
75% VOR	2	75.33	4707.37	0.00	4703.36
100% VOR^2	3	77.24	4709.28	0.00	4703.28
% Shrub Cover^2	3	86.33	4718.37	0.00	4712.36
100% VOR	2	87.87	4719.91	0.00	4715.90
% Shrub Cover	2	88.52	4720.56	0.00	4716.56
% Bare Cover^2	3	88.82	4720.86	0.00	4714.86
% Bare Cover	2	98.63	4730.67	0.00	4726.68
Null	1	108.86	4740.90	0.00	4738.90
% Grass Cover	2	109.26	4741.30	0.00	4737.30
Litter depth	2	109.78	4741.82	0.00	4737.82
Litter depth SD	2	110.53	4742.57	0.00	4738.56
% Forb Cover	2	110.60	4742.64	0.00	4738.64
Litter depth SD^2	3	111.10	4743.14	0.00	4737.14
Litter depth^2	3	111.77	4743.81	0.00	4737.80
% Forb Cover^2	3	112.59	4744.63	0.00	4738.62

[a]Number of parameters.
[b]Akaike's Information Criterion, corrected for small sample size.
[c]Difference in Akaike's Information Criterion, corrected for small sample size.
[d]Akaike weights.
[e]Deviance or -2*loglikelihood.

Table 3.6 ***A priori*** **candidate models used to estimate breeding season (Mar 15-Sep 15) landscape-scale selection of vegetation metrics by SAT-PTT-marked lesser prairie-chickens translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019, but locations and vegetation were collected from 2018-2020. Models include covariates included averaged, percent cover of; bare ground, forb, grass, litter, and shrub; averaged visual obstruction reading (VOR) at 0%, 25%, 50%, 75%, and 100%; averaged litter depth and standard deviation of averaged litter depth, a quadratic term of each covariate, and a null model.**

Model	K[a]	Δ AICc[c]	AICc[b]	w_i[d]	Deviance[e]
25% VOR	2	0.00	3008.72	0.71	3004.72
25% VOR^2	3	1.83	3010.55	0.29	3004.54
0% VOR	2	21.41	3030.13	0.00	3026.12
0% VOR^2	3	22.94	3031.66	0.00	3025.66
% Litter Cover^2	3	24.49	3033.21	0.00	3027.20
% Littler Cover	2	26.32	3035.05	0.00	3031.04
% Grass Cover^2	3	29.02	3037.74	0.00	3031.72
% Shrub Cover^2	3	39.78	3048.50	0.00	3042.50
% Shrub Cover	2	41.90	3050.62	0.00	3046.62
75% VOR^2	3	65.31	3074.03	0.00	3068.02
% Bare Cover^2	3	66.05	3074.77	0.00	3068.76
50% VOR^2	3	67.25	3075.97	0.00	3069.96
% Grass Cover	2	68.15	3076.87	0.00	3072.86
100% VOR^2	3	68.77	3077.49	0.00	3071.48
% Bare Cover	2	69.02	3077.74	0.00	3073.74
% Forb Cover^2	3	69.37	3078.09	0.00	3072.08
% Forb Cover	2	69.42	3078.14	0.00	3074.14
Null	1	69.76	3078.49	0.00	3076.48
50% VOR	2	70.59	3079.32	0.00	3075.32
Litter depth SD	2	70.83	3079.55	0.00	3075.54
75% VOR	2	71.36	3080.08	0.00	3076.08
100% VOR	2	71.47	3080.19	0.00	3076.18
Litter depth	2	71.66	3080.38	0.00	3076.38
Litter depth SD^2	3	72.23	3080.95	0.00	3074.94
Litter depth^2	3	73.16	3081.88	0.00	3075.88

[a]Number of parameters.
[b]Akaike's Information Criterion, corrected for small sample size.
[c]Difference in Akaike's Information Criterion, corrected for small sample size.
[d]Akaike weights.
[e]Deviance or -2*loglikelihood.

Table 3.7 *A priori* candidate models used to estimate nonbreeding season (Sep 16-Mar 14) landscape-scale selection of vegetation metrics by SAT-PTT-marked lesser prairie-chickens translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019, but locations and vegetation were collected from 2018-2020. Models include covariates included averaged, percent cover of; bare ground, forb, grass, litter, and shrub; averaged visual obstruction reading (VOR) at 0%, 25%, 50%, 75%, and 100%; averaged litter depth and standard deviation of averaged litter depth, a quadratic term of each covariate, and a null model.

Model	K[a]	Δ AICc[c]	AICc[b]	w_i[d]	Deviance[e]
75% VOR^2	2	0.00	1528.37	0.89	1522.36
75% VOR	3	6.04	1534.41	0.04	1530.40
50% VOR^2	2	6.70	1535.07	0.03	1529.06
100% VOR^2	3	7.30	1535.67	0.02	1529.66
100% VOR	2	9.43	1537.80	0.01	1533.80
50% VOR	3	13.03	1541.41	0.00	1537.40
0% VOR^2	3	22.99	1551.36	0.00	1545.34
0% VOR	3	24.63	1553.00	0.00	1549.00
25% VOR^2	2	32.33	1560.70	0.00	1554.70
25% VOR	3	33.98	1562.35	0.00	1558.34
% Bare Cover^2	3	62.94	1591.31	0.00	1585.30
% Grass Cover^2	3	67.11	1595.48	0.00	1589.48
% Bare Cover	2	67.38	1595.75	0.00	1591.74
% Littler Cover	3	71.55	1599.93	0.00	1595.92
% Littler Cover^2	2	72.43	1600.80	0.00	1594.78
Litter depth	3	75.86	1604.24	0.00	1600.24
Null	2	76.19	1604.56	0.00	1602.56
% Grass Cover	1	77.10	1605.48	0.00	1601.48
Litter depth^2	2	77.71	1606.09	0.00	1600.08
Litter depth SD^2	2	77.82	1606.20	0.00	1600.18
% Shrub Cover	2	77.89	1606.26	0.00	1602.26
% Forb Cover	2	78.11	1606.48	0.00	1602.48
Litter depth SD	2	78.19	1606.56	0.00	1602.56
% Shrub Cover^2	3	79.66	1608.04	0.00	1602.02
% Forb Cover^2	3	79.92	1608.30	0.00	1602.28

[a]Number of parameters.
[b]Akaike's Information Criterion, corrected for small sample size.
[c]Difference in Akaike's Information Criterion, corrected for small sample size.
[d]Akaike weights.
[e]Deviance or -2*loglikelihood.

Table 3.8 ***A priori*** **candidate models used to estimate landscape-scale selection of vegetation metrics by male SAT-PTT-marked lesser prairie-chickens within Colorado. Lesser prairie-chickens were translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019, but locations and vegetation were collected from 2018-2020. Models include covariates included averaged, percent cover of; bare ground, forb, grass, litter, and shrub; averaged visual obstruction reading (VOR) at 0%, 25%, 50%, 75%, and 100%; averaged litter depth and standard deviation of averaged litter depth, a quadratic term of each covariate, and a null model.**

Model	K[a]	Δ AICc[c]	AICc[b]	w_i[d]	Deviance[e]
Litter depth	2	0.00	741.22	0.55	737.22
50% VOR^2	3	1.80	743.02	0.22	737.02
Litter depth^2	3	1.83	743.05	0.22	737.04
50% VOR	2	7.98	749.20	0.01	745.20
% Grass Cover^2	3	19.31	760.53	0.00	754.52
75% VOR^2	3	19.45	760.67	0.00	754.66
75% VOR	2	22.10	763.32	0.00	759.32
% Littler Cover	2	26.03	767.26	0.00	763.26
% Littler Cover^2	3	26.48	767.71	0.00	761.70
100% VOR^2	3	30.36	771.58	0.00	765.58
% Shrub Cover^2	3	33.76	774.98	0.00	768.98
% Bare Cover^2	3	35.51	776.74	0.00	770.72
% Shrub Cover	2	38.19	779.41	0.00	775.40
% Forb Cover	2	39.13	780.35	0.00	776.34
Litter depth SD^2	3	39.56	780.79	0.00	774.78
% Forb Cover^2	3	39.62	780.84	0.00	774.84
25% VOR	2	40.13	781.35	0.00	777.34
25% VOR^2	3	42.01	783.24	0.00	777.22
% Bare Cover	2	42.34	783.56	0.00	779.56
0% VOR	2	42.85	784.08	0.00	780.08
100% VOR	2	43.85	785.07	0.00	781.06
0% VOR^2	3	44.80	786.02	0.00	780.02
Litter depth SD	2	45.44	786.66	0.00	782.66
Null	1	47.12	788.34	0.00	786.34
% Grass Cover	2	49.07	790.29	0.00	786.28

[a]Number of parameters.
[b]Akaike's Information Criterion, corrected for small sample size.
[c]Difference in Akaike's Information Criterion, corrected for small sample size.
[d]Akaike weights.
[e]Deviance or -2*loglikelihood.

Table 3.9 ***A priori*** **candidate models used to estimate landscape-scale selection of vegetation metrics by female SAT-PTT-marked lesser prairie-chickens within Colorado. Lesser prairie-chickens were translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019 but locations and vegetation were collected from 2018-2020. Models include covariates included averaged, percent cover of; bare ground, forb, grass, litter, and shrub; averaged visual obstruction reading (VOR) at 0%, 25%, 50%, 75%, and 100%; averaged litter depth and standard deviation of averaged litter depth, a quadratic term of each covariate, and a null model.**

Model	K[a]	Δ AICc[c]	AICc[b]	w_i[d]	Deviance[e]
% Grass Cover^2	3	0.00	847.70	0.91	841.70
% Shrub Cover^2	3	5.36	853.06	0.06	847.04
% Shrub Cover	2	8.67	856.37	0.01	852.36
Litter depth SD^2	3	9.39	857.09	0.01	851.08
Litter depth	2	13.46	861.16	0.00	857.16
% Bare Cover^2	3	14.08	861.78	0.00	855.76
Litter depth^2	3	15.25	862.95	0.00	856.94
25% VOR^2	3	15.69	863.39	0.00	857.38
0% VOR^2	3	19.18	866.88	0.00	860.88
50% VOR	2	20.19	867.89	0.00	863.88
% Littler Cover	2	20.92	868.62	0.00	864.62
50% VOR^2	3	21.14	868.84	0.00	862.84
% Littler Cover^2	3	22.40	870.10	0.00	864.10
% Bare Cover	2	27.33	875.03	0.00	871.02
% Grass Cover	2	27.89	875.59	0.00	871.60
% Forb Cover^2	3	28.47	876.17	0.00	870.16
0% VOR	2	28.48	876.18	0.00	872.18
75% VOR	2	29.04	876.74	0.00	872.74
75% VOR^2	3	30.12	877.82	0.00	871.82
Null	1	31.73	879.43	0.00	877.42
25% VOR	2	32.00	879.70	0.00	875.70
% Forb Cover	2	32.72	880.42	0.00	876.42
Litter depth SD	2	33.03	880.73	0.00	876.72
100% VOR	2	33.72	881.42	0.00	877.42
100% VOR^2	3	35.73	883.43	0.00	877.42

[a]Number of parameters.
[b]Akaike's Information Criterion, corrected for small sample size.
[c]Difference in Akaike's Information Criterion, corrected for small sample size.
[d]Akaike weights.
[e]Deviance or -2*loglikelihood.

Table 3.10 *A priori* candidate models used to estimate landscape-scale selection of vegetation metrics by male SAT-PTT-marked lesser prairie-chickens within Kansas. Lesser prairie-chickens were translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019 but locations and vegetation were collected from 2018-2020. Models include covariates included averaged, percent cover of; bare ground, forb, grass, litter, and shrub; averaged visual obstruction reading (VOR) at 0%, 25%, 50%, 75%, and 100%; averaged litter depth and standard deviation of averaged litter depth, a quadratic term of each covariate, and a null model.

Model	K[a]	Δ AICc[c]	AICc[b]	w_i[d]	Deviance[e]
25% VOR	2	0.00	2419.69	0.56	2415.68
25% VOR^2	3	0.68	2420.36	0.40	2414.36
0% VOR	2	6.21	2425.90	0.03	2421.90
0% VOR^2	3	7.92	2427.60	0.01	2421.60
% Shrub Cover	2	62.15	2481.84	0.00	2477.84
% Shrub Cover^2	3	62.58	2482.27	0.00	2476.26
50% VOR^2	3	70.80	2490.49	0.00	2484.48
75% VOR^2	3	71.45	2491.13	0.00	2485.12
% Littler Cover^2	3	89.22	2508.90	0.00	2502.90
50% VOR	2	92.49	2512.17	0.00	2508.18
% Littler Cover	2	94.68	2514.36	0.00	2510.36
75% VOR	2	94.86	2514.54	0.00	2510.54
100% VOR^2	3	98.82	2518.50	0.00	2512.50
100% VOR	2	117.98	2537.67	0.00	2533.66
% Grass Cover^2	3	120.68	2540.36	0.00	2534.36
% Bare Cover^2	3	127.46	2547.14	0.00	2541.14
% Bare Cover	2	133.61	2553.29	0.00	2549.30
% Grass Cover	2	138.04	2557.72	0.00	2553.72
% Forb Cover	2	143.14	2562.83	0.00	2558.82
Litter depth SD^2	3	144.16	2563.84	0.00	2557.84
% Forb Cover^2	3	145.14	2564.82	0.00	2558.82
Null	1	149.32	2569.00	0.00	2567.00
Litter depth SD	2	150.31	2569.99	0.00	2566.00
Litter depth	2	150.32	2570.00	0.00	2566.00
Litter depth^2	3	151.94	2571.63	0.00	2565.62

[a]Number of parameters.
[b]Akaike's Information Criterion, corrected for small sample size.
[c]Difference in Akaike's Information Criterion, corrected for small sample size.
[d]Akaike weights.
[e]Deviance or -2*loglikelihood.

Table 3.11 ***A priori*** **candidate models used to estimate landscape-scale selection of vegetation metrics by female SAT-PTT-marked lesser prairie-chickens within Kansas. Lesser prairie-chickens were translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019, but locations and vegetation were collected from 2018-2020. Models include covariates included averaged, percent cover of; bare ground, forb, grass, litter, and shrub; averaged visual obstruction reading (VOR) at 0%, 25%, 50%, 75%, and 100%; averaged litter depth and standard deviation of averaged littler depth, a quadratic term of each covariate, and a null model.**

Model	K[a]	Δ AICc[c]	AICc[b]	w_i[d]	Deviance[e]
50% VOR^2	3	0.00	2518.91	1.00	2512.90
% Littler Cover^2	3	13.09	2532.01	0.00	2526.00
25% VOR^2	3	15.49	2534.40	0.00	2528.40
% Littler Cover	2	16.23	2535.15	0.00	2531.14
75% VOR^2	3	19.60	2538.52	0.00	2532.52
0% VOR^2	3	28.91	2547.83	0.00	2541.82
25% VOR	2	29.52	2548.43	0.00	2544.42
50% VOR	2	34.90	2553.81	0.00	2549.80
0% VOR	2	35.39	2554.30	0.00	2550.30
% Shrub Cover	2	36.85	2555.77	0.00	2551.76
% Shrub Cover^2	3	37.53	2556.44	0.00	2550.44
100% VOR^2	3	47.52	2566.44	0.00	2560.44
75% VOR^2	2	47.64	2566.55	0.00	2562.54
% Bare Cover	2	52.38	2571.29	0.00	2567.28
% Bare Cover^2	3	53.96	2572.87	0.00	2566.86
% Forb Cover	2	54.89	2573.80	0.00	2569.80
% Forb Cover^2	3	56.89	2575.80	0.00	2569.80
% Grass Cover^2	3	58.46	2577.37	0.00	2571.36
100% VOR	2	63.01	2581.93	0.00	2577.92
Litter depth^2	3	67.79	2586.70	0.00	2580.70
Null	1	69.10	2588.02	0.00	2586.02
Litter depth SD	2	70.10	2589.02	0.00	2585.02
Litter depth	2	70.59	2589.50	0.00	2585.50
% Grass Cover	2	70.91	2589.82	0.00	2585.82
Litter depth SD^2	3	71.81	2590.72	0.00	2584.72

[a]Number of parameters.
[b]Akaike's Information Criterion, corrected for small sample size.
[c]Difference in Akaike's Information Criterion, corrected for small sample size.
[d]Akaike weights.
[e]Deviance or -2*loglikelihood.

Table 3.12 Mean (±SD) values of vegetation characteristics measured at all SAT-PTT equipped lesser-prairie chicken used locations and randomly paired available locations within 300 m (*n* = 1,670) from 2018-2020. Lesser prairie-chickens were translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019.

	Used Location		Paired Available Location	
Variable	$\bar{x}$	**SD**	$\bar{x}$	**SD**
Veg Height (cm)	56.98	17.66	58.29	18.40
Visual Obstruction (dm)				
100%	0.79	0.88	0.89	0.98
75%	1.40	1.10	1.51	1.22
50%	1.90	1.36	2.01	1.49
25%	5.05	2.68	5.20	2.94
0%	6.30	2.66	6.42	2.83
Percent Cover				
Litter	15.74	13.17	15.55	12.61
Grass	58.24	23.84	58.08	23.49
Shrub	2.78	7.75	2.65	6.91
Forb	11.38	12.44	11.46	12.18
Bare	13.93	12.81	14.63	13.66
Litter Depth (cm)	1.43	0.97	1.45	1.09
Litter Depth SD	1.29	1.81	1.37	1.94

Table 3.13 Mean (±SD) values of vegetation characteristics measured at breeding season (Mar 15-Sep 15) SAT-PTT equipped lesser-prairie chicken used locations and randomly paired available locations within 300 m (*n* = 1,220) from 2018-2020. Lesser prairie-chickens were translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019.

	Used Location		Paired Available Location	
Variable	$\bar{x}$	**SD**	$\bar{x}$	**SD**
Veg Height (cm)	56.90	18.91	55.54	17.60
Visual Obstruction (dm)				
100%	0.90	0.99	0.76	0.85
75%	1.53	1.25	1.37	1.11
50%	2.04	1.52	1.85	1.36
25%	5.11	2.85	4.97	2.67
0%	6.30	2.75	6.18	2.65
Percent Cover				
Litter	16.64	12.73	16.52	13.07
Grass	56.95	23.49	56.35	23.66
Shrub	2.28	6.58	2.36	7.03
Forb	12.50	13.05	12.75	13.16
Bare	14.34	12.79	14.38	13.19
Litter Depth (cm)	1.43	0.98	1.43	0.94
Litter Depth SD	1.29	1.81	1.26	1.68

Table 3.14 Mean (±SD) values of vegetation characteristics measured at female SAT-PTT equipped lesser-prairie chicken used locations and randomly paired available locations within 300 m (*n* = 852) from 2018-2020. Lesser prairie-chickens were translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019.

	Used Location		Paired Available Location	
Variable	$\bar{x}$	**SD**	$\bar{x}$	**SD**
Veg Height (cm)	55.22	15.36	56.70	16.83
Visual Obstruction (dm)				
100%	0.75	0.82	0.87	0.97
75%	1.34	1.05	1.48	1.21
50%	1.85	1.30	2.01	1.48
25%	4.69	2.17	4.88	2.51
0%	5.91	2.20	6.05	2.40
Percent Cover				
Litter	15.48	12.91	15.24	12.50
Grass	55.85	24.51	56.78	23.43
Shrub	3.27	8.23	3.12	7.53
Forb	13.51	13.84	12.96	13.48
Bare	13.59	13.08	13.66	13.09
Litter Depth (cm)	1.44	0.84	1.41	0.80
Litter Depth SD	1.31	1.61	1.32	1.61

Table 3.15 Mean (±SD) values of vegetation characteristics measured at male SAT-PTT equipped lesser-prairie chicken used locations and randomly paired available locations within 300 m (*n* = 814) from 2018-2020. Lesser prairie-chickens were translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019.

	Used Location		Paired Available Location	
Variable	$\bar{x}$	**SD**	$\bar{x}$	**SD**
Veg Height (cm)	58.88	19.64	59.95	19.83
Visual Obstruction (dm)				
100%	0.84	0.94	0.91	1.00
75%	1.47	1.15	1.54	1.25
50%	1.95	1.42	2.02	1.50
25%	5.44	3.07	5.55	3.30
0%	6.72	3.02	6.82	3.18
Percent Cover				
Litter	16.05	13.46	15.80	12.68
Grass	60.83	22.73	59.49	23.55
Shrub	2.26	7.19	2.12	6.13
Forb	9.10	10.22	9.90	10.48
Bare	14.25	12.51	15.70	14.19
Litter Depth (cm)	1.43	1.09	1.49	1.33
Litter Depth SD	1.27	2.01	1.41	2.23

Table 3.16 Mean (±SD) values of vegetation characteristics measured at Colorado SAT-PTT equipped lesser-prairie chicken used locations and randomly paired available locations within 300 m (*n* = 278) from 2018-2020. Lesser prairie-chickens were translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019.

	Used Location		**Paired Available Location**	
Variable	$\bar{x}$	**SD**	$\bar{x}$	**SD**
Veg Height (cm)	45.98	13.04	46.61	13.29
Visual Obstruction (dm)				
100%	0.51	0.92	0.45	0.79
75%	0.77	0.87	0.69	0.88
50%	1.00	1.16	0.88	1.06
25%	3.58	1.77	3.51	2.38
0%	4.89	1.70	4.65	1.73
Percent Cover				
Litter	8.63	8.07	9.35	9.35
Grass	52.27	20.83	55.12	19.56
Shrub	9.46	13.93	7.83	10.36
Forb	10.57	10.34	9.41	7.92
Bare	20.72	14.83	20.10	15.48
Litter Depth	1.03	0.51	1.00	0.54
Litter Depth SD	1.04	0.75	0.96	0.54

Table 3.17 Mean (±SD) values of vegetation characteristics measured at Kansas SAT-PTT equipped lesser-prairie chicken used locations and randomly paired available locations within 300 m (*n* = 1,390) from 2018-2020. Lesser prairie-chickens were translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019.

	Used Location		**Paired Available Location**	
Variable	$\bar{x}$	**SD**	$\bar{x}$	**SD**
Veg Height (cm)	59.14	17.64	60.61	18.41
Visual Obstruction (dm)				
100%	0.85	0.87	0.97	0.99
75%	1.53	1.10	1.67	1.22
50%	2.07	1.32	2.24	1.46
25%	5.34	2.73	5.54	2.93
0%	6.58	2.73	6.77	2.88
Percent Cover				
Litter	17.18	13.53	16.78	12.83
Grass	59.42	24.25	58.69	24.18
Shrub	1.45	4.78	1.62	5.44
Forb	11.55	12.83	11.85	12.83
Bare	12.58	11.93	13.55	13.02
Litter Depth (cm)	1.51	1.02	1.54	1.15
Litter Depth SD	1.34	1.95	1.45	2.10

Table 3.18 Mean (±SD) values of vegetation characteristics measured at nonbreeding season (Sep 16-Mar 14) SAT-PTT equipped lesser-prairie chicken used locations and randomly paired available locations within 300 m (*n* = 450) from 2018-2020. Lesser prairie-chickens were translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019.

	Used Location		**Paired Available Location**	
Variable	$\bar{x}$	**SD**	$\bar{x}$	**SD**
Veg Height (cm)	60.89	17.29	62.04	16.41
Visual Obstruction (dm)				
100%	0.86	0.96	0.85	0.95
75%	1.48	1.07	1.44	1.16
50%	2.03	1.36	1.94	1.39
25%	5.25	2.68	5.44	3.15
0%	6.61	2.67	6.74	3.03
Percent Cover				
Litter	13.63	13.23	12.58	11.80
Grass	63.37	23.63	61.13	23.28
Shrub	3.94	9.34	3.66	7.66
Forb	7.67	9.30	8.63	8.89
Bare	12.70*	11.64	15.44	15.79
Litter Depth (cm)	1.44	1.07	1.52	1.35
Litter Depth SD	1.37	2.13	1.58	2.24

Table 3.19 Mean (±SD) values of vegetation characteristics measured at lesser-prairie chicken nest locations and randomly paired available locations within 300 m (*n* = 114) from 2018-2020. Lesser prairie-chickens were translocated to U.S. Forest Service, Cimarron and Comanche National Grasslands, in Kansas and Colorado, USA, respectively, during 2016-2019.

	Nest Location		Paired Available Location	
Variable	$\bar{x}$	**SD**	$\bar{x}$	**SD**
Veg Height (cm)	55.53	11.10	53.21	14.88
Visual Obstruction (dm)				
100%	1.36	0.80	0.91	0.71
75%	2.14*	1.11	1.55	1.00
50%	2.50	1.18	1.95	1.13
25%	4.63	1.31	3.96	1.56
0%	5.98	1.42	5.37	1.66
Percent Cover				
Litter	13.65	9.31	12.27	9.54
Grass	70.04	17.44	65.27	21.92
Shrub	2.53	9.64	0.82	2.85
Forb	12.02	12.29	15.42	18.01
Bare	5.91	6.88	9.06	9.43
Litter Depth (cm)	1.68	0.74	1.65	1.11
Litter Depth SD	1.46	1.54	1.43	1.70

Figures

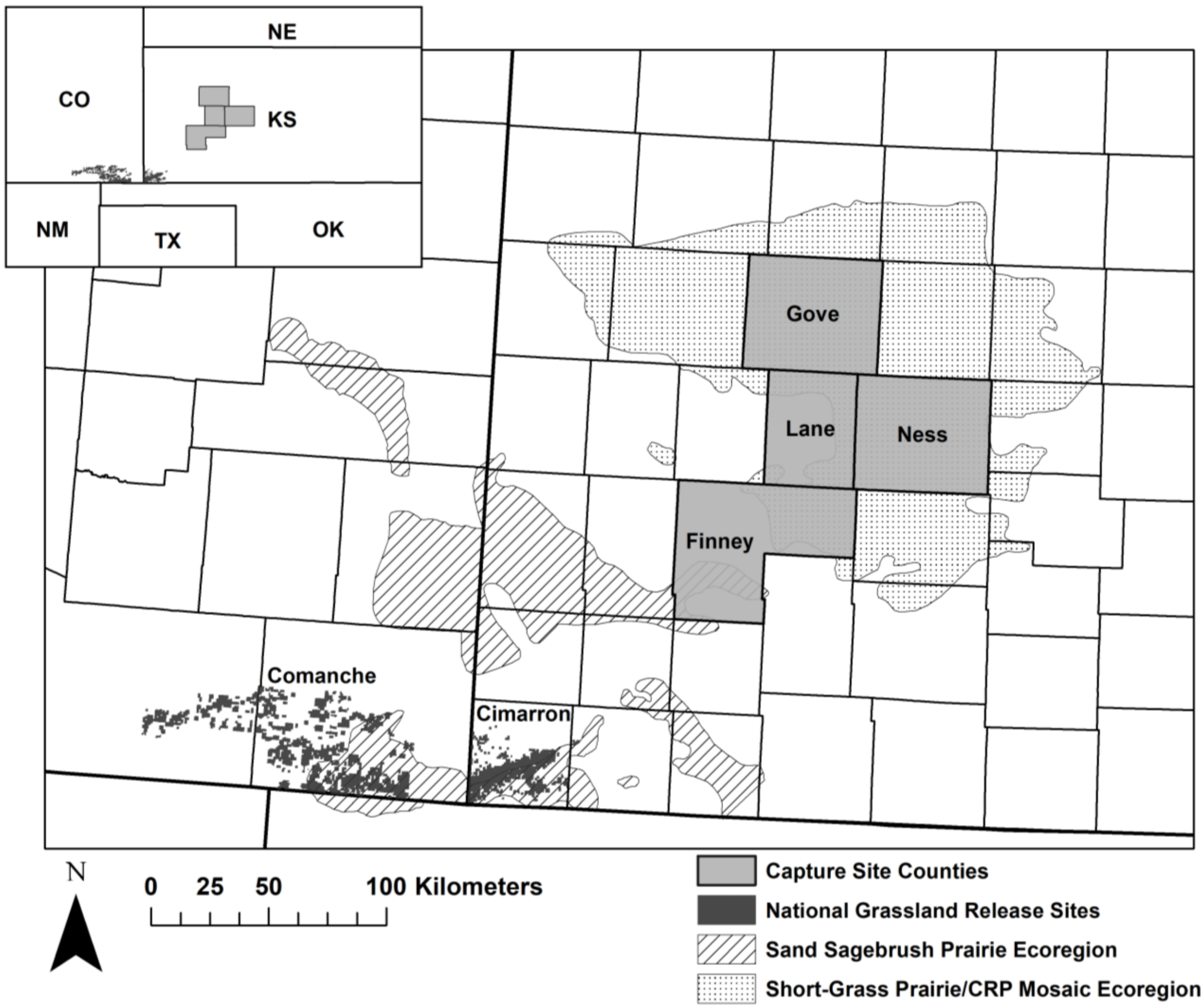

Figure 3.1 Locations of four capture counties (Gove, Lane, Ness, and Finney) in Kansas, USA, where lesser prairie-chickens were trapped on leks and released on the U.S. Forest Service, Cimarron and Comanche National Grasslands. Kansas and Colorado, USA, respectively, during 2016-2019, shown in dark gray. The capture site leks were in the Short-Grass Prairie/Conservation Reserve Program (CRP) Mosaic Ecoregion and release sites were in the Sand Sagebrush Prairie Ecoregion of the lesser prairie-chicken range.

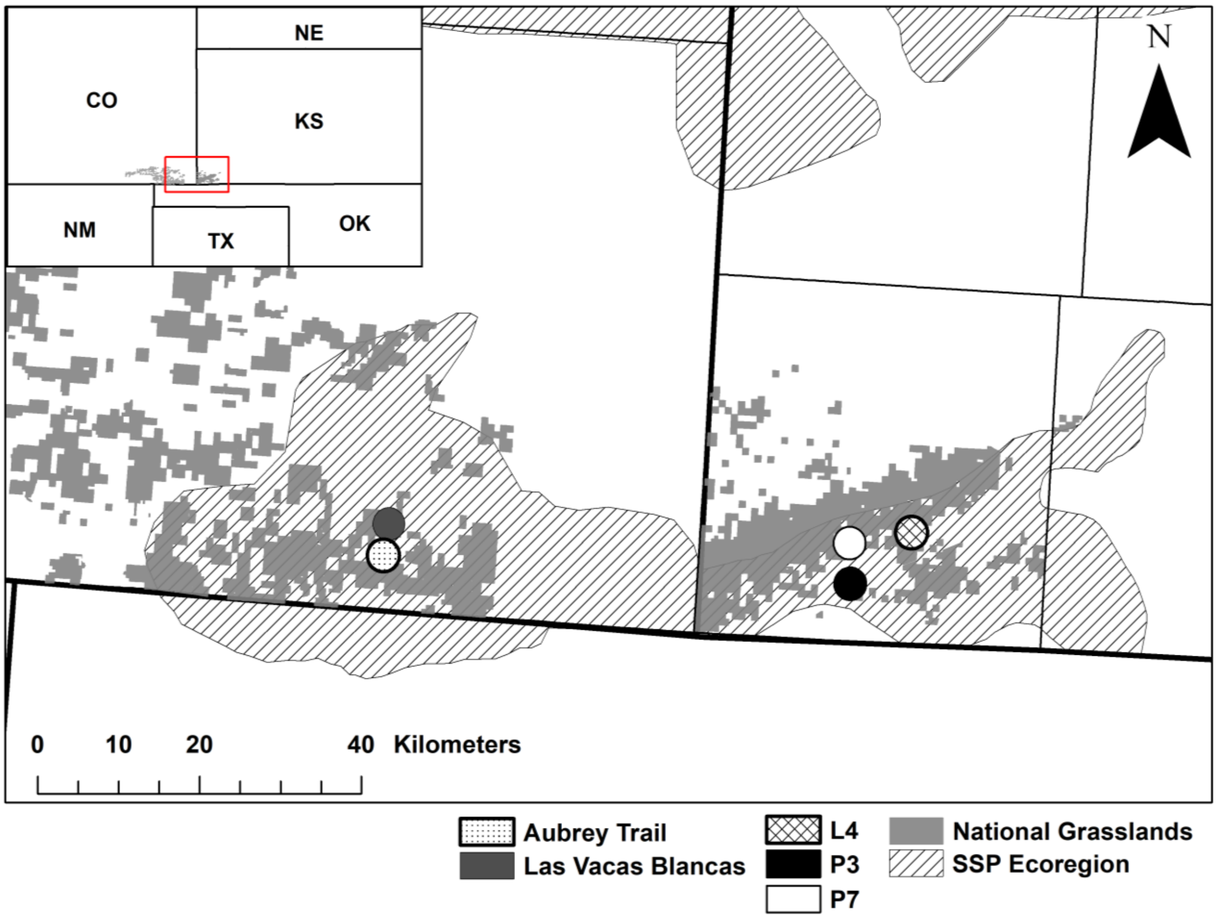

Figure 3.2Locations of release sites (either active or historic leks) on the U.S. Forest Service, Cimarron or Comanche National Grasslands, in Kansas (KS) and Colorado (CO), USA, respectively, during 2016-2019 in the Sand Sagebrush Prairie Ecoregion (SSP). Release sites were utilized as follows: CO Aubrey Trail (2016-2017) and Las Vacas Blancas (2018-2019); KS L4 (2019), P3 (2016-2018), and L7 (2018). Locations are buffered by a 2-km radius.

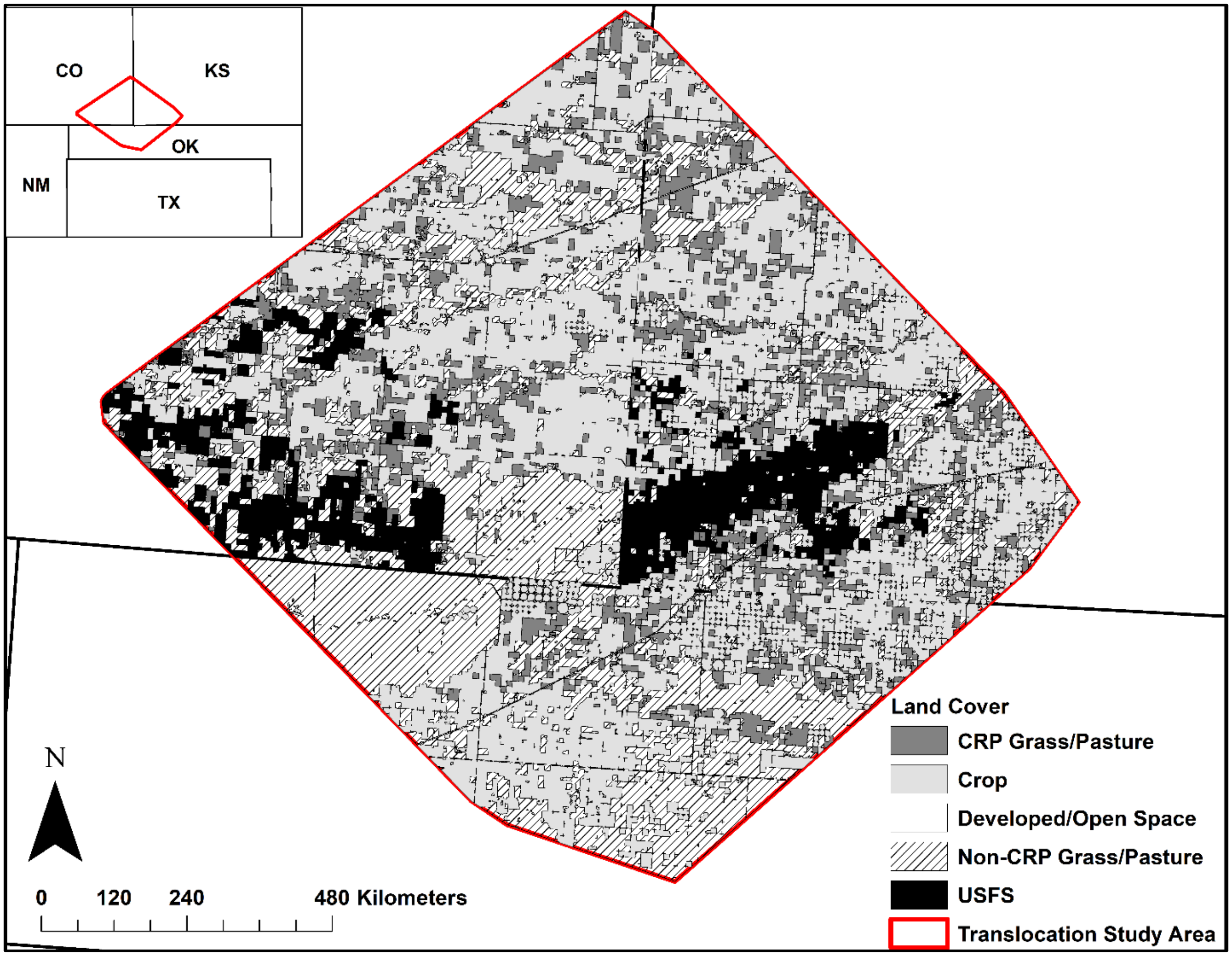

Figure 3.3 The study area in Kansas, Colorado, and Oklahoma, USA, detailing the extent of dominant land cover types encountered by dispersing and settling lesser prairie-chickens translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2021. Cover types include CRP Grass / Pasture (Conservation Reserve Program fields), crop, developed/open space (urban, water, wooded, etc.), Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO).

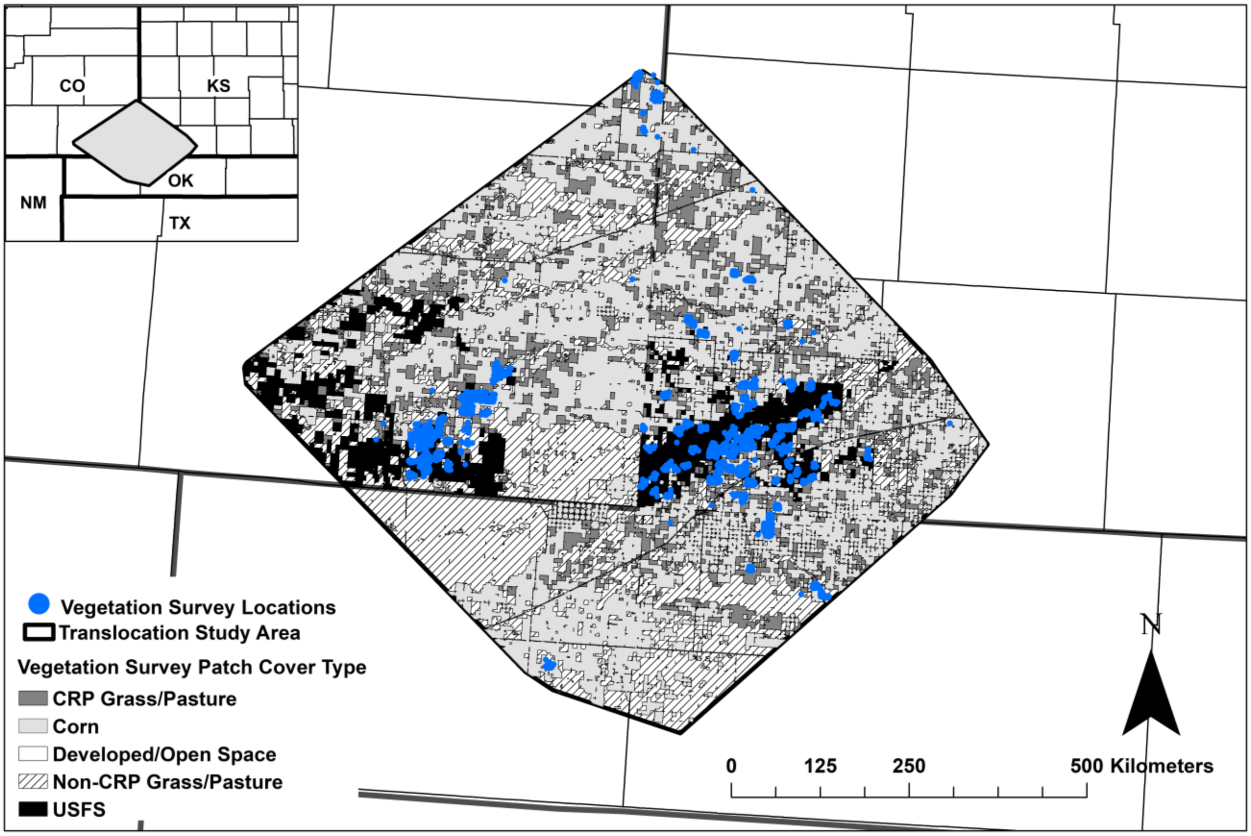

Figure 3.4 The study area in Kansas, Colorado, and Oklahoma, USA, detailing the extent of randomly selected available vegetation surveys and dominant land cover types encountered by dispersing and settling lesser prairie-chickens translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2018-2020. Cover types include CRP Grass / Pasture (Conservation Reserve Program fields), crop, developed/open space (urban, water, wooded, etc.), Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO).

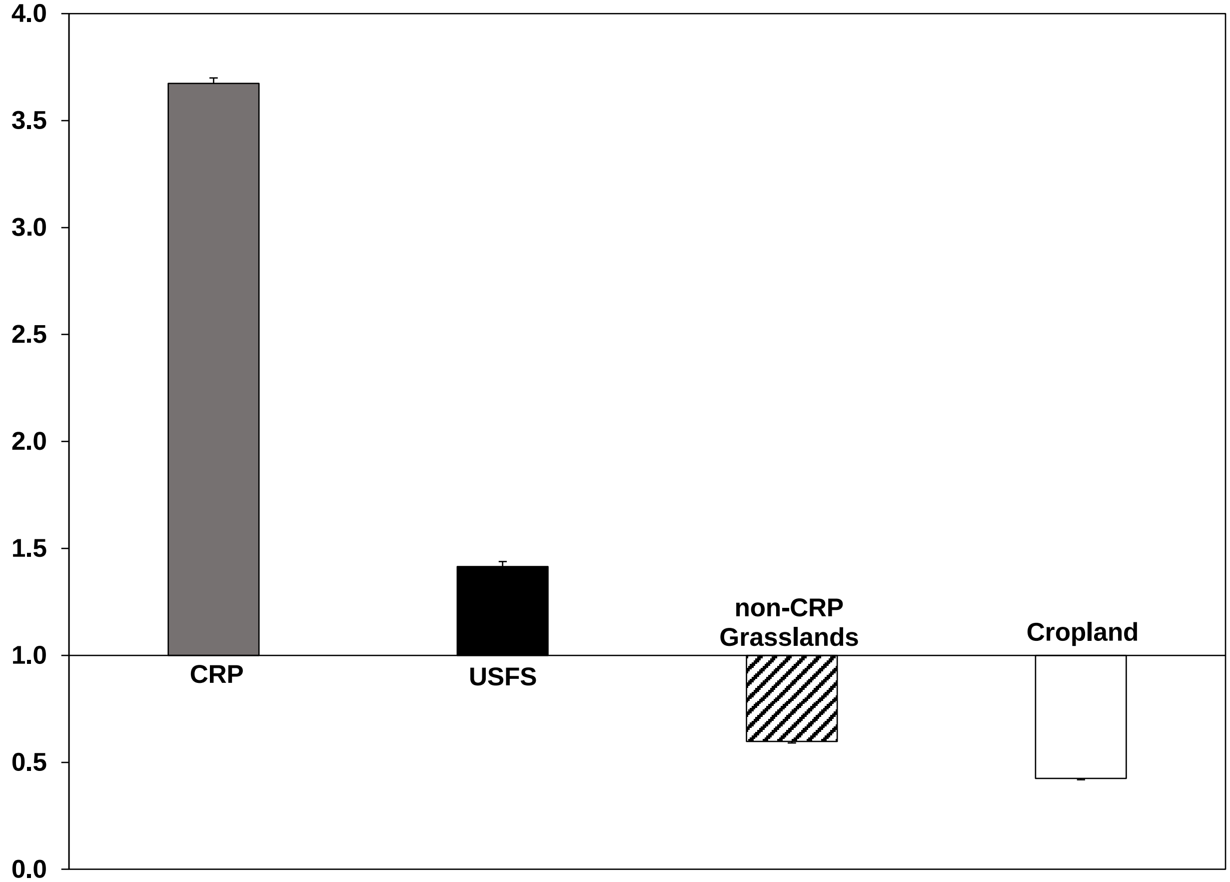

Figure 3.5 Resource selection ratios from translocated lesser prairie-chickens (Use: Availability; Manly et al. 2002) during the breeding season (Mar 15 – Sep 15) of four main cover types. Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

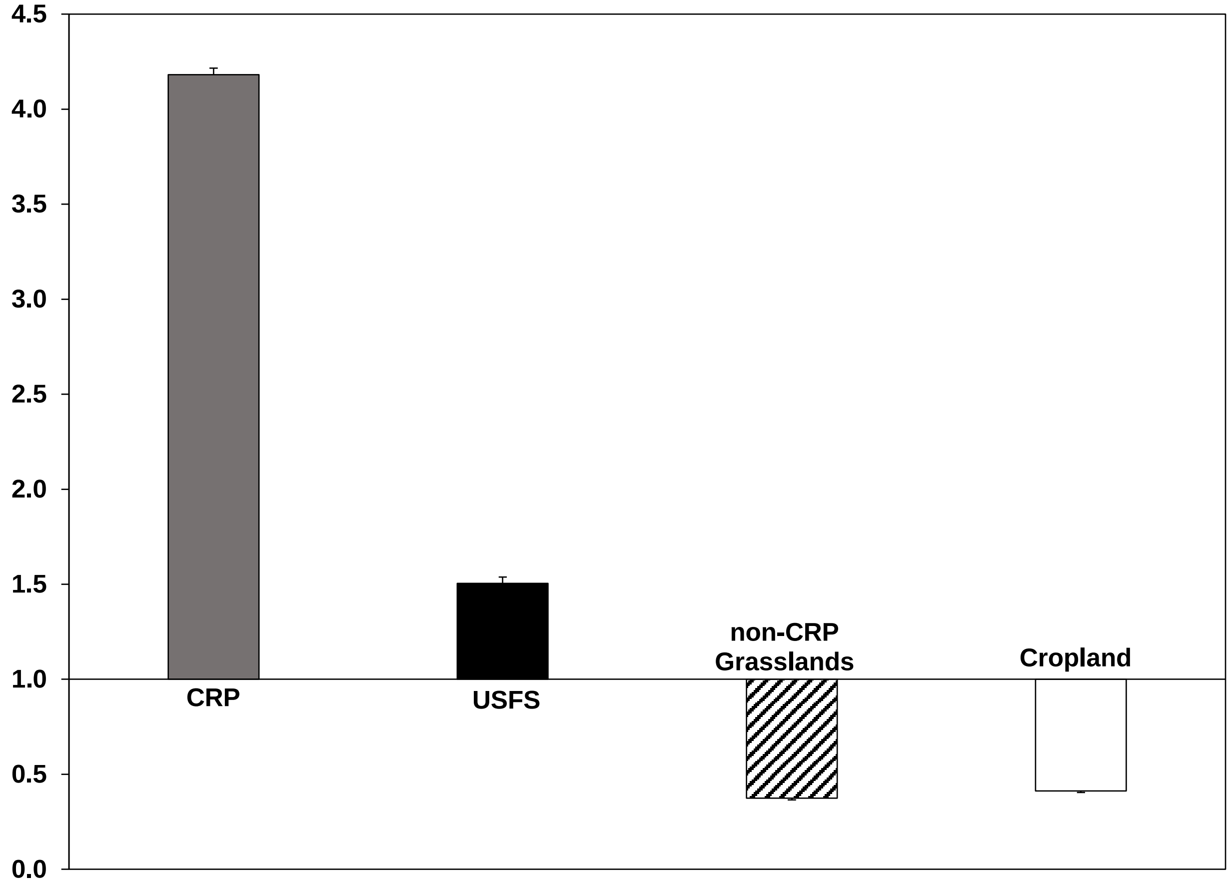

Figure 3.6 Resource selection ratios from translocated lesser prairie-chickens (Use: Availability; Manly et al. 2002) during the nonbreeding season (Sep 16 – Mar 14) of four main cover types. Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

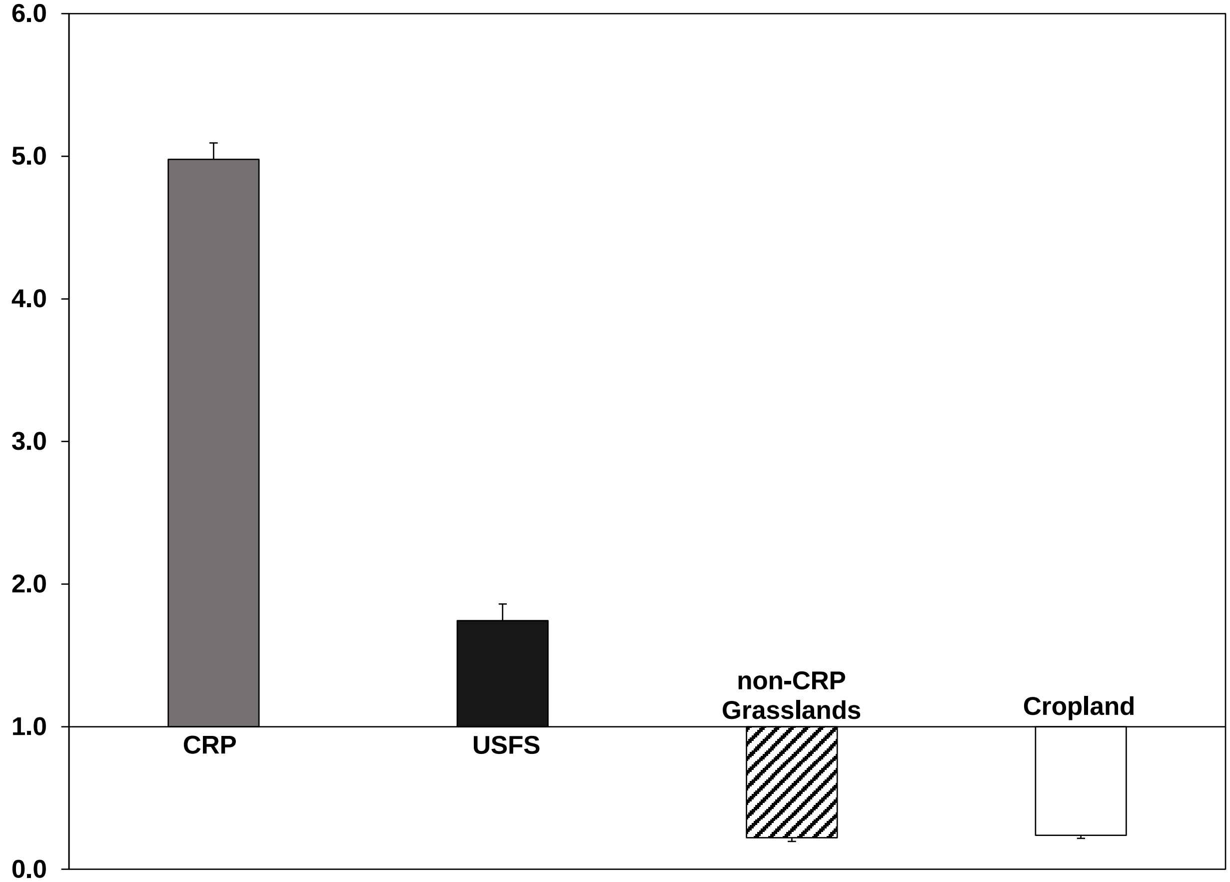

Figure 3.7 Resource selection ratios from VHF-marked translocated lesser prairie-chickens (Use: Availability; Manly et al. 2002) of four main cover types. Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

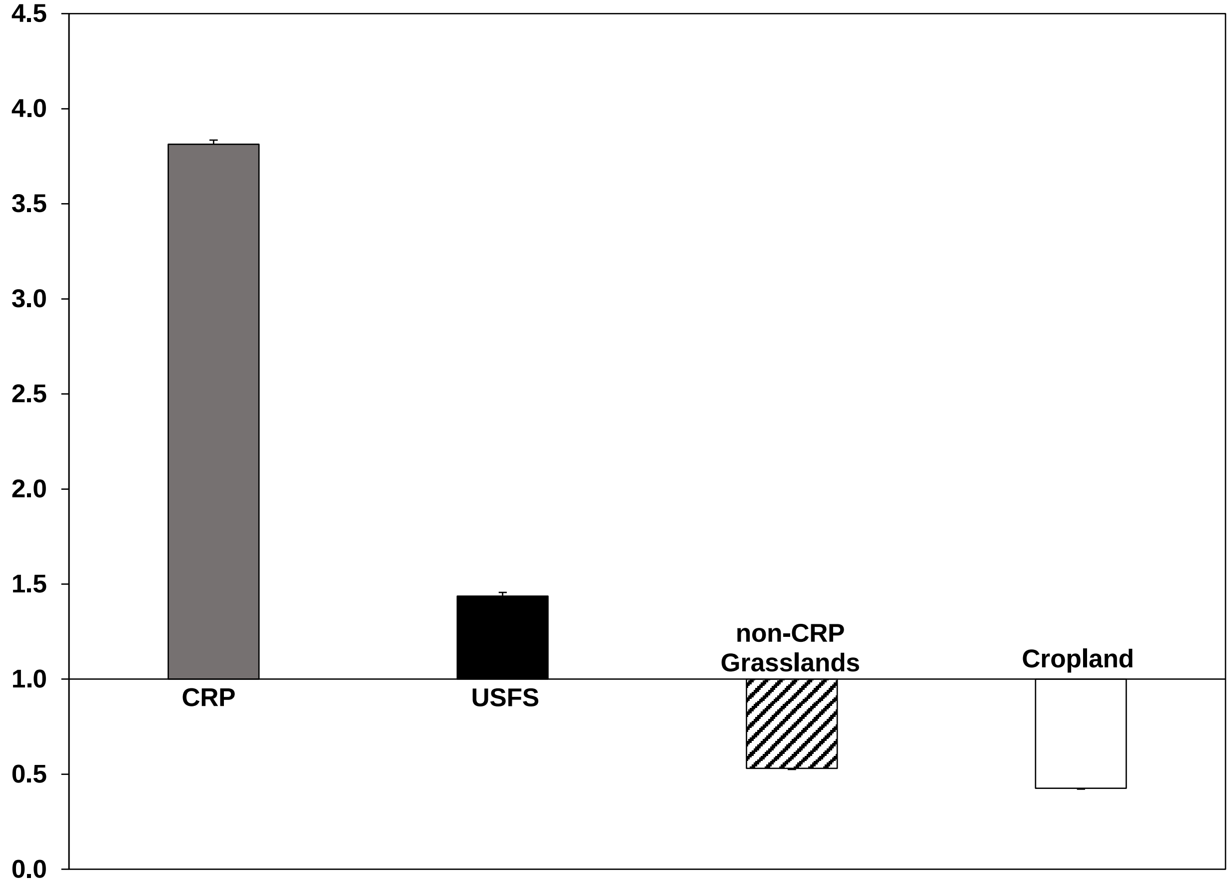

Figure 3.8 Resource selection ratios from SAT-PTT-marked translocated lesser prairie-chickens (Use: Availability; Manly et al. 2002) of four main cover types. Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

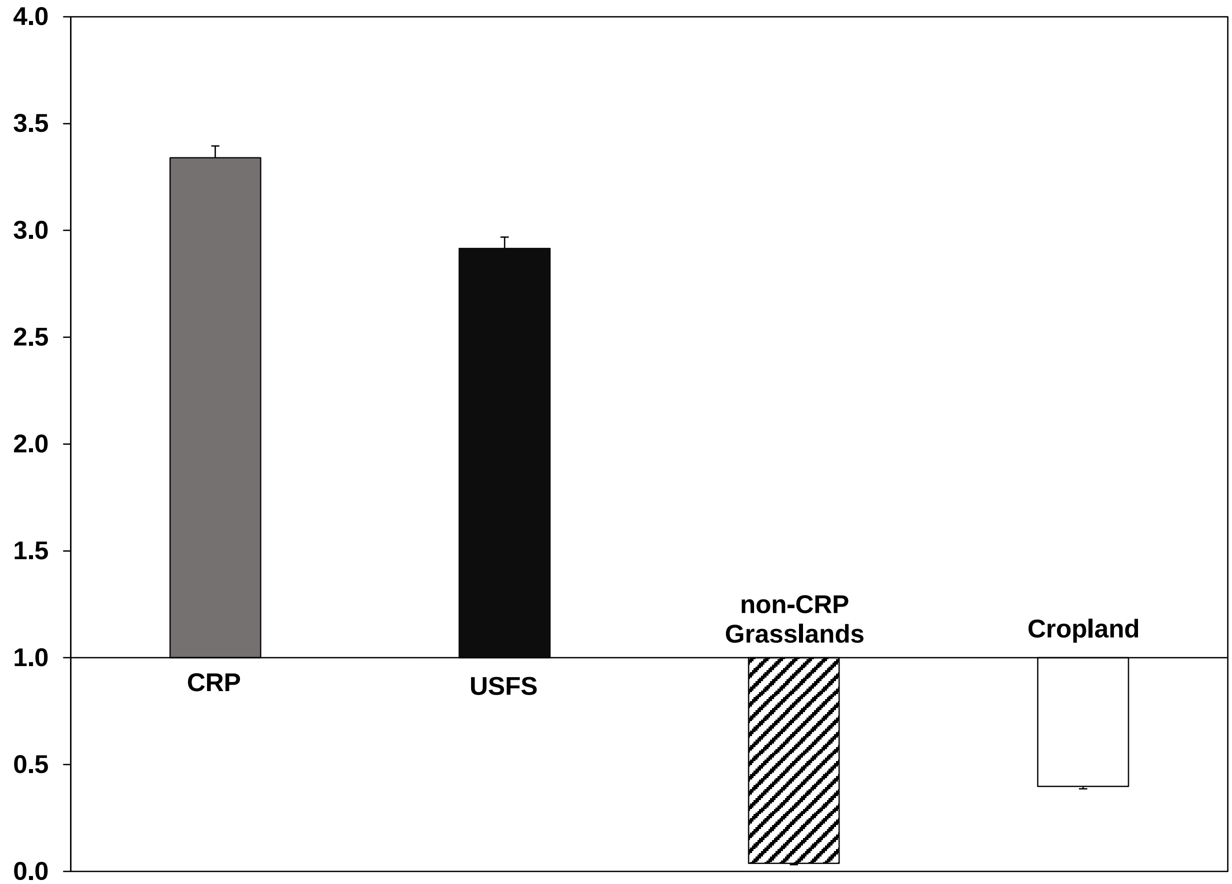

Figure 3.9 Resource selection ratios from female translocated lesser prairie-chickens in Colorado (Use: Availability; Manly et al. 2002) of four main cover. Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

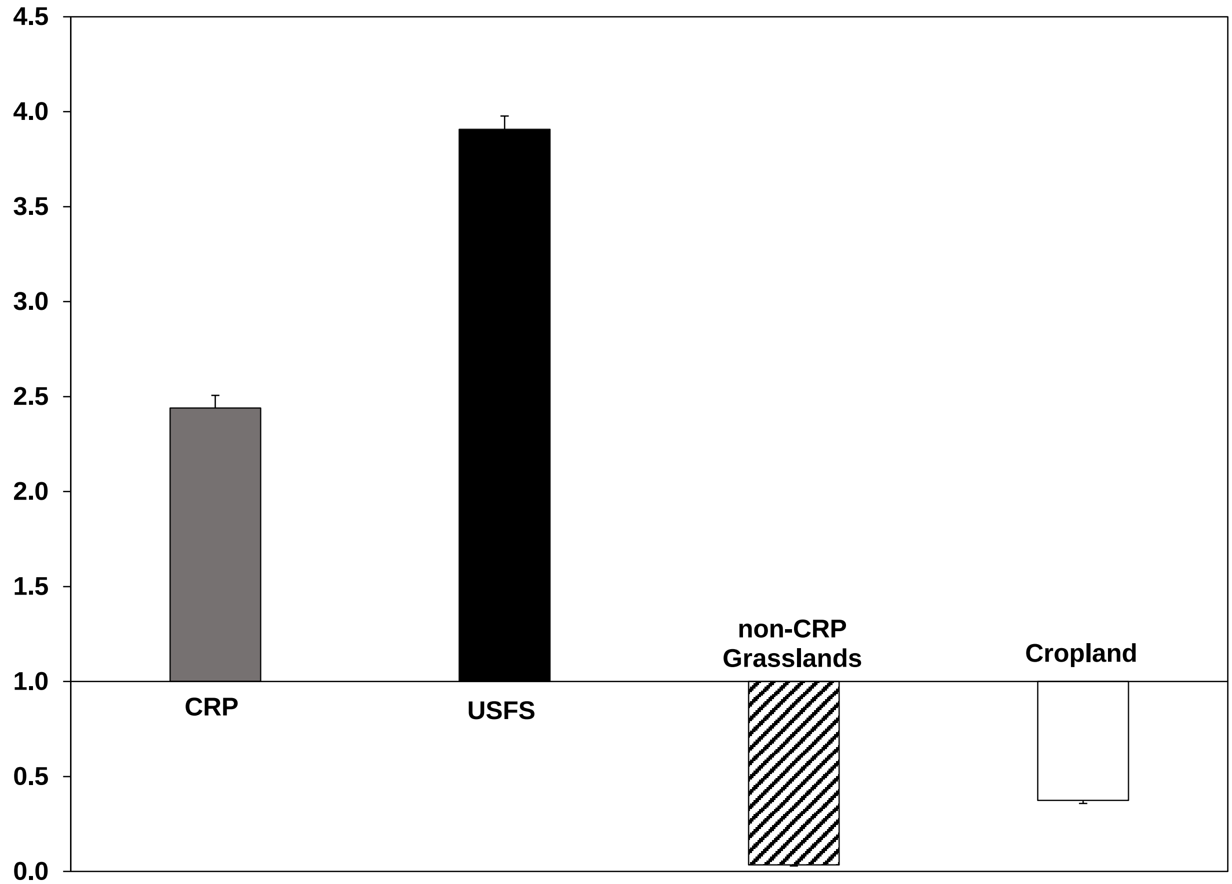

Figure 3.10 Resource selection ratios from male translocated lesser prairie-chickens in Colorado (Use: Availability; Manly et al. 2002) of four main cover types. Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

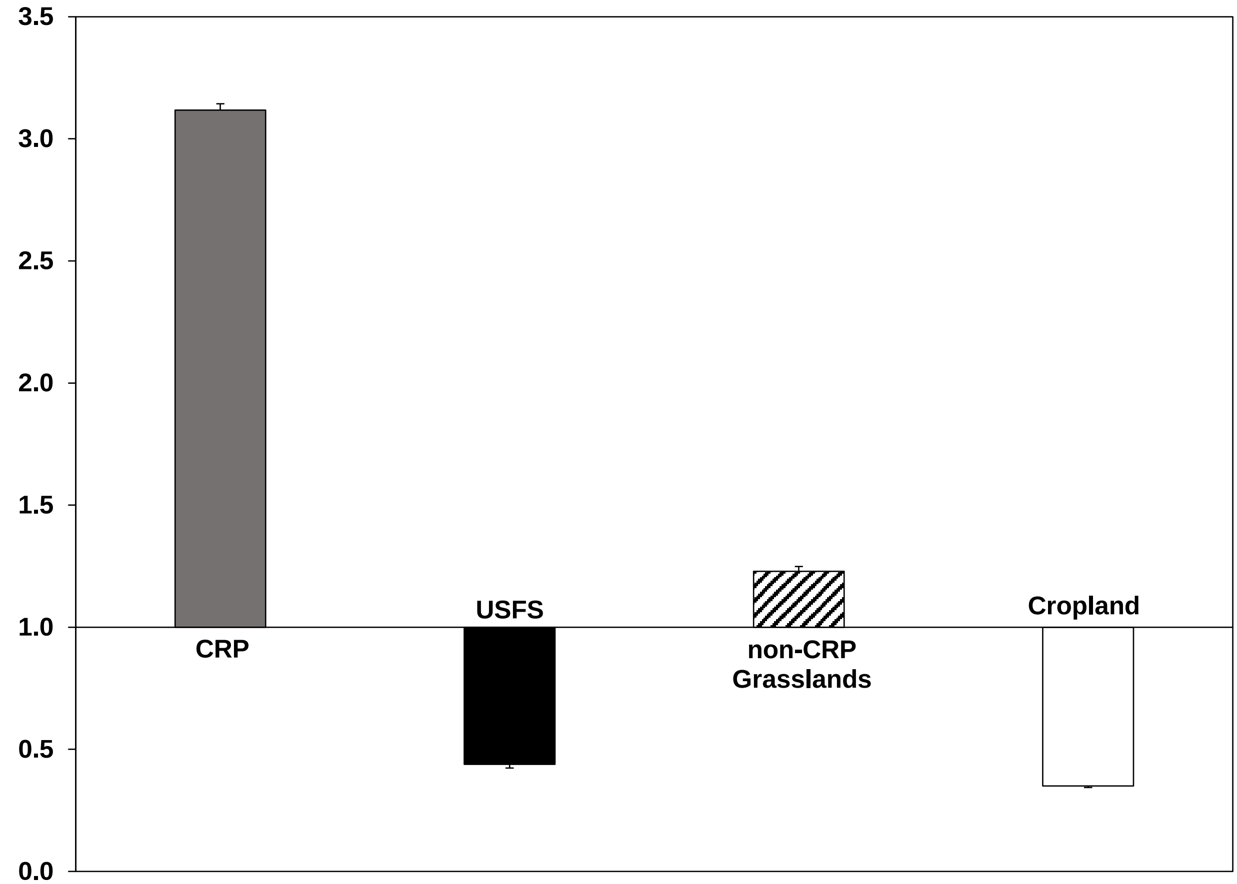

Figure 3.11 Resource selection ratios from female translocated lesser prairie-chickens in Kansas (Use: Availability; Manly et al. 2002) of four main cover types. Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

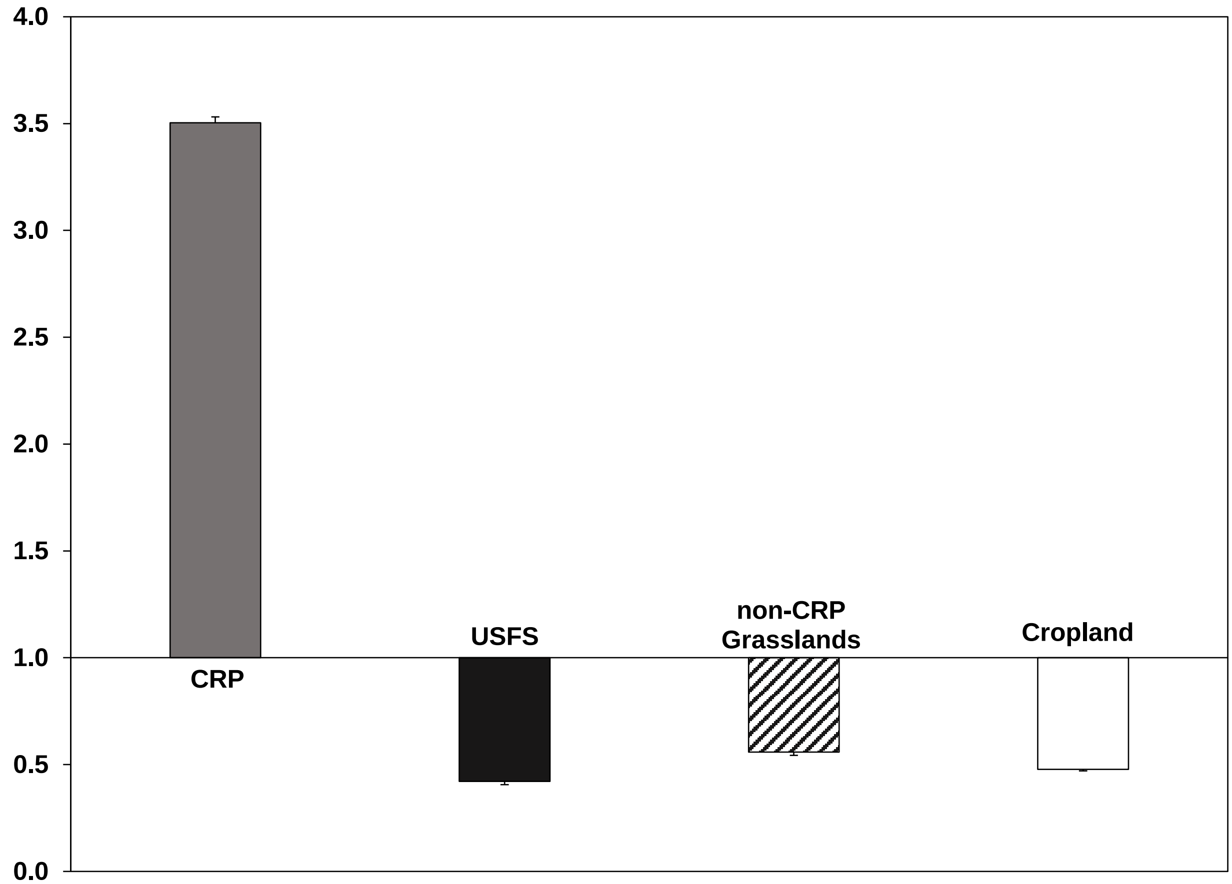

Figure 3.12 Resource selection ratios from male translocated lesser prairie-chickens in Kansas (Use: Availability; Manly et al. 2002) of four main cover types. Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

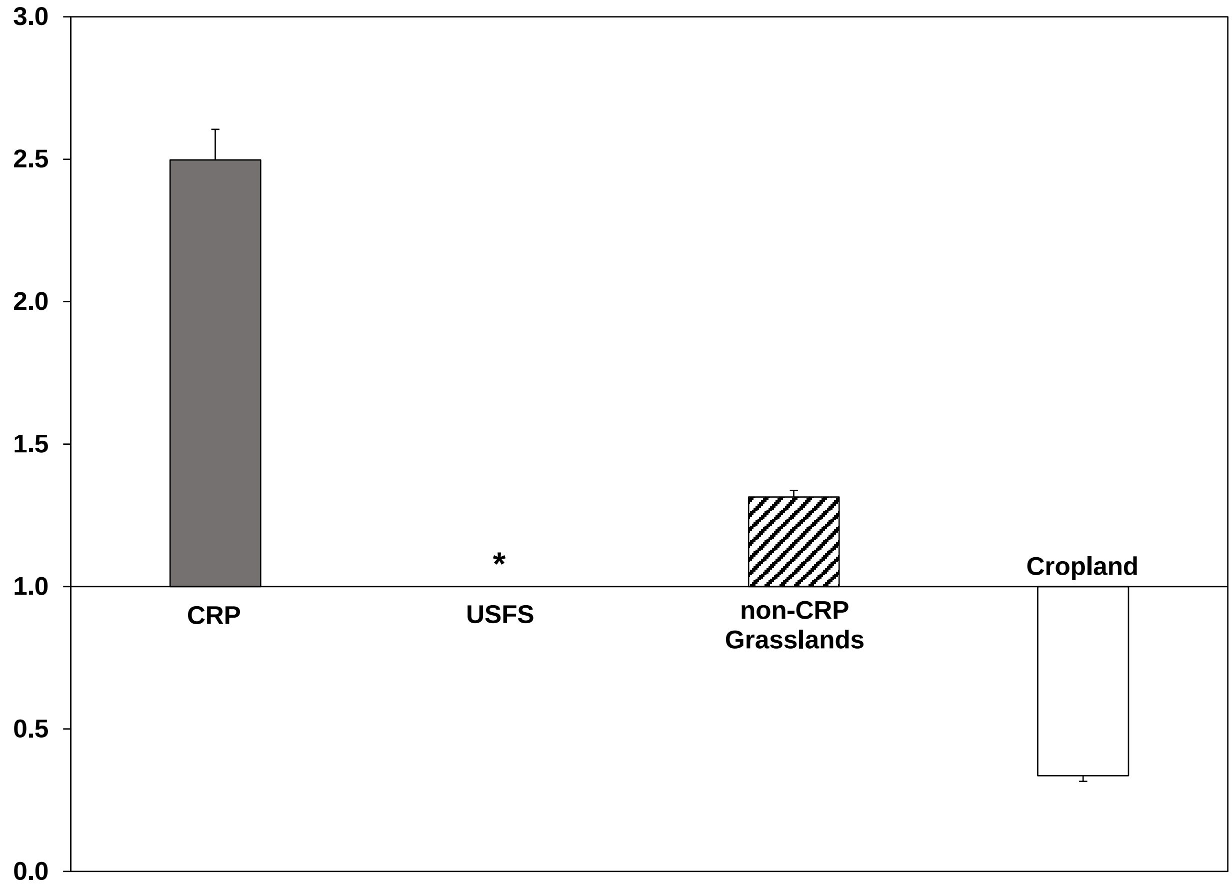

Figure 3.13 Resource selection ratios from female translocated lesser prairie-chickens in Oklahoma (Use: Availability; Manly et al. 2002) of four main cover types. Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020. Note: U.S. Forest Service land does not occur in Oklahoma within our study area.

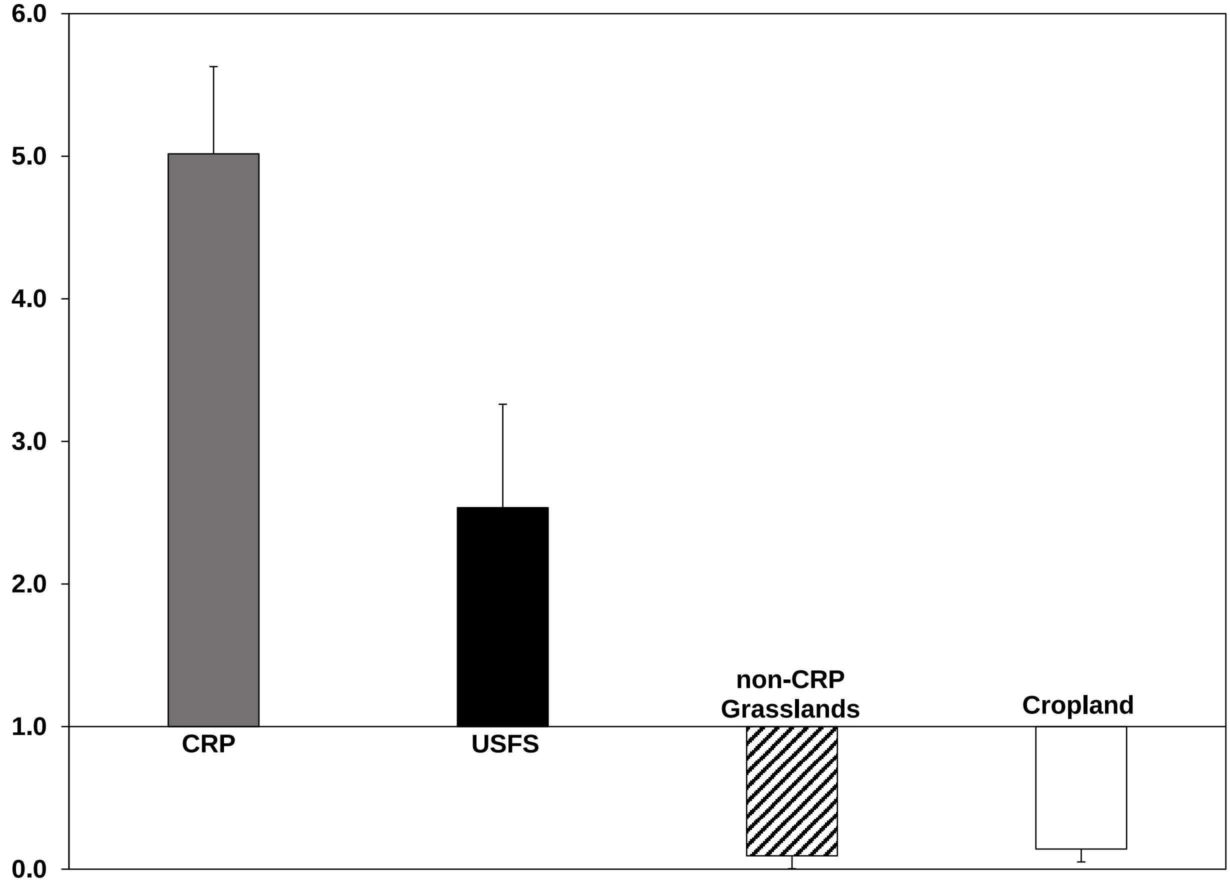

Figure 3.14 Resource selection ratios from nests of translocated lesser prairie-chickens (Use: Availability; Manly et al. 2002) of four main cover. Ratios >1.0 and <1.0 indicate positive selection and negative selection (avoidance), respectively. Cover types include CRP (Conservation Reserve Program fields), Crop, Non-CRP Grass/Pasture (Private Working Rangeland), and U.S. Forest Service, Cimarron (KS) and Comanche National Grasslands (CO). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 but locations are from 2017-2020.

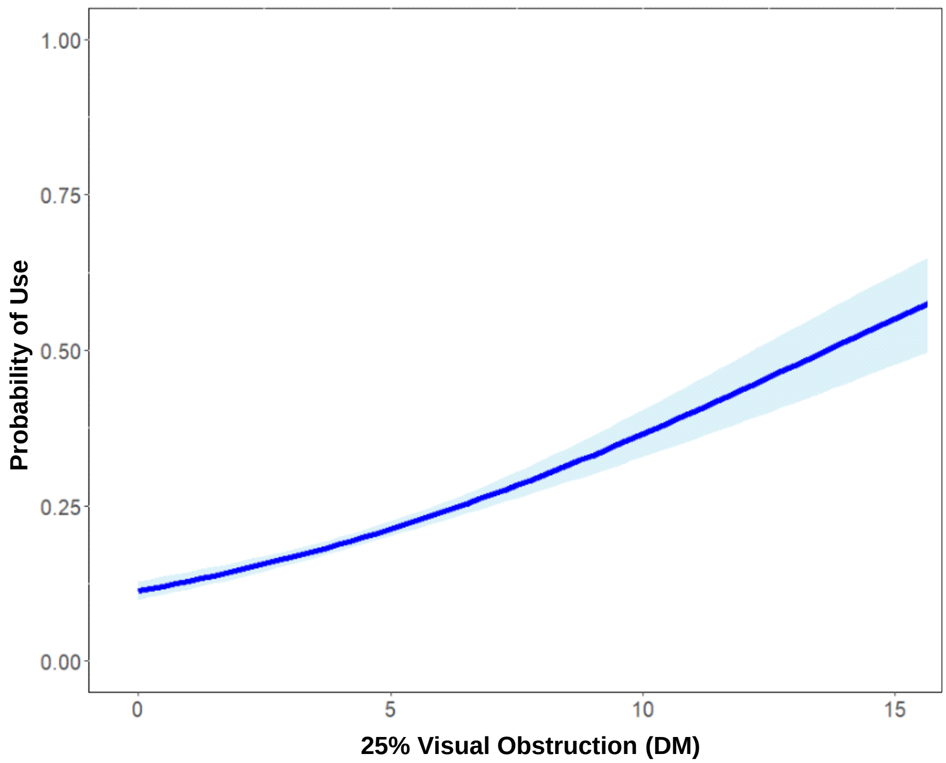

Figure 3.15 Relative probability of use (±95% CI) predicted based on quadratic relationship with 25% visual obstruction (VOR) by SAT-PTT-marked translocated lesser prairie-chickens at the landscape scale (i.e., entire study area). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019; however, locations are from 2018-2020.

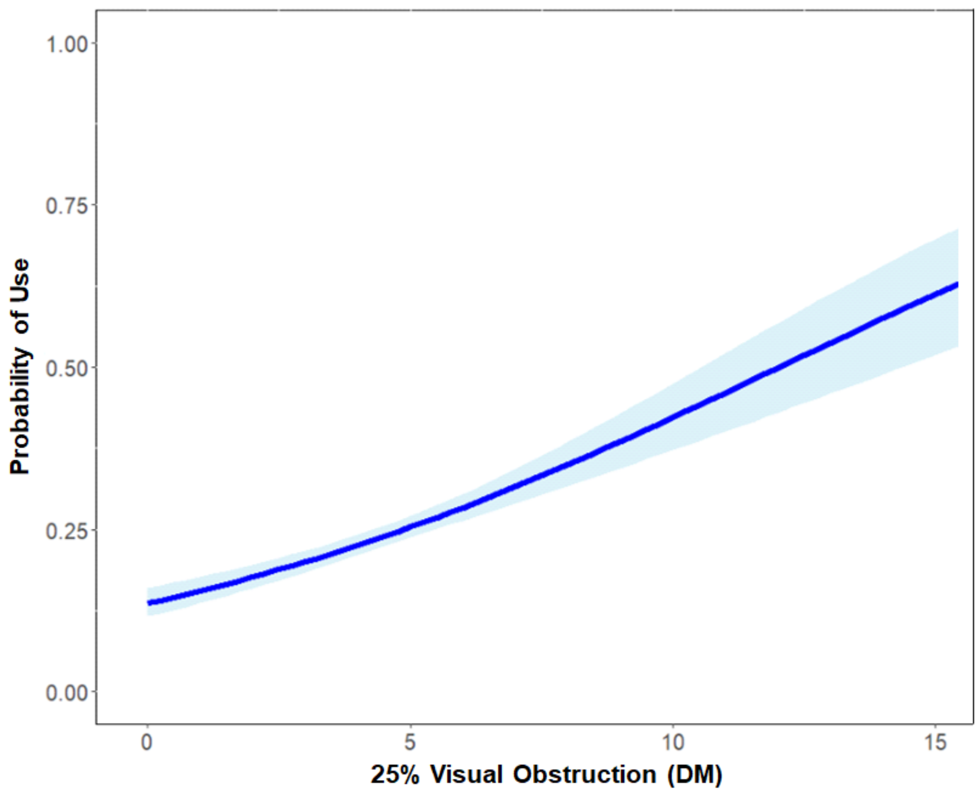

Figure 3.16 Relative probability of use (±95% CI) predicted based on linear relationship with 25% visual obstruction by SAT-PTT-marked translocated lesser prairie-chickens during the breeding season (Mar 15 – Sep 15) at the landscape scale (i.e., entire study area). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019; however, locations are from 2018-2020.

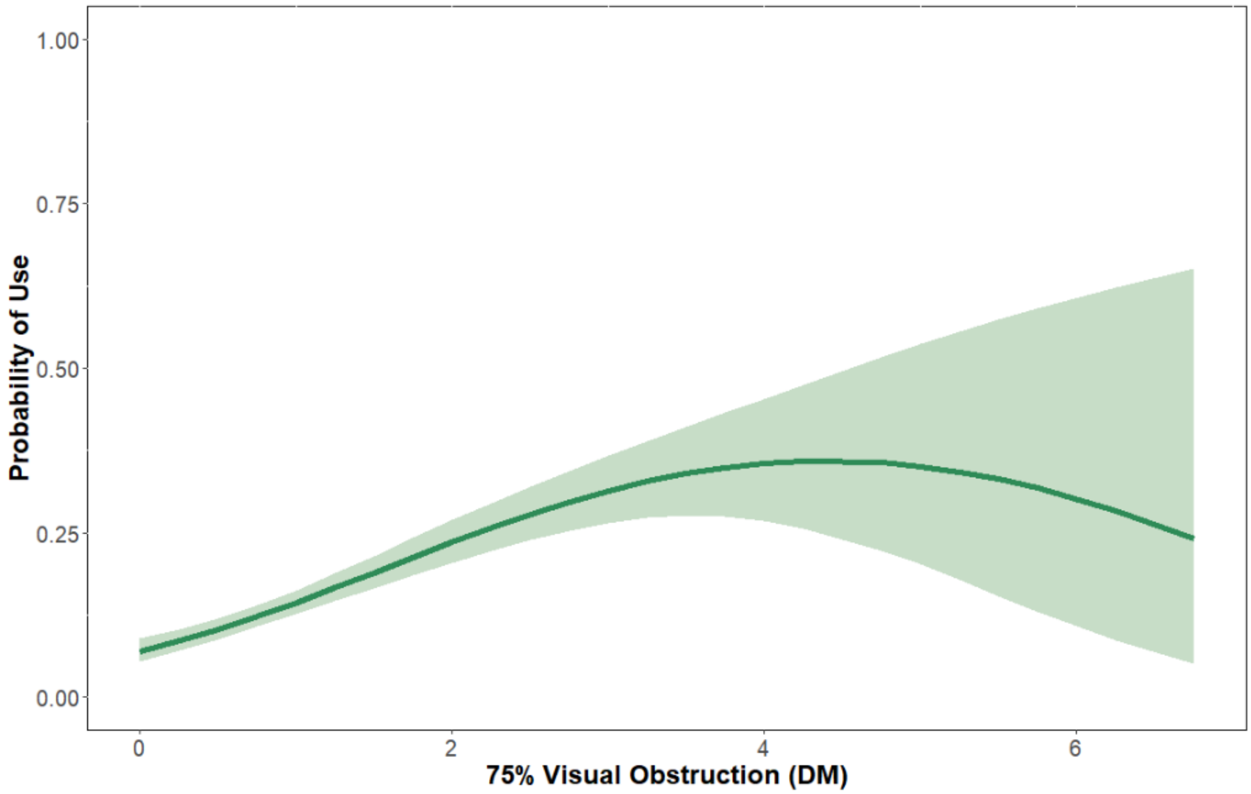

Figure 3.17 Relative probability of use (±95% CI) predicted based on quadratic relationship with 75% visual obstruction by SAT-PTT-marked translocated lesser prairie-chickens during the nonbreeding season (Sep 16 – Mar 14) at the landscape scale (i.e. entire study area). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 however locations are from 2018-2020.

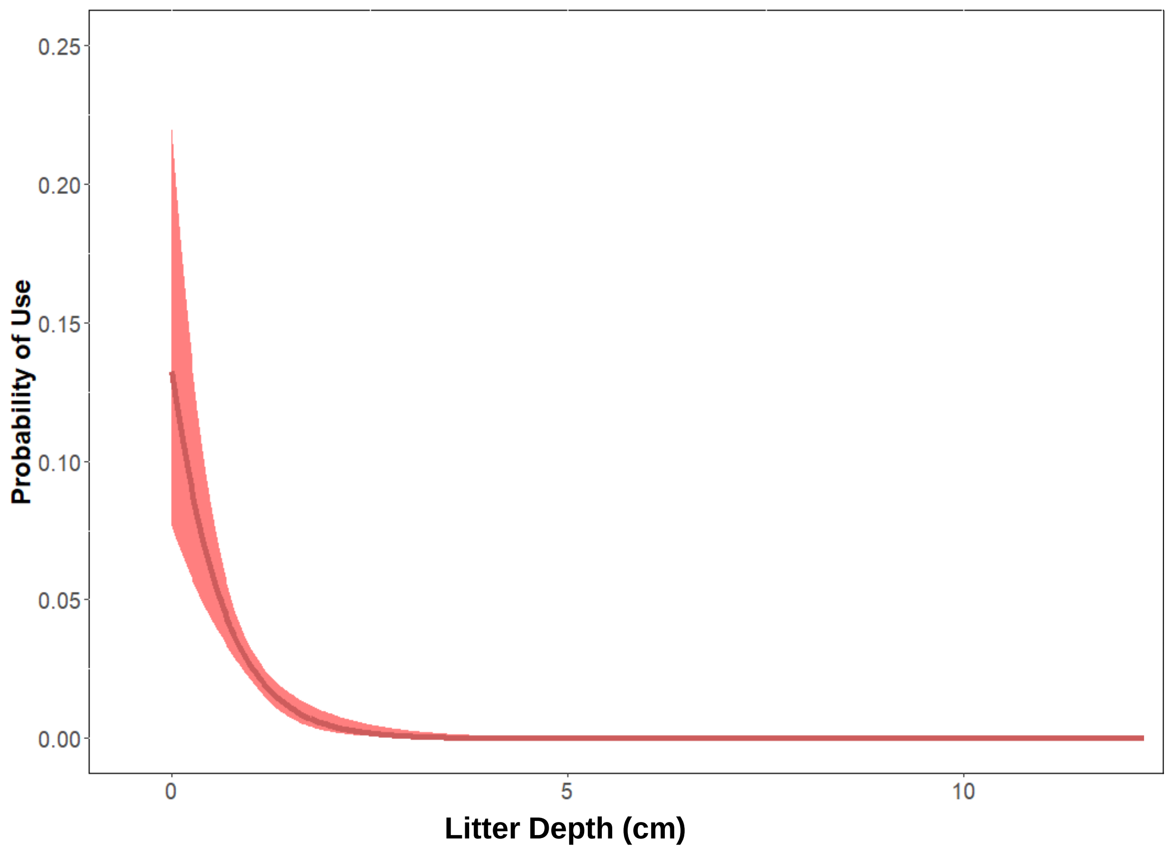

Figure 3.18 Relative probability of use (±95% CI) predicted based on linear relationship with of litter depth by SAT-PTT male lesser prairie-chickens in Colorado at the landscape scale (i.e., entire study area). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019; however, locations are from 2018-2020.

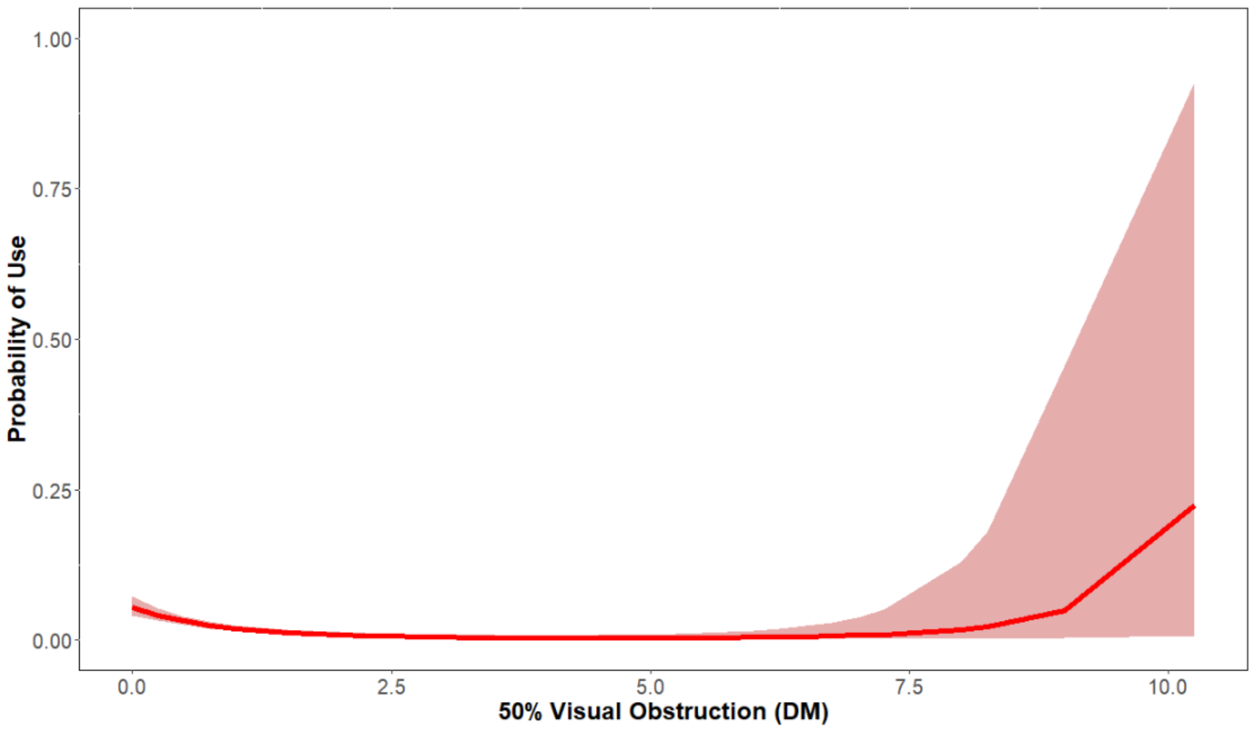

Figure 3.19 Relative probability of use (±95% CI) predicted based on quadratic relationship with 50% visual obstruction by SAT-PTT male lesser prairie-chickens in Colorado at the landscape scale (i.e., entire study area). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019; however, locations are from 2018-2020.

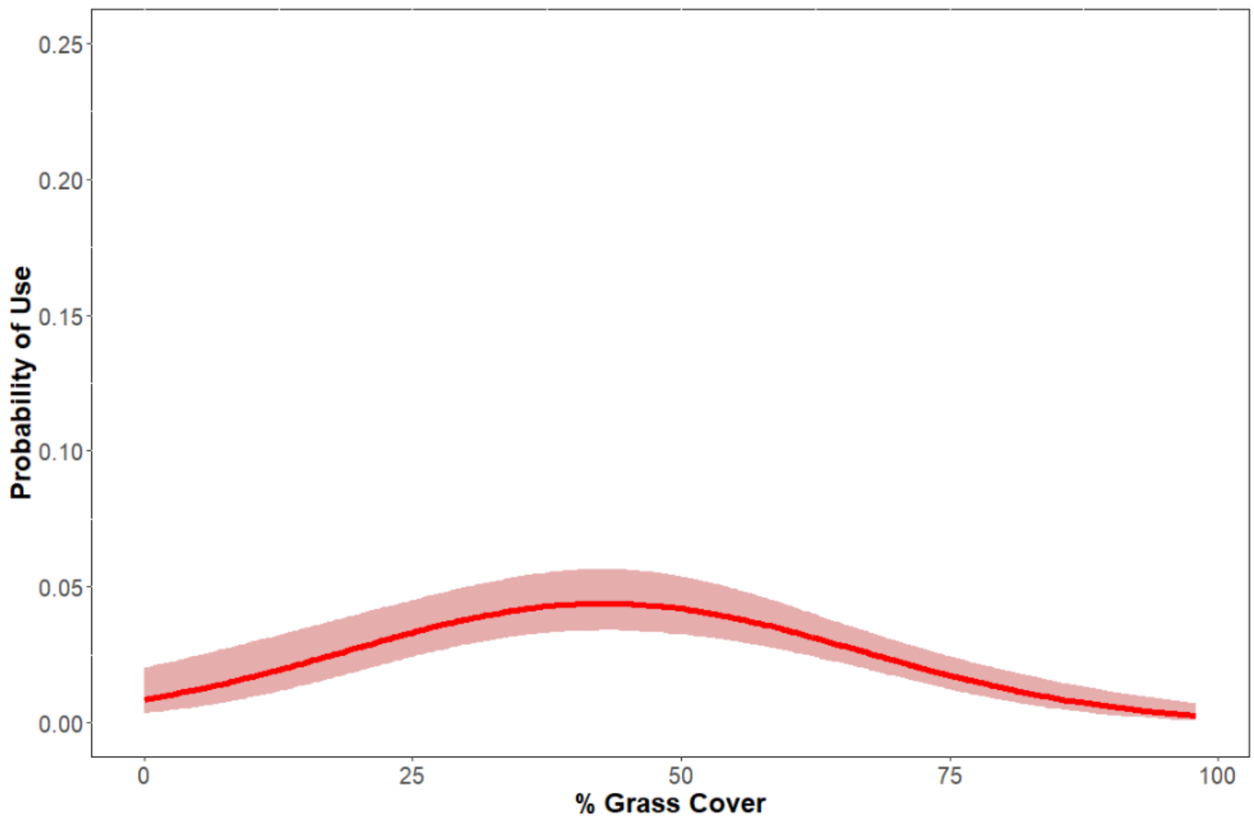

Figure 3.20 Relative probability of use (±95% CI) predicted based on quadratic relationship with percent grass cover by SAT-PTT-marked female lesser prairie-chickens in Colorado at the landscape scale (i.e. entire study area). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019 however locations are from 2018-2020.

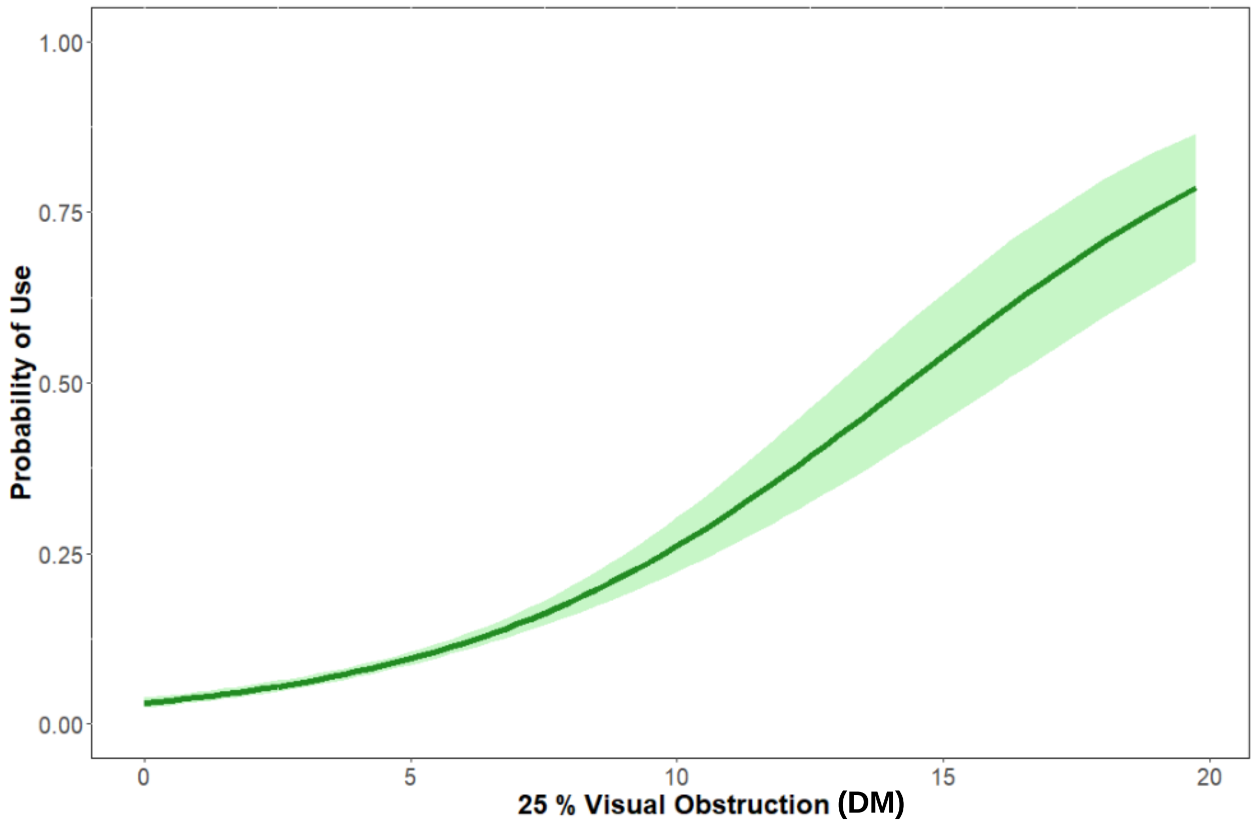

Figure 3.21 Relative probability of use (±95% CI) predicted based on quadratic relationship with 25% visual obstruction by SAT-PTT male lesser prairie-chickens in Kansas at the landscape scale (i.e., entire study area). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019; however, locations are from 2018-2020.

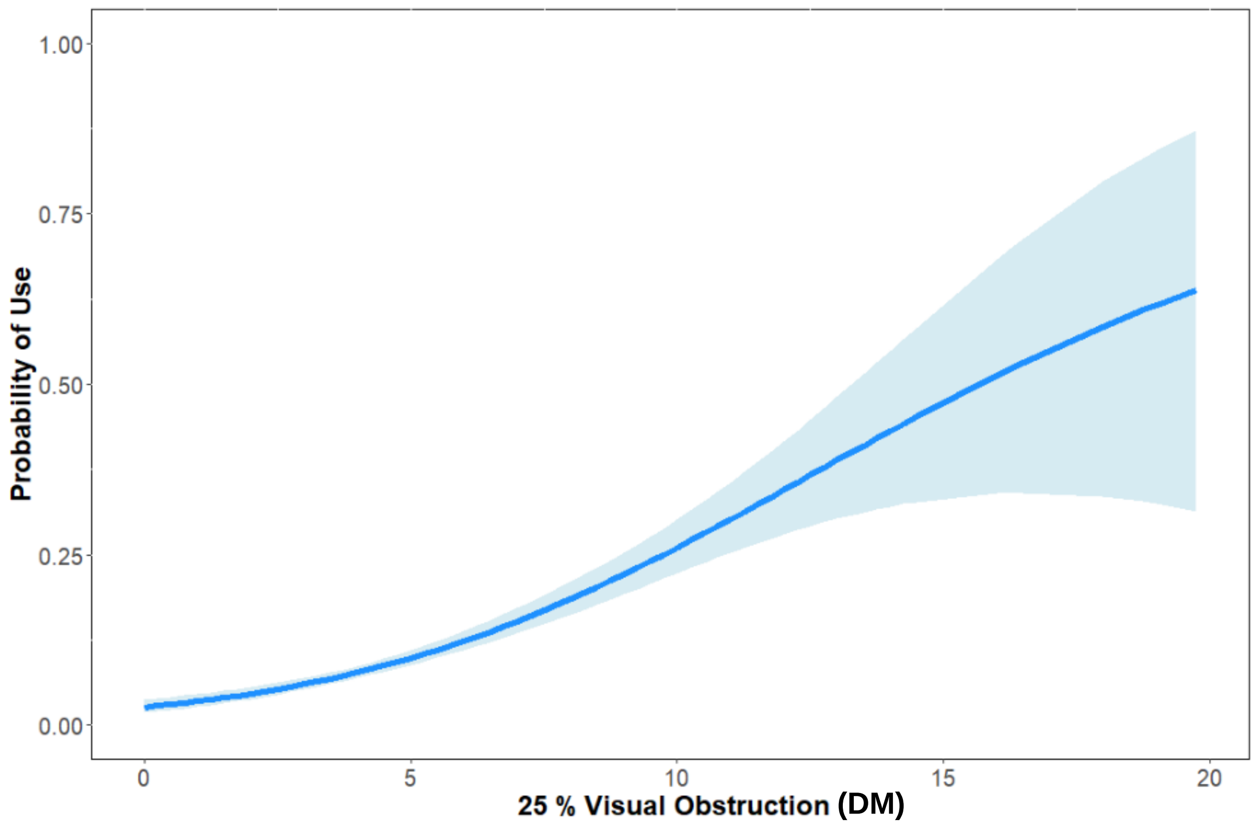

Figure 3.22 Relative probability of use (±95% CI) predicted based on linear relationship with 25% visual by SAT-PTT male lesser prairie-chickens in Kansas at the landscape scale (i.e., entire study area). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019; however, locations are from 2018-2020.

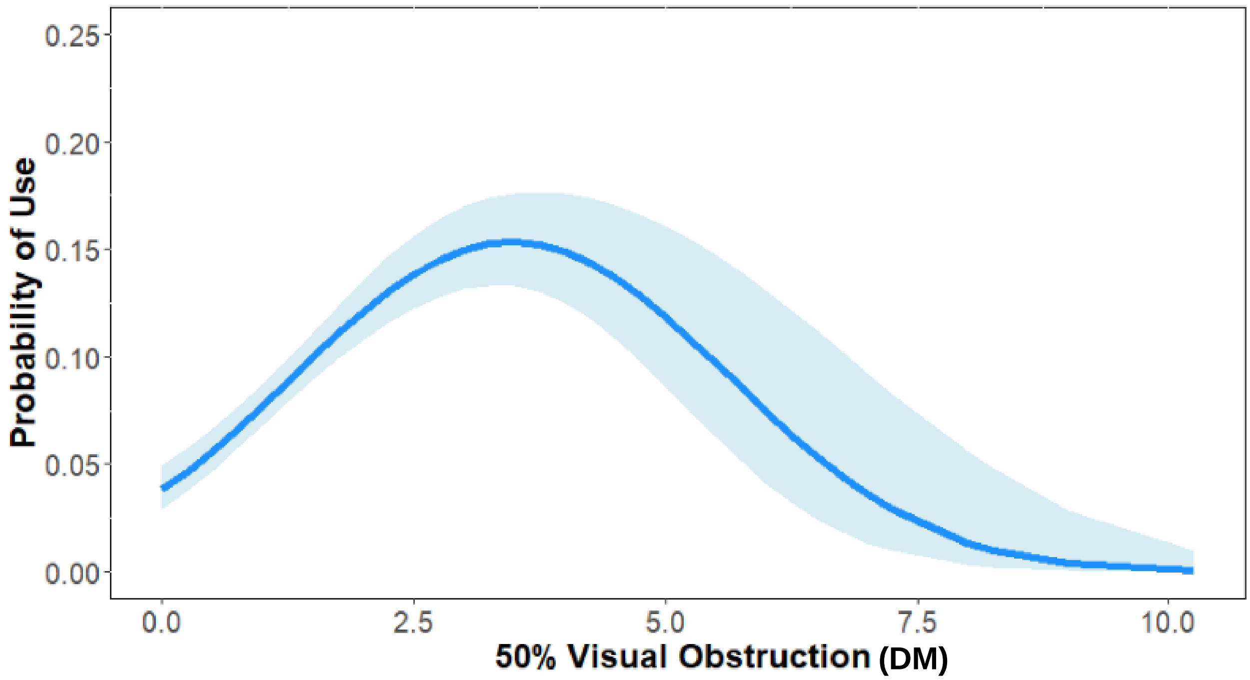

Figure 3.23 Relative probability of use (±95% CI) predicted based on quadratic relationship with 50% visual obstruction SAT-PTT female lesser prairie-chickens in Kansas at the landscape scale (i.e. entire study area). Lesser prairie-chickens were translocated from the Short-Grass Prairie/CRP Mosaic Ecoregion of northwest Kansas and released on U.S. Forest Service (USFS) land during 2016-2019; however, locations are from 2018-2020.