LESSER PRAIRIE-CHICKEN DEMOGRAPHICS IN TEXAS: SURVIVAL, REPRODUCTION, AND POPULATION VIABILITY

A Dissertation

by

EDDIE KEITH LYONS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2008

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

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ABSTRACT

Lesser Prairie-Chicken Demographics in Texas: Survival, Reproduction, and Population Viability.

(May 2008)

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Lesser prairie-chickens (*Tympanuchus pallidicinctus*) have declined throughout their range because of overgrazing and loss or fragmentation of habitat from conversion of native prairie to agricultural cropland. Lesser prairie-chickens were radio-marked (*n* = 225) as part of 2 separate field studies in the Texas Panhandle (2001–2003, 2003–2007). These data were used to evaluate whether differences in demographic parameters existed between populations occurring in 2 areas dominated by different vegetation types (sand sagebrush [*Artemisia filifolia*] versus shinnery oak [*Quercus havardii*]) in the Texas Panhandle from 2001–2007. A model-selection approach was used to test hypotheses explaining differences in survival and reproductive success of lesser prairie-chickens. Additionally, a population viability analysis was constructed using the above demographic parameters to evaluate effects of harvest and no harvest scenarios on viability and population persistence of lesser prairie-chickens in Texas. Overall, survival, reproduction, and population viability were lower in the shinnery oak compared to the sand sagebrush vegetation type. Lesser prairie-chicken survival differed between breeding and non-breeding periods. I estimated annual survival of lesser prairie-chickens at 31% in the shinnery oak and 52% in the sand sagebrush vegetation type. Nest success was (41%, 95% *CI* = 25–56%) in the shinnery oak population compared to the sand sagebrush population (75%, 95% *CI* = 54–94%). Population viability analysis predicted continued declines in lesser prairie-chicken populations in Texas. Estimates of local occupancy indicated lesser prairie-chicken populations would go extinct in the southwestern shinnery oak vegetation type more quickly compared to the northeastern sand sagebrush vegetation type (approximately 10 years compared to 30 years, respectively) without changes in population vital rates. Harvest at all levels increased risk of extinction. Results suggest that differences in survival and reproduction of lesser prairie-chickens within sand sagebrush and shinnery oak vegetation types throughout the Texas Panhandle should be evaluated, especially during the breeding season. Improvements to vegetation conducive for successful nesting are important to the viability of lesser prairie-chickens. Conservation and recovery strategies for lesser prairie-chicken populations should address variables that increase survival and nest success and consideration of no harvest.

DEDICATION

To my family

Jennie
Without you, none of this would have been possible

Cody and Connor
You keep me humble and make it all worthwhile

My parents Eddie and Cindy Lyons
For your unwavering support and that conversation
that kept me in school so long ago

ACKNOWLEDGEMENTS

I would like to thank my fellow graduate students who provided assistance whenever it was needed, especially during trapping seasons. I am grateful to Ryan Jones, Ben Toole, Mark Hess, C. J. Randel, and Shane Whisenant for all the cold, early mornings spent on lek sites. I would like to thank my fellow students and colleagues that have provided assistance with various drafts of this dissertation. Robert McCleery, Bret Collier, and Kyle Melton provided valuable support in the editing process. I am grateful to Bret Collier and Robert McCleery for statistical support.

I would like to thank my committee members for their advice and knowledge on various aspects of review of this dissertation: Roel Lopez, Bill Grant, and Fred Smeins. Special thanks go to Nova Silvy for his day to day guidance through this process, both in the field and in the classroom.

I am grateful to the landowners and land managers who allowed us access to their properties over the course of this study. I am also grateful to Duane Lucia (Texas Parks and Wildlife Department), and John Hughes (United States Fish and Wildlife Service) for logistical support. This project was funded by Texas Parks and Wildlife Department.

Finally, I would like to thank my family for their constant support throughout this process, both good times and bad. I cannot express thanks enough to my wife Jennie for her infinite patience and understanding in allowing me to complete this crazy idea of obtaining my Ph.D.

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CHAPTER I

INTRODUCTION

BACKGROUND

The purpose of this chapter is to provide the reader with general information on the status, distribution, and ecology of the lesser prairie-chicken (*Tympanuchus pallidicinctus*) in Texas. The chapter begins by describing the lesser prairie-chicken, its historic and current distribution and abundance, description of vegetation types historically and currently occupied by lesser prairie-chickens, and possible mechanisms for the species decline in the Texas Panhandle. Next, a description of study sites, including dominant vegetation and soil types, along with land-use practices will be presented. Lastly, research objectives for this dissertation conclude this chapter.

Lesser prairie-chicken

The lesser prairie-chicken is 1 of 3 remaining species in the genus *Tympanuchus* that includes greater prairie-chickens (*T. cupido*) and sharp-tailed grouse (*T. phasianellus*). Although similar to greater prairie-chickens in appearance, lesser prairie-chickens are smaller with slightly different colorations. Males can be identified by bright yellow eye combs and reddish air sacs on the side of the neck (Johnsgard 1983, Giesen and Hagen 2005). Both males and females have elongated feathers (pinnae), however, male's pinnae are longer and held erect during courtship displays.

Format and style follows the Journal of Wildlife Management.

Lesser prairie-chickens range from 38–41 cm in length (Johnsgard 1983, Olwalsky 1987), and body mass of males is greater than that of females (Giesen and Hagen 2005). Adults can be distinguished from juveniles based on shape, wear, and coloration of the ninth and tenth primaries (Amman 1944, Copelin 1963). Adults are identified as birds with rounded, smooth tips of the ninth and tenth primaries, and no banding or spotting to the tips.

Distribution

Extensive documentation exists regarding the continued decline, extirpation, and extinction of various species of pinnated grouse across their historic ranges (Taylor and Guthery 1980, Johnsgard 1983, 2002, Schroeder and Robb 1993, Connelly et al. 1998, Hagen et al. 2004, Silvy and Hagen 2004, Silvy et al. 2004, Giesen and Hagen 2005). The heath hen (*T. c. cupido*) became extinct in 1932 (Johnsgard 1983), sharp-tailed grouse have declined extensively across their range (Connelly et al. 1998), and greater prairie-chickens which once inhabited up to 19 states in the United States and portions of Canada, have now been extirpated over much of their range or exist as small isolated populations (Johnsgard 1983, Silvy et al. 2004). Declines in distribution of lesser prairie-chickens (Fig. 1.1) also have been widely documented (Litton 1978, 1994, Sullivan et al. 2000, Silvy et al. 2004) with population declines in eastern New Mexico, southeastern Colorado, southwestern Kansas, and western Oklahoma (Crawford 1980, Taylor and Guthery 1980, Giesen and Hagen 2005).

In Texas, pinnated grouse distribution (Fig. 1.2) has decreased from a historical high of 199 to 13 counties (Silvy et al. 2004). Greater prairie-chickens once inhabited up to 67 counties, but were extirpated by the 1930's. Attwater's prairie-chicken (*T. c. attwateri*) once inhabited up to 48 counties and 12 parishes and is now sustained in 2 counties only through the release of captive-reared birds (Silvy et al. 1999, 2004). Lesser prairie-chickens appear to have declined (Fig. 1.3) throughout their range from a historic high of approximately 100 counties to a current distribution of 11 counties (Silvy et al. 2004). By 1940, lesser prairie-chickens inhabited portions of 26 counties (Henika 1940) in the Texas Panhandle and 23 counties in 1945 (Texas Game, Fish and Oyster Commission 1945). By 1989, occupied range had decreased and lesser prairie-chickens were restricted to portions of 12 counties (Brownlee 1990, Sullivan et al. 2000). Currently, lesser prairie-chickens are confined to portions of 11 counties (Fig. 1.3) comprising 2 disjunct populations; 1 in the northeastern and 1 in the southwestern portions of the Texas Panhandle (Taylor and Guthery 1980, Silvy et al. 2004).

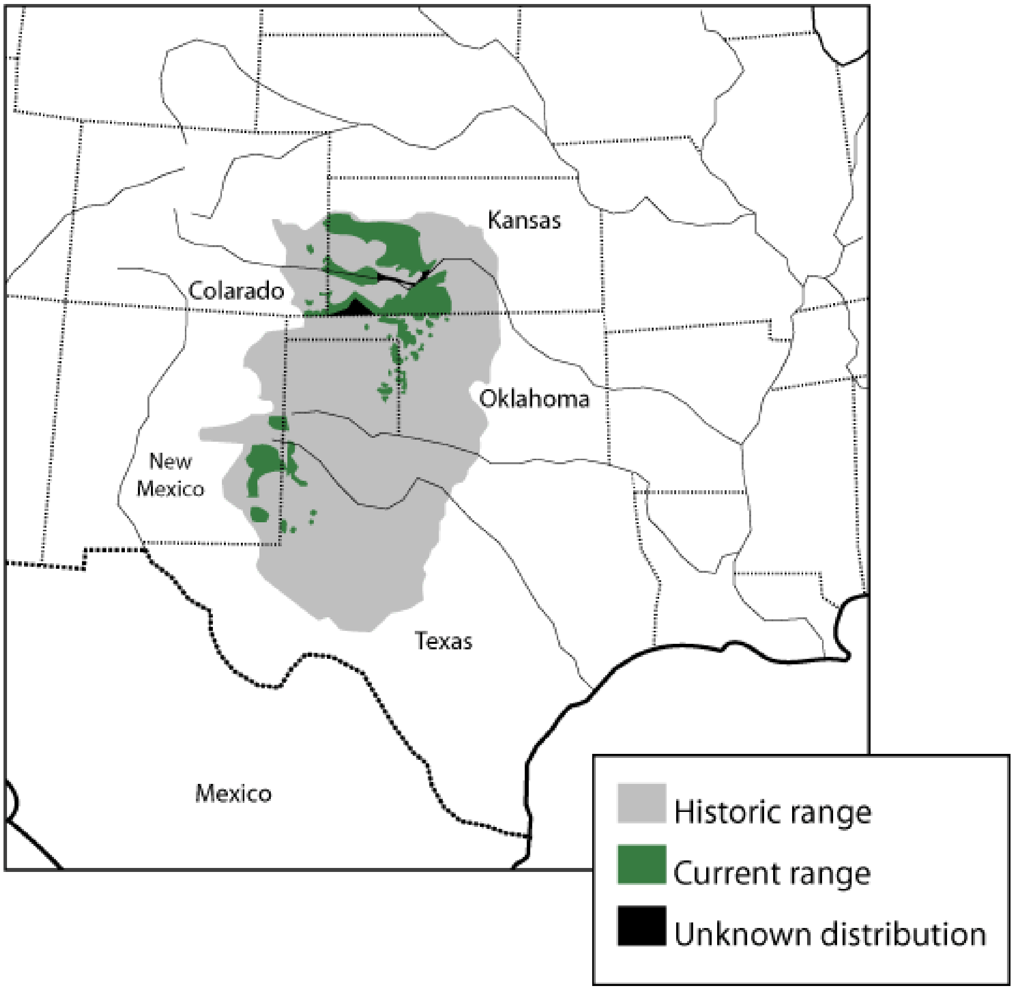

Fig. 1.1. Estimated historic and current range of lesser prairie-chickens (*Tympanuchus pallidicinctus*) (Hagen and Giesen 2005).

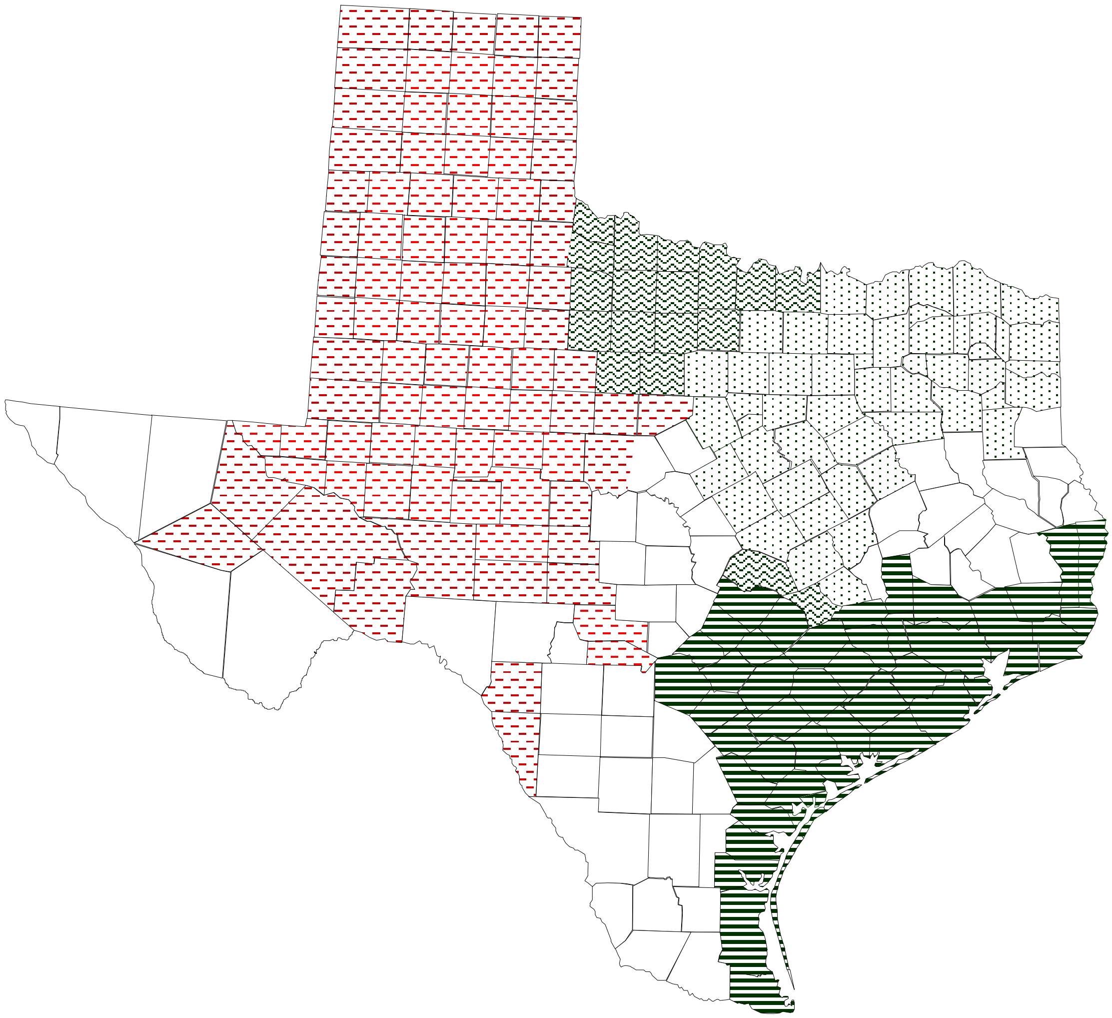

Fig. 1.2. Historic distribution of pinnated grouse in Texas (Silvy et al. 2004). Dashed areas denotes approximate historic range of lesser prairie-chickens, striped areas denotes approximate historic range of Attwater's prairie-chicken, and dotted areas denotes approximate historic range of greater prairie-chickens. Other patterns are areas of overlap of species.

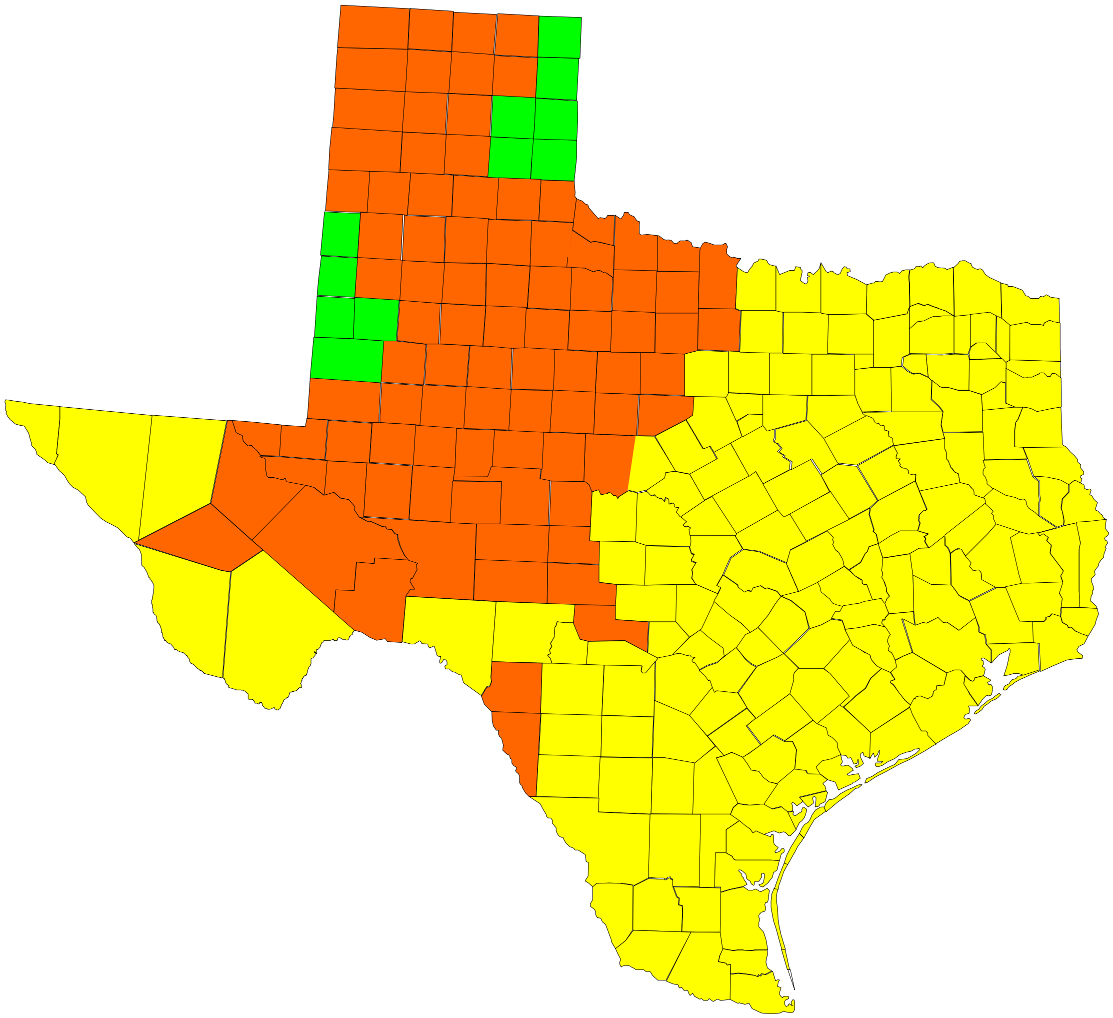

Fig. 1.3. Estimated historical (orange) and current (green) distribution of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in Texas by county (Silvy et al. 2004).

Abundance

The decline in distribution is mirrored by declines in density. In Texas, pinnated grouse have experienced precipitous declines in abundance. Greater prairie-chicken populations in Texas once approximated 500,000 birds (Oberholser 1974), and the critically endangered Attwater's prairie-chicken has declined from an estimated 1 million birds (Lehmann 1941) to populations sustained only by captive breeding programs. Lesser prairie-chickens in Texas have declined from about 2 million birds prior to 1900 to 17,000 birds by 1974 (Litton 1978), to recent estimates of only 3,000 remaining (Texas Parks and Wildlife Department [TPWD] 2005, unpublished data).

A petition to list the lesser prairie-chicken as threatened under the Endangered Species Act was submitted to the United States Fish and Wildlife Service (USFWS) in 1995, and in 1998 the USFWS determined that such listing was "warranted but precluded" by other species priorities (Federal Register 1998, 50 CFR 17). Lesser prairie-chickens were classified as vulnerable by the International Union for Conservation of Nature and Natural Resources (IUCN) and placed on the IUCN red list in 2004 (Storch 2007). The remaining number of lesser prairie-chickens in the United States is estimated at 10,000–25,000 individuals (Storch 2007) and concern for conservation for this species continues (Bailey and Williams 2000, Giesen 2000, Horton 2000, Jensen et al. 2000, Sullivan 2000).

Habitat loss

Declines (Fig. 1.4) in pinnated grouse populations have been attributed to habitat fragmentation and loss, overgrazing, and range-wide land conversion from native short and mid-grass prairies to agricultural cropland (Crawford 1980, Taylor and Guthery 1980). Remaining lesser prairie-chicken habitat is in areas occupied by soils unsuitable for cultivation such as Brownfield-Tivoli fine sands (Dittemore and Hyde 1960). Changing land use practices (Fig. 1.4) such as land conversion from prairie to cropland have forced lesser prairie-chickens into marginal range conditions dominated by woody species such as shinnery oak (*Quercus havardii*) (Silvy et al. 2004). It has been suggested that >97% of available habitat for lesser prairie-chickens in Texas has been destroyed (Taylor and Guthery 1980), and distribution and abundance mirror this effect. Lesser prairie-chickens now inhabit rangelands dominated primarily by shinnery oak and sand sagebrush (*Artemisia filifolia*) in 5 western states within the southern Great Plains (Giesen and Hagen 2005).

Fig. 1.4. Evidence of habitat loss and fragmentation in shinnery oak dominated landscapes. Light brown areas of circles and stripes indicate center pivot irrigated cropland. Grayish-green areas include CRP lands and shinnery oak rangelands fragmented by roads and oil and gas development.

In Texas, lesser prairie-chickens in the northeastern portion of the Panhandle occupy areas characterized as sand sagebrush rangelands while southwestern populations occupy areas dominated by shinnery oak with sand sagebrush occurring in lesser amounts (Taylor and Guthery 1980). While lesser prairie-chickens occur in all 5 states of their historic range (Fig. 1.1), population numbers have decreased into isolated, fragmented, local populations (Giesen and Hagen 2005). Taylor and Guthery (1980) estimated the northeastern population occupied approximately 3,238 km^2, and the southwestern population occupied 1,388 km^2.

Declines in habitat quantity and quality such as changes in shinnery oak age, composition, and structure may account for conflicting study results, and may explain declining chicken populations in the southwestern Texas Panhandle. A need to understand the effect of shinnery oak on the population dynamics of lesser prairie-chickens is imperative to the recovery of the species. Decreases in forage (grass and forbs) production and loss of livestock due to shinnery oak poisoning have prompted ranchers to control this plant with herbicides (e.g., Silvex, Picloram, and Tebuthiuron). Since herbicides are commonly used by ranchers in controlling shinnery oak encroachment, the effects of such treatments on lesser prairie-chicken populations need to be evaluated. Jackson and DeArment (1963) reported that chemical treatment of shinnery oak negatively affected prairie-chickens by depleting winter food and cover sources.

However, shinnery oaks also compete with other food and cover plant species that can be beneficial to lesser prairie-chicken, and can comprise 90% of vegetation on heavily-grazed rangelands (Pettit 1979). The micro-habitat use of shinnery oak rangelands also is poorly understood where the presence of shinnery is cited as both beneficial (Sell 1979, Haukos and Smith 1989) and negative (Donaldson 1969, Martin 1990) to lesser prairie-chickens. A need to understand the micro-habitat use of prairie-chickens in shinnery oak rangelands, particularly between areas that are treated with herbicides and those that are not, is necessary for improving habitat for lesser prairie-chickens.

STUDY AREA

Data on lesser prairie-chicken population dynamics were collected during studies from 2001–2003, and 2003–2007. Data were collected from sites in the northeastern portion (Hemphill, Lipscomb, and Wheeler counties) of the Texas Panhandle (Fig. 1.5) from April 2001 through August 2003 (Toole 2005, Jones, R.; unpublished data). I initiated an additional study on a second site in the southwestern portion (Yoakum and Cochran counties) of the Panhandle (Fig 1.5) for comparison purposes from April 2003 through August 2007.

The northeastern study sites were comprised of areas dominated primarily by sand sagebrush with shinnery oak occurring in Wheeler County (Fig. 1.6). These study sites were described in detail in Toole (2005), and have been the historical strongholds (Fig. 1.7) of lesser prairie-chicken habitat in Texas (Silvy, N. J., personal communication). The southwestern region was dominated by shinnery oak with occasional areas of sand sagebrush.

Common herbaceous species included little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardi*), sand bluestem (*Andropogon hallii*), sand lovegrass (*Eragrostis tichodes*), sand dropseed (*Sporobolus cryptandrus*), and three-awn (*Aristida sp.*). Common forbs included camphorweed (*Heterotheca pilosa*), Texas croton (*Croton texensis*), western ragweed (*Ambrosia psilostachya*), and queensdelight (*Stillingia sylvatica*).

The study was conducted on private land in northern Yoakum and southern Cochran County, Texas. Soils were consistent with the Brownfield-Tivoli association, which produced deep undulating sands (Dittemore and Hyde 1960). Topology of the study site and surrounding areas was mostly flat land interspersed by vegetative sand dunes (Fig. 1.8). Annual rainfall was approximately 48 cm (NOAA 2005).

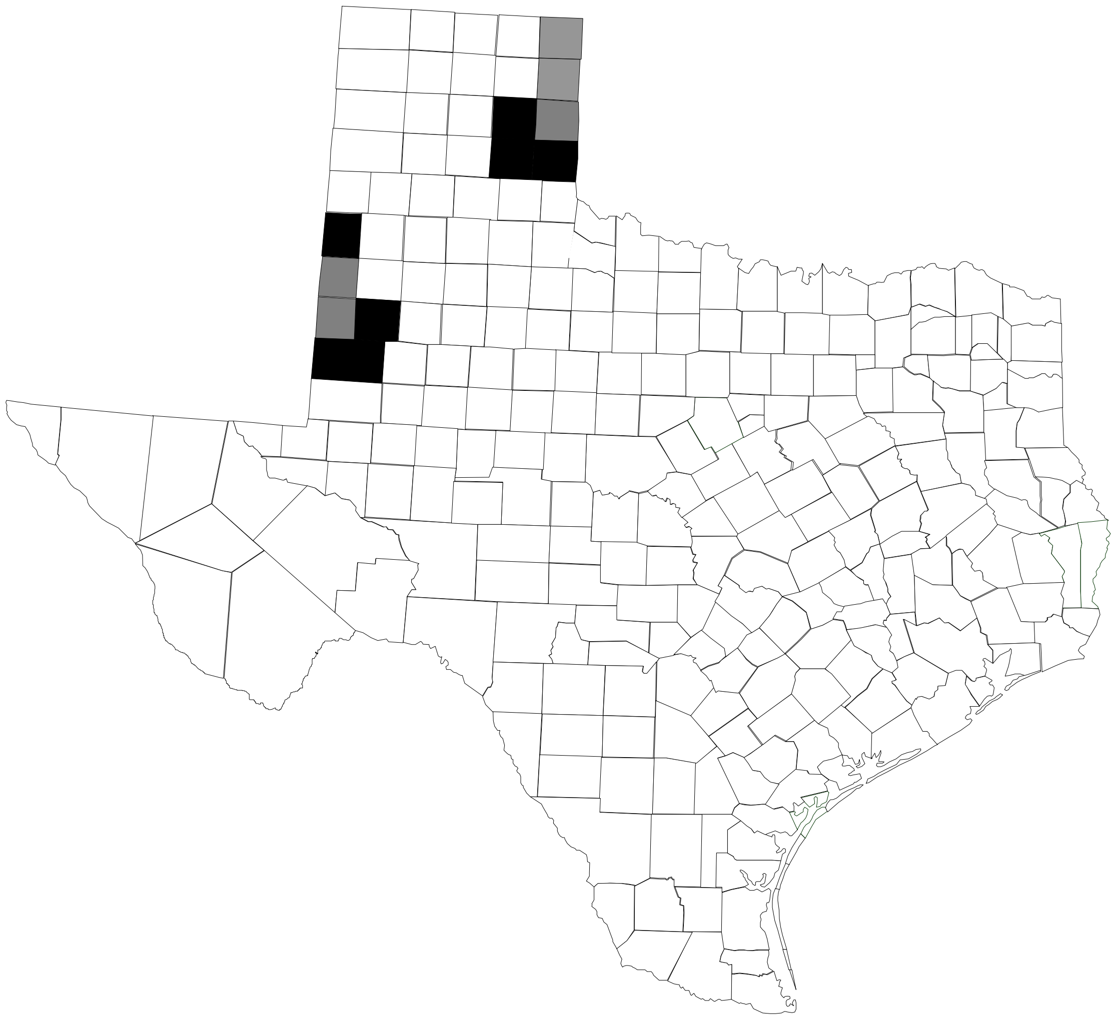

Fig. 1.5. Current (black) distribution (11 counties) of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in Texas, USA (after Silvy et al. 2004). Gray areas represent counties where study areas were located, 2001–2007.

Fig. 1.6. Topography and vegetation characteristics of Wheeler County study site, 2001–2003.

Fig. 1.7. Topography and vegetation characteristics of Hemphill County study site, 2001–2003.

Fig. 1.8. Topography of shinnery oak dominated landscapes on northern Yoakum and southern Cochran County study sites.

RESEARCH OBJECTIVES

The overall objective of my dissertation was to estimate demographic parameters of lesser prairie-chickens in differing vegetation types in the Texas Panhandle. I synthesized data from multiple studies to evaluate the status of remaining lesser prairie-chicken populations in Texas. Specifically, I compared lesser prairie-chicken survival and reproductive parameters of the 2 populations of lesser prairie-chickens in Texas. These data along with existing literature were used to develop a simulation model (population viability analysis) for evaluating of management practices (i.e., harvest) of lesser prairie-chicken populations in Texas. This information will serve to inform local ranchers and wildlife professionals on best management practices to restore and improve existing habitat while maintaining viable lesser prairie-chicken populations. Three chapters in this dissertation addressed these objectives. The chapters are:

1. Breeding and non-breeding survival of lesser prairie-chickens in the Texas Panhandle (Chapter II).
2. Reproductive success of lesser prairie-chickens in the Texas Panhandle (Chapter III).
3. Simulation model for the viability of lesser prairie-chicken populations in Texas (Chapter VI).
4. A final chapter (Chapter V) summarizes this dissertation and discusses conclusions from research findings and proposes future management

actions for lesser prairie-chickens in Texas. Chapters are independent papers; however, a certain amount of repetition should be expected.

CHAPTER II

BREEDING AND NON-BREEDING SURVIVAL OF LESSER PRAIRIE-CHICKENS IN THE TEXAS PANHANDLE

SYNOPSIS

Lesser prairie-chickens have declined throughout their range because of overgrazing and loss or fragmentation of habitat from conversion of native prairie to agricultural cropland. I radio-marked lesser prairie-chickens to determine whether differences in survival existed between populations occurring in 2 areas dominated by different vegetation types (sand sagebrush versus shinnery oak) in the Texas Panhandle from 2001–2005. I used a model-selection approach to evaluate potential generalities in lesser prairie-chicken survival. Results indicated survival of lesser prairie-chickens differed between breeding and non-breeding periods and between study populations. I estimated annual survival of lesser prairie-chickens at 31% in the shinnery oak vegetation type and 52% in the sand sagebrush vegetation type. My results suggest that demographic differences in lesser prairie-chicken populations within sand sagebrush and shinnery oak vegetation types throughout the Texas Panhandle should be evaluated, especially during the breeding season.

INTRODUCTION

Continued declines, extirpation, and extinction of pinnated grouse across their historic ranges in North America have been extensively documented (Johnsgard 1983, Connelly et al. 1998, Silvy et al. 2004). Lesser prairie-chickens (*Tympanuchus pallidicinctus*) inhabit rangelands in all 5 states, however, they have one of the smallest population sizes second only to Gunnison's Sage grouse (*Centrocercus minimus*), and most restricted range of any native North American grouse (Giesen & Hagen 2005). In Texas, lesser prairie-chickens currently exist in 2 disjunct populations in 11 counties in the northeastern and southwestern portions of the Texas Panhandle (Fig. 1.1), and have declined from ~2 million birds before 1900 to recent estimates of ~3,000 (Silvy et al. 2004).

Declines in pinnated grouse populations have been attributed to loss or fragmentation of habitat caused by range-wide land conversion from native short and mid-grass prairies to agricultural cropland, urban sprawl, energy development, and overgrazing (Crawford 1980, Taylor & Guthery 1980). It has been estimated that >90% of historic lesser prairie-chicken range has been destroyed and that trends in distribution and abundance parallel habitat loss (Taylor & Guthery 1980). Given the decline of lesser prairie-chickens over the last century, factors affecting demography must be understood to assist managers with management and conservation measures.

Parental input differs between male and females for grouse in promiscuous mating systems (Bergerud 1988). The primary responsibility for males in promiscuous mating systems is to advertise for mates. Males do not contribute to nest building and provide little input in caring for young (Bergerud 1988). Female grouse must determine where to place a nest to maximize survival of her and the nest along with investing time in nest building, incubation, and brood rearing. Therefore, the 2 sexes should have different survival rates which may be exacerbated during the breeding compared to the non-breeding season.

Survival estimates are important components to avian demography and are essential for management and the development of demographic models (Caizergues and Ellison 1997, Hagen et al. 2007). Although studies have attempted to quantify differing aspects of survival of lesser prairie-chickens (Patten et al. 2005*a*, Pitman et al. 2006*a*, Hagen et al. 2005, 2007,), little is known about annual or seasonal survival of lesser prairie-chickens, and no recent studies have evaluated survival of the 2 Texas populations (Sell 1979, Haukos et al. 1988). Because of uncertainty surrounding lesser prairie-chicken recovery, I initiated studies to determine survival of lesser prairie-chickens in these 2 populations in Texas. I used radio telemetry to (1) estimate survival in differing regions of the Texas Panhandle, and (2) determine whether generalizations about factors contributing to variation in lesser prairie-chicken survival can be made to Texas populations.

METHODS

Study area

This study was conducted from April 2001–August 2005 in 2 areas in the Texas Panhandle (Chapter I, Fig. 1.5). Data were collected from regions of the northeastern portion (Hemphill, Lipscomb, and Wheeler counties) of the Texas Panhandle from April 2001 through August 2003. I collected data from regions of the southwestern portion (Yoakum and Cochran counties) of the Panhandle for comparison purposes from April 2003 through August 2005 (Chapter I, Fig. 1.1).

All study areas were located in native rangelands with different woody species, but contained similar grass and forb associations as described by Jackson and DeArment (1963). My study areas ranged from 5,000–18,000 ha and were bordered by center-pivot irrigated cropland, conservation reserve program lands (CRP), and grazed rangelands. Primary land uses were ranching and natural gas and oil extraction.

In 2001, trapping sites were located in portions of Hemphill and Wheeler counties. In 2002, trapping sites were expanded to include the southern portion of Lipscomb County, Texas. This region (hereafter northeast region) was dominated by sand sagebrush, with lesser amounts of Chickasaw plum (*Prunus angustifolia*) and fragrant sumac (*Rhus aromatica*). In 2003, Yoakum and southern Cochran counties (hereafter southwest region) were added. The southwest region was dominated by shinnery oak. Environmental conditions were similar across both study regions and a severe drought occurred on both areas in 2003 (NOAA 2005). Average precipitation across the regions was approximately 48 cm/year during my study (NOAA 2005).

Data collection

I trapped lesser prairie-chickens using non-explosive Silvy drop nets on leks (Silvy et al. 1990). Birds were trapped during the breeding season from late March through early June from 2001 through 2005. At capture, gender was determined and birds were aged as juvenile or adult based on shape, wear, and coloration of the ninth and tenth primaries (Amman 1944, Copelin 1963). All birds were equipped with a numbered leg band, and fitted with a 12–15 g battery-powered, mortality-sensitive radio transmitter. Two models of necklace-style radio transmitters were used during the study; non-adjustable collar-style radio transmitters with fixed-loop antennas (Telemetry Solutions, Walnut Creek, California USA) and adjustable collar-style transmitters with whip antennas (Wildlife Materials Inc., Carbondale, Illinois USA).

I monitored radio-marked lesser prairie-chickens 3 days per week throughout the study using triangulation (White and Garrott 1990) or homing during random tracking periods using a vehicle mounted 5-element Yagi antenna or 3-element handheld Yagi antenna. Observations were increased to 5 times a week during the spring and early summer to estimate nest and brood success and breeding season mortality.

Statistical analysis

I estimated survival of adult lesser prairie-chickens using a staggered entry (Pollock et al. 1989), known fate design in program MARK (White and Burnham 1999). I defined encounter occasions monthly, and survival estimates were based on the best fitting model. I estimated period survival (monthly) for radio-marked individuals beginning 20 April 2001. I used 20 April as the initial date individuals entered the survival dataset and I allowed at least 2 weeks after capture before entering individuals for analysis to ensure transmitter effects had declined (Winterstein et al. 2001, Hagen et al. 2006).

An information-theoretic approach to model selection (Burnham and Anderson 2002) as implemented in MARK was used to evaluate factors contributing to variation in survival. For each region (northeast and southwest), I independently analyzed the survival data using a standardized candidate model set in an effort to determine if generalities in factors contributing to variation in survival were assumable for lesser prairie-chickens in different populations during different time frames. I applied my standardized candidate set to the data collected on both regions during 2003, removing those models which included a year effect. Because parameters for region and time were confounded based on my study design, I focused primarily on inter-annual variation.

RESULTS

I trapped 187 lesser prairie-chickens from 2001–2005 (Table 2.1). A total of 115 birds was trapped in the northeast region from 2001–2003, and 72 in the southwest region from 2003–2005. A total of 98 males (68 adults, 30 juveniles), and 89 females (35 adults, 54 juveniles) was trapped over the course of the study. Forty six and 37 lesser prairie-chickens were tracked in 2001 and 2002, respectively in the northwest region. Fifty-five birds were monitored in 2003 (32 in the northeast region and 23 in the southwest region). I monitored 24 birds in 2004 and 25 birds in 2005 in the southwest region. I did not include 30 captured individuals in the analysis due to mortality, transmitter failure, or slipped radios (radios during 2001 with fixed loop antennas were too large and many were lost) within 2 weeks of capture.

Table 2.1. Number of lesser prairie-chickens (*Tympanuchus pallidicinctus*) (by sex) trapped in the northeast and southwest region of the Texas Panhandle from 2001–2005.

Year	Region	Male	Female	Total
2001	Northeast	27	19	46
2002	Northeast	24	13	37
2003	Northeast	15	17	32
Total		66	49	115
2003	Southwest	9	14	23
2004	Southwest	16	9	25
2005	Southwest	7	17	24
Total		32	40	72

For both study regions for both study periods the best approximating models consisted of those which outlined differences between breeding and non-breeding season survival (Table 2.2). I found evidence of model selection uncertainty, as several models in each set were viable models based on ΔAIC_c (Table 2.3). Models which included year effects had little support in my candidate model sets, which indicated that intra-annual variation was less relevant than inter-annual variation to lesser prairie-chicken survival. In addition, the model set which I used to evaluate data collected on both regions during 2003 also showed the same pattern (Table 2.3).

For 2 of the 3 candidate model sets (southwest and combined 2003), the best fitting model was the model where survival differed between early breeding, mid to late breeding, and non-breeding season, but was constant within each season ($S_{BREED\ (AM;\ JJ;\ ASOCNJFM)}$) (Table 2.3). For the northeast, the best fitting model was one where survival differed between breeding and non-breeding season, but was constant within each season ($S_{BREED\ (AMJJ;\ ASOCNJFM)}$) with the aforementioned model ($S_{BREED\ (AM;\ JJ;\ ASOCNJFM)}$) also being plausible (Table 2.3).

Because model ($S_{BREED\ (AM;\ JJ;\ ASOCNJFM)}$) was one of the best 2 models for each model set, I estimated survival and associated variance measures by model averaging over parameters in this candidate model. Model averaged monthly survival in the northeast was higher during both breeding season periods (0.92, [*SE* = 0.02] and 0.93 [*SE* = 0.02], respectively) and the non-breeding period (0.96 [*SE* = 0.01]) than survival in the southwest for the breeding season periods (0.85 [*SE* = 0.04] and 0.89 [*SE* = 0.03], respectively) and the non-breeding period (0.93 [*SE* = 0.03]). When I combined areas

Table 2.2. Notation and description of models used to estimate survival of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in Texas, 2001–2005.

Model	Model notation	Model description
1	S_{SEX}	Survival differs by sex
2	S_{SITE}	Survival differs by site
3	$S_{BREED\ (AMJJ;\ ASOCNJFM)}$	Survival differs between breeding and non-breeding season, constant within each season
4	$S_{BREED\ (AMJ;\ JASOCNJFM)}$	Survival differs between early to mid-breeding season and non-breeding season, constant within each season
5	$S_{BREED\ (T\text{-}AMJJ;\ ASOCNJFM)}$	Survival varies according to linear trend during breeding season and is constant during non-breeding season
6	$S_{BREED\ (AM;\ JJ;\ ASOCNJFM)}$	Survival differs between early breeding, mid to late breeding, and non-breeding season, constant within each season
7	$S_{YEAR:\ BREED\ (AMJJ;\ ASOCNJFM)}$	Survival differs between years, between breeding and non-breeding season, constant within each year-season combination

Table 2.2. Continued.

Model	Model notation	Model description
8	$S_{YEAR: BREED (AMJ; JASOCNJFM)}$	Survival differs between years, between early to mid-breeding season and non-breeding season, constant within each year-season combination
9	$S_{YEAR: BREED (AM; JJ; ASOCNJFM)}$	Survival differs between years, between early breeding, mid to late breeding, and non-breeding season, constant within each year-season combination
10	$S_{YEAR: BREED (AM; JJASOCNJFM)}$	Survival differs between years, between early breeding, and non-breeding season, constant within each year-season combination
11	S_{YEAR}	Survival differs between years, constant within a year
12	S_{REGION}	Survival differs between regions

Table 2.3. Plausible candidate models[a] used to estimate survival of radio-tagged lesser prairie-chickens (*Tympanuchus pallidicinctus*) in the Texas Panhandle from 2001–2005.

Region	Model notation	-2 log likelihood	# of parameters	ΔAIC_c	w_i
Northeast					
	$S_{BREED\ (AMJJ;\ ASOCNJFM)}$	244.90	2	0.00	0.287
	$S_{BREED\ (AM;\ JJ;\ ASOCNJFM)}$	244.13	3	1.25	0.154
	$S_{BREED\ (T\text{-}AMJJ;\ ASOCNJFM)}$	240.19	5	1.39	0.144
	$S_{BREED\ (AMJ;\ JASOCNJFM)}$	246.36	2	1.45	0.139
	$S_{YEAR:\ BREED\ (AMJJ;\ ASOCNJFM)}$	241.12	5	2.31	0.090
	S_{SEX}	248.22	2	3.31	0.055
	S_{SITE}	248.43	2	3.53	0.049
	S_{YEAR}	247.31	3	4.43	0.031
	$S_{YEAR:\ BREED\ (AM;\ JJ;\ ASOCNJFM)}$	237.19	8	4.56	0.029
	$S_{YEAR:\ BREED\ (AM;\ JJASOCNJFM)}$	242.65	6	5.89	0.015
	$S_{YEAR:\ BREED\ (AMJ;\ JASOCNJFM)}$	244.29	6	7.53	0.006
Southwest[b]					
	$S_{BREED\ (AM;\ JJ;\ ASOCNJFM)}$	182.59	3	0.00	0.213
	$S_{YEAR:\ BREED\ (AM;\ JJASOCNJFM)}$	176.73	6	0.34	0.180
	$S_{BREED\ (AMJJ;\ ASOCNJFM)}$	185.49	2	0.86	0.139
	S_{SEX}	185.59	2	0.96	0.132
	$S_{BREED\ (AMJ;\ JASOCNJFM)}$	185.88	2	1.24	0.115

Table 2.3. Continued.

Region	Model notation	-2 log likelihood	# of parameters	ΔAIC_c	w_i
	$S_{YEAR: BREED (AMJ; JASOCNJFM)}$	178.51	6	2.12	0.074
	$S_{BREED (T-AMJJ; ASOCNJFM)}$	180.62	8	2.15	0.073
	$S_{YEAR: BREED (AMJJ; ASOCNJFM)}$	182.38	8	3.91	0.030
	$S_{YEAR: BREED (AM; JJ; ASOCNJFM)}$	176.46	8	4.28	0.025
	S_{YEAR}	187.46	3	4.87	0.019
Combined (2003)[c]					
	$S_{BREED (AM; JJ; ASOCNJFM)}$	141.62	3	0.00	0.348
	S_{REGION}	144.53	2	0.85	0.228
	S_{SEX}	145.99	2	2.31	0.109
	$S_{BREED (T-AMJJ; ASOCNJFM)}$	139.79	5	2.34	0.108
	$S_{BREED (AMJJ; JASOCNJFM)}$	146.11	2	2.43	0.104
	$S_{BREED (AMJ; JASOCNJFM)}$	146.14	2	2.46	0.102

[a]The lowest AIC_c values for the best fitting models for each group were: Northeast = 248.929; Southwest = 188.674; Combined (2003) = 147.737.
[b]The Southwest area had 1 fewer model tested than then Northeast area in that I did not evaluate differences between sites in this region.
[c]Model selection results for the Combined 2003 comparisons of birds in both the Southwest and Northeast areas do not include Year effects.

for analysis based on the 2003 data, monthly survival for the breeding season periods was 0.88 (*SE* = 0.03) and 0.92 (*SE* = 0.02) with non-breeding season survival of 0.89 (*SE* = 0.04). Based on my monthly survival estimates, I estimated annual survival for the northeast region at 0.52, while annual survival for the southwest region was 0.31.

Period (monthly) survival estimates indicated survival was ~4% lower during breeding than non-breeding seasons for both study areas. A period estimate of 0.92 (for the breeding season) indicated that breeding season survival for 4 months was 0.71(0.92^4), while a period estimate of 0.96 (for the non-breeding season) indicated that non-breeding season survival for 8 months was 0.72 (0.96^8).

DISCUSSION

Breeding season survival of both males and females was lower compared to the non-breeding season on both study sites as an equal proportion were likely to die during the 4 month breeding season compared to the 8 month non-breeding season. Similar results were found for populations of lesser prairie-chickens in New Mexico and Oklahoma as mortality of both male and females peaked during the breeding season (Patten et al. 2005*a*, *b*, Wolfe et al. 2007). Hagen et al. (2007) also reported higher mortality during the reproductive season (0.69, *SE* = 0.04) compared to the non-breeding season (0.77, *SE* = 0.06) in Kansas, and estimated that approximately 30% of all female mortalities were directly related to breeding season activities.

Other grouse species show similar trends in survival during breeding and non-breeding seasons. Populations of sharp-tailed grouse, black grouse (*Tetrao tetrix*), willow ptarmigan, (*Lagopus lagopus*), and spruce grouse (*Falcipennis canadensis*) exhibited increased mortality associated with breeding season activities (Marks and Marks 1988, Boag and Schroeder 1992, Caizergues and Ellison 1997, Hannon et al. 2003, Leupin 2003).

Understanding the mechanisms driving survival during the breeding and non-breeding seasons is critical for lesser prairie-chickens and other grouse species given the conservation status of grouse around the world (Storch 2007). The most critical component for female survival during the breeding season may be nest placement, and survival of females may be lower during the breeding season because of the costs incurred during reproduction (Bergerud 1988, Hagen et al. 2007). The relationship between cover at nest sites and hen survival may be of importance to grouse demographics (Wiebe and Martin 1998). For males, survival may be lower during the breeding season than the non-breeding season because of increased vulnerability and conspicuousness on the display grounds (Bergerud 1988, Hagen et al. 2005).

Results suggest differences between regions, likely tied to differences between sand sagebrush and shinnery oak vegetation types throughout the Texas Panhandle may be important to survival of lesser prairie-chickens. Patten et al. (2005*a*) found annual survival in New Mexico and Oklahoma was maximized when shrub cover was ~20% and survival was positively correlated with lower temperatures and higher relative humidity. Hagen et al. (2007) found survival of females during the breeding season was associated with nest sites with greater shrub cover, but less vertical vegetation structure. Specific differences in vegetation for nesting and brooding may be factors related to lower survival in the southwestern compared to the northeastern populations in the Texas Panhandle. Shrub cover on the southwestern study site exceeded 20% and was detrimental to survival of lesser prairie-chickens (Chapter I, Fig. 1.8). Lesser prairie-chickens also see their habitat as patchy in regard to microclimate (Patten et al. 2005*a*). A monoculture of shinnery oak (i.e., southwestern study site) may be detrimental to lesser prairie-chickens survival if arthropod density and residual cover in the form of bunchgrasses are decreased.

Annual survival estimates from my study were similar to those reported elsewhere in the literature (Hagen et al. 2005). Estimates from the southwestern region were similar to estimates from other studies in shinnery dominated areas (Campbell 1972), and estimates from the northeastern study site were similar to studies in Kansas (Jamison 2000, Hagen et al. 2005, 2007) where lesser prairie-chicken populations continue to occupy the majority of their historic range (Taylor and Guthery 1980, Hagen 2003).

Caution should be taken when making direct comparisons of annual survival estimates because of the variety of methods used to calculate survival estimates (Hagen et al. 2005). Increasing breeding season survival of lesser prairie-chickens is important if not imperative, to the short-term conservation and long-term recovery of lesser prairie-chickens in Texas. As evidenced by continued population declines (Storch 2007), current rates of survival will not sustain the population and further research on lesser prairie-chicken demographics in both shinnery oak and sand sagebrush vegetation types is needed.

CHAPTER III

REPRODUCTIVE SUCCESS OF LESSER PRAIRIE-CHICKENS IN THE TEXAS PANHANDLE

SYNOPSIS

Declines in lesser prairie-chicken populations have been attributed primarily to overgrazing and loss or fragmentation of habitat from conversion of native prairie to agricultural cropland. Loss of adequate vegetation for nesting and brooding of lesser prairie-chickens may exacerbate population declines observed in the Texas Panhandle. Radio-marked lesser prairie-chickens were monitored in the Texas Panhandle from 2001–2007 to determine if nest success of lesser prairie-chicken populations differed in areas dominated by sand sagebrush versus shinnery oak. I used a model-selection approach to test hypotheses explaining differences in nest success of lesser prairie-chickens. Nest success was lower in the shinnery oak population (41%, 95% *CI* = 25–56%) compared to the sand sagebrush population (75%, 95% *CI* = 54–96%). Results suggest that vegetation types affect nest success of lesser prairie-chickens in Texas and further research is needed to determine which micro-habitat variables within these vegetation types reflect these differences.

INTRODUCTION

Pinnated grouse populations have declined throughout their range and many are considered species of concern (Storch 2007). Declines in distribution and abundance of sharp-tailed grouse, greater prairie-chicken, and lesser prairie-chicken populations have been extensively documented (Taylor and Guthery 1980, Johnsgard 1983, Schroeder and Robb 1993, Connelly et al. 1998, Silvy et al. 2004). Given their historically small range, relatively small population size, and continued declines, in 1998 lesser prairie-chickens were listed as a candidate species (Federal Register 1998, 50 CFR 17) by the United States Fish and Wildlife Service, and placed on the International Union for Conservation of Nature and Natural Resources (IUCN) red list in 2004 (IUCN 2004). Population declines of lesser prairie-chickens have been attributed to habitat loss or fragmentation, overgrazing, and land conversion from rangelands to agricultural cropland (Crawford 1980, Taylor and Guthery 1980).

Historically, lesser prairie-chickens occupied rangelands throughout the Texas Panhandle (Oberholser 1974, Litton et al. 1994). Changing land use practices have forced lesser prairie-chickens into marginal range conditions dominated by woody species such as shinnery oak resulting in small isolated populations (McCleery et al. 2007). They now exist as 2 disjunct populations in portions of ~11 counties with the majority of birds located in the northeastern portion of the Texas Panhandle in rangelands dominated by sand sagebrush and bunchgrasses, and a smaller population inhabiting shinnery oak rangelands of the southwestern Panhandle (Taylor and Guthery 1980, Sullivan et al. 2000, Silvy et al. 2004).

Numerous studies have documented nest success of lesser prairie-chickens across their range in varying habitats (Riley et al. 1992 [New Mexico], Giesen 1994 [Colorado], Patten et al. 2005*b* [New Mexico and Oklahoma], Pitman et al. 2006*b* [Kansas]); however, no recent studies have evaluated nest success of lesser prairie-chickens in the 2 remaining populations in Texas (Sell 1979, Haukos 1988). Because of uncertainty surrounding lesser prairie-chicken recovery, studies were initiated studies to determine if nest success differed between populations in sand sagebrush versus shinnery oak vegetation types. The goals of this study were to (1) estimate nest success in different regions of the Texas Panhandle, and (2) determine what vegetation components may influence nest success in lesser prairie-chicken populations.

METHODS

Study area

This study was conducted from April 2001–August 2007 in 2 areas in the Texas Panhandle (Chapter I, Fig. 1.5). Field research was conducted from 2001–2003 in the northeastern portion of the Rolling Plains ecoregion (Gould et al. 1960) of the Texas Panhandle in portions of Lipscomb, Hemphill, and Wheeler counties. The northeastern region consisted of 2 study areas. Study area 1 was dominated by sand sagebrush with lesser amounts of Chickasaw plum and fragrant sumac, whereas study area 2 was dominated by shinnery oak. I initiated an additional study in the High Plains ecoregion of the Texas Panhandle (Gould et al. 1960) in northern Yoakum and southern Cochran counties for comparison purposes from 2003–2007. The southwestern region also was dominated by shinnery oak with lesser amounts of sand sagebrush.

All sites contained similar grass and forb associations as described by Jackson and DeArment (1963). Common herbaceous species included little bluestem, big bluestem, sand bluestem, sand lovegrass, sand dropseed, and three-awn. Common forbs included camphorweed, Texas croton, western ragweed, and queensdelight.

Data collection

Lesser prairie-chickens were captured using non-explosive Silvy drop nets (Silvy et al. 1990) on leks prior to and during the breeding season from late March to 1 June from 2001 through 2007. At capture, I aged birds as yearling or adult based on shape, wear, and coloration of the ninth and tenth primaries (Amman 1944, Copelin 1963). I equipped each hen with a numbered leg band, and a 12–15 g battery-powered, mortality-sensitive radio transmitter. Two models of necklace-style radio transmitters were used during the study; non-adjustable collar-style radio transmitters with fixed-loop antennas (Telemetry Solutions, Walnut Creek, California USA) and adjustable collar-style transmitters with whip antennas (Wildlife Materials Inc., Carbondale, Illinois USA).

Lesser prairie-chickens were monitored 3 days per week throughout the study using a vehicle mounted 5-element Yagi antenna. Observations were increased to 5 times a week during the spring and early summer to estimate nest success. Nests were located by "walk-ins" using a 3-element handheld Yagi antenna after hen locations remained unchanged for approximately 3 days. I determined clutch size if the hen flushed off the nest. Hens were not unnecessarily flushed to obtain data on clutch size. I marked each nest by geo-referencing (GPS), and nest sites were not visited again until movements indicated that a hen left a nest. I relocated nests and determined fate as abandoned, destroyed, or hatched.

Statistical analysis

Differences in nest success were evaluated (incubating females with ≥1 egg hatched) using logistic regression and comparing candidate models using an information-theoretic approach (Burnham and Anderson 2002). This approach was used to evaluate the influence of region (NE vs. SW), vegetation type (sand sagebrush vs. shinnery oak), and temporal factors (year). These variables were combined into 6 candidate models along with a global (model with all variables considered) and null model (intercept only model) (Table 1). Logistic regressions were performed (PROC GENMOD, SAS version 9.1; SAS Institute, Inc., Cary, NC) for each model (dependant variable = nest success, independent variables = candidate models). The fit of each model was evaluated using Akaike weights (w_i) and Akaike's Information Criterion corrected for small sample size (AIC_c, Simonoff 2003), and considered models with a ΔAIC_c <2 as best competing models (Burnham and Anderson 2002). Additionally, individual nest success statistics of best competing models were reported as a percent with binomial 95% confidence intervals also reported as percents.

RESULTS

I trapped 114 females over the course of the study. Forty-nine females were trapped from 2001–2003 in the northeastern region and 65 were trapped from 2003–

2007 in the southwestern region. A total of 53 nests was established and 27 (51%) were successful.

Model 1, vegetation type ($\Delta AIC_c = 0.0$) was the best competing model and had a w_i of 65.6 (Table 3.1). Models including vegetation as a parameter had a combined w_i of 72.2 while region only had a combined w_i of 14.3. Comparing nest success estimates from parameters of best competing models, birds found in the shinnery oak population (41%, 95% CI = 25–56%) had lower success compared to birds found in sand sagebrush (75%, 95% CI = 54–96%).

DISCUSSION

My results indicated differences between sand sagebrush and shinnery oak vegetation types throughout the Texas Panhandle were important for successful nests of lesser prairie-chickens. Model selection indicated differences in nest success were due more to differences in vegetation characteristic than region, and higher nest success in the sand sagebrush vegetation type compared to the shinnery oak demonstrated this vegetation type provided more of the requirements necessary for successful nests. In similar habitat in Texas, Sell (1979) found lesser prairie-chickens preferred sand sagebrush for nest concealment and recommended that nesting cover in the form of sand sagebrush and residual cover be provided.

Table 3.1. Notation and description of models used to describe variation in nest success of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in the Texas Panhandle, 2001–2007.

Candidate model	# of Parameters	-2lnL	ΔAIC_c	Akaike Weight (w_i)
Vegetation type	2	67.96	0.0	0.66
Region	2	71.01	3.1	0.14
Null	1	73.46	3.2	0.14
Vegetation type*Region	2	72.60	4.6	0.06
Vegetation type*Year	7	65.68	13.1	0.00
Year	7	66.85	14.3	0.00
Vegetation type + Year	8	63.28	14.8	0.00
Global	11	61.61	28.8	0.00

*Vegetation type corresponded to sand sagebrush vs. shinnery oak.
Year corresponded to temporal periods from 2001–2007.
Region corresponded to NE vs. SW.
Null were intercept only models.
Global were models with all variables considered.

Nest success of lesser prairie-chickens during this study was higher (51%) than estimates from studies on lesser prairie-chickens in other states throughout their range [Merchant 1982 (27%), Riley et al. 1992 (28%), Patten et al. 2005*b* (41%), Pitman et al. 2006*b*, (26%)]. Giesen and Hagen (2005) estimated nest success of lesser prairie-chickens at 28% from 10 studies throughout their range, although they cautioned that results may be negatively influenced by observer disturbance. Observer disturbance was not considered a factor as most birds were not flushed off their nests and nests were not visited a second time until nest fate was determined.

Although the mechanisms responsible for lesser prairie-chicken decline are not understood, previous literature on other grouse species has shown nest success followed by chick success as the most significant factors influencing grouse population numbers (Bergerud 1988, Peterson and Silvy 1996, Wisdom and Mills 1997). Adequate habitat for nesting is probably the mitigating factor in determining nest success of lesser prairie-chickens, and improvements in habitat quality and quantity to provide sufficient cover and reduce predation are necessary for management of lesser prairie-chickens in Texas (Kirsch 1974, Hagen et al. 2004). The success of lesser prairie-chicken nests point to the importance of vegetative cover (Haukos et al. 1989), and habitat management studies in the form of providing essential nesting cover are needed. These results suggest vegetation types affect nest success of lesser prairie-chickens in Texas and further research is needed to determine which micro-habitat variables within these vegetation types reflect these differences. To increase lesser prairie-chickens in Texas, I recommend managers should focus on providing conditions that maximize successful nesting such as sand sagebrush and bunchgrasses for cover requirements.

CHAPTER IV

SIMULATION MODEL FOR THE VIABILITY OF LESSER PRAIRIE-CHICKEN POPULATIONS IN TEXAS

SYNOPSIS

I evaluated effects of harvest and no harvest scenarios on viability and population persistence of 2 distinct populations of lesser prairie-chickens in Texas using a stage-structured simulation model. Simulations predicted continued declines in lesser prairie-chicken populations in Texas. Under best case scenarios, population trajectories suggested lesser prairie-chickens in Texas would likely go extinct within 25–30 years. Estimates of local occupancy indicated lesser prairie-chicken populations would go extinct in the southwestern shinnery oak vegetation type more quickly compared to the northeastern sand sagebrush vegetation type (9.8 years compared to 29.6 years, respectively) without changes in population vital rates. Harvest at all levels increased risk of extinction. Conservation and recovery strategies for lesser prairie-chicken populations should address variables that increase survival (e.g., habitat management practices such as improved quality and quantity of habitats) and consideration of no harvest.

INTRODUCTION

Although lesser prairie-chickens inhabit all 5 states within their historic range, >90% of their range has been destroyed (Crawford 1980, Taylor and Guthery 1980, Giesen and Hagen 2005). In Texas, lesser prairie-chicken populations have declined from historic highs of ~100 counties (Oberholser 1974, Litton 1978) to 2 distinct populations occupying portions of ~11 counties (Taylor and Guthery 1980, Silvy et al. 2004). Density estimates have declined to ~3000 birds remaining in Texas (Silvy et al. 2004).

Lesser prairie-chickens were historically a popular game species; however, due to population declines, only Kansas and Texas have hunting seasons. Declines during the 1930s caused the Texas Legislature to end legal hunting of lesser prairie-chickens from 1937-1967 (Litton 1994). Population surveys conducted in 1967 indicated a surplus of birds, and a 2-day season was held in the northeastern Panhandle, followed by a similar season in 1970 in the southwestern Panhandle (Permian Basin) (Litton 1994). Lesser prairie-chicken hunters were required to obtain a special permit, issued at no cost, from 1987 through 1992. This permit requirement was reinstated in 1997. In 2005, regulation changes precluded hunting of lesser prairie-chickens in Texas, except on properties involved in a TPWD approved wildlife management plan focusing on lesser prairie-chicken habitat enhancement and harvest recommendations.

Given continued declines of lesser prairie-chickens throughout their range, current management practices (i.e., harvest in Kansas and Texas) (Crawford 1980, Taylor and Guthery 1980, Giesen and Hagen 2005), their current status as a candidate species (Federal Register 1998, 50 CFR 17) by the United States Fish and Wildlife Service, and listing by the International Union for Conservation of Nature and Natural Resources (IUCN) red list in 2004 (IUCN 2004), population viability estimates are critical to the conservation of the species.

Managers and conservationists now face the challenge of predicting how expansion of human-influenced systems will impact not only endangered species viability, but species of concern that demonstrate decline such as lesser prairie-chicken. Simulation models can provide an opportunity to evaluate declining populations that otherwise might not be studied and are useful for evaluating the relative importance of factors thought to constrain population growth (Peterson et al. 1998). Population models that fully integrate physical, biological, and human systems are useful for evaluating risks associated with accommodating changes in natural habitats (Grant and Thompson 1997, Liu 2001).

A Population Viability Analysis is a collection of methods used to evaluate the viability of threatened or endangered species using computer simulation models (Boyce 1992, Burgman et al. 1993). Species viability is often expressed as the risk or probability of extinction or population decline, the expected time to extinction, or the expected chance of recovery (Akçakaya and Sjogren-Gulve 2000). Population viability analysis models attempt to predict such measures based on demographic and habitat data (e.g., structured models) including differences in discrete populations (Akçakaya 2000, Akçakaya et al. 2004).

Compared to other alternatives for making conservation decisions, population viability analysis provide a rigorous methodology that can incorporate different types of data, uncertainties, and natural variation and then provide outputs or predictions that are relevant to conservation goals (Akçakaya and Sjogren-Gulve 2000). Results from population viability analysis also can incorporate uncertainties using sensitivity analyses based on ranges of parameters, which gives a range of extinction risk estimates and other assessment end-points (Akçakaya 2000). This approach allows users to understand the effect of uncertain input, and to make decisions with full knowledge of those uncertainties. In response to continued decline of lesser prairie-chicken and need for management recommendations, I estimated viability for 2 distinct populations of lesser prairie-chickens in Texas under harvest and no harvest scenarios.

METHODS

Study area

Lesser prairie-chicken demographic data were collected on 2 sites in 5 counties in the northeastern and southwestern portions of the Texas Panhandle from April 2001–August 2005 (Chapter I, Fig. 1.5). The northeastern region was dominated by sand sagebrush, with lesser amounts of Chickasaw plum (*Prunus angustifolia*) and fragrant sumac (*Rhus aromatica*) while the southwest region was dominated by shinnery oak with occasional areas of sand sagebrush. Both study areas were located in native rangelands with different woody species but contained similar grass and forb associations as described by Jackson and DeArment (1963). Study areas ranged from

5,000–18,000 ha and were bounded by center-pivot irrigated cropland, CRP, and heavily grazed rangelands. Primary land uses were ranching and natural gas and oil extraction.

Model overview

I parameterized a demographic, stage-structured population model using RAMAS Metapop software to model 2 lesser prairie-chicken populations in Texas. The model consisted of 3 stages: juveniles (<10 months), yearlings (approximately 10 months), and adults (≥22 months) and I assumed constant age-specific fecundity and survivorship rates. In species where 1 male may mate with several females, males do not contribute significantly to the fecundity and only females should be modeled (Akçakaya 2000). Therefore, given the reproductive strategy of lesser prairie-chickens, only females were modeled in my population viability analysis.

I incorporated demographic stochasticity into my analyses by sampling vital rates from a binomial distribution and a Poisson distribution, for number of survivors and number of offspring, respectively (Akçakaya 1991). I assumed no density-dependence (exponential growth) to obtain a conservative estimate of risk (Ginzburg et al. 1990). Initial abundances were estimated at 400 and 500 females, respectively for the counties sampled in the NE and SW region of the Panhandle (Litton 1994, unpublished data, TPWD 2005). Due to the distance between populations, I considered them to be distinct and independent and assumed no dispersal.

Data used to estimate model parameters were collected via radio-telemetry studies for both the northeastern and southwestern populations (Chapters II and III). I identified knowledge gaps in demographic parameters and supplemented them with estimates of vital rates from published and unpublished studies of lesser prairie-chickens. Where data were insufficient from these studies in Texas, I used studies from states where lesser prairie-chickens are increasing to obtain more conservative results (i.e., Kansas).

I estimated survival of adult lesser prairie-chickens (*n* = 157) using a staggered entry (Pollock et al. 1989), known-fate design in program MARK (White and Burnham 1999) (Chapter II). I was unaware of data on lesser prairie-chicken juvenile and yearling survival in Texas. I averaged juvenile survival estimates from Hagen (2003) and Pitman et al. (2006*a*) for an estimate of (0.33). I used an estimate of 0.51 for yearling survival from Hagen et al. (2007) in Kansas.

Annual fecundity parameter estimates were calculated by multiplying estimates for survival, young per hen, and chick-sex ratio. Young per hen was calculated by average clutch size that hatched * nest success. Average clutch size that hatched was calculated as average clutch size * hatchability. Estimates for average clutch size and hatchability were determined from published accounts (Giesen and Hagen 2005, Pitman et al. 2006*b*). Adult lesser prairie-chicken nest success estimates were taken from published and unpublished studies in Texas (Chapter III). I used estimates for apparent nest success as 41% and 75% for the southwestern and northeastern populations, respectively. I was unaware of data on yearling nest success of lesser prairie-chicken in Texas. I used yearling nest success estimates (35%) from Pitman (2006*b*) in Kansas. Chick sex ratio was assumed to be 1:1 similar to that used by (Akçakaya et al. 2004) for sharp-tailed grouse.

Model use

No known hunting of lesser prairie-chickens occurred on the study sites from 2001-2007. I assumed mortality due to harvest to be additive to natural mortality and modeled the effects of harvest using the population management action feature in RAMAS. I simulated harvest of lesser prairie-chickens from both populations using 5 harvest scenarios at rates of 0, 5, 10, 20 and 25%. I harvested once per time step (i.e., annually) for the duration of the simulation (30 years). For each model scenario, I ran 1,000 simulations over 30 years. I varied all demographic estimates except initial abundances ±10% for low and high parameter estimates. High parameter estimates were considered the "best case" scenario for biologically plausible demographic rates. I used 3 criteria to evaluate the viability of lesser prairie-chicken populations: terminal extinction risk (probability of the lesser prairie-chicken populations going extinct in 30 years), median time to extinction in years of each population, and population trajectories (Akçakaya 2000). I evaluated the sensitivity of my parameters to model output by varying each of the above demographic parameters ±10% while holding all other parameters constant (Akçakaya 2000).

RESULTS

Population viability analysis predicted continued declines in lesser prairie-chicken populations in Texas. Under best case scenarios (i.e., high parameter estimates and no harvest), population viability analysis predicted a terminal extinction risk of 0.120 and a median time to extinction of approximately 27 years. Population trajectories suggested lesser prairie-chicken populations in Texas would likely go extinct within 25–30 years, and the southwestern population would go extinct more quickly than the northeastern population (10 years compared to 30 years, respectively) without changes in population vital rates. Under less than ideal conditions (i.e., medium parameter estimates), lesser prairie-chicken populations were more likely to go extinct with a terminal extinction risk of 0.99 and a median time to extinction of ~10 years.

All 5 scenarios modeled with low, medium and high parameters (Fig. 4.1) yielded an average population abundance of <100 female lesser prairie-chicken remaining in Texas after 10 years except for the best case scenario (i.e., high parameter estimates and no harvest [134 lesser prairie-chicken remaining]). Harvest lowered population persistence of lesser prairie-chicken in Texas in all scenarios (Fig. 4.2), and extinction risk increased from ~12% to ~40%, and 72% with 5 and 10% harvest rates, respectively using high parameter estimates (Fig. 4.3). Extinction risk was high with low and medium parameter estimates (≥ 99%) irregardless of harvest rates.

Juvenile and adult survival was the most sensitive parameters with changes of 9.3 and 5.1 years in median time to extinction between high and low parameters (Fig. 4.4). Increases in juvenile survival vital rates also had the largest impact on viability of each local population by increasing local occupancy from approximately 5 to 7 years and 15 to 24 years in the southwestern and northeastern populations, respectively.

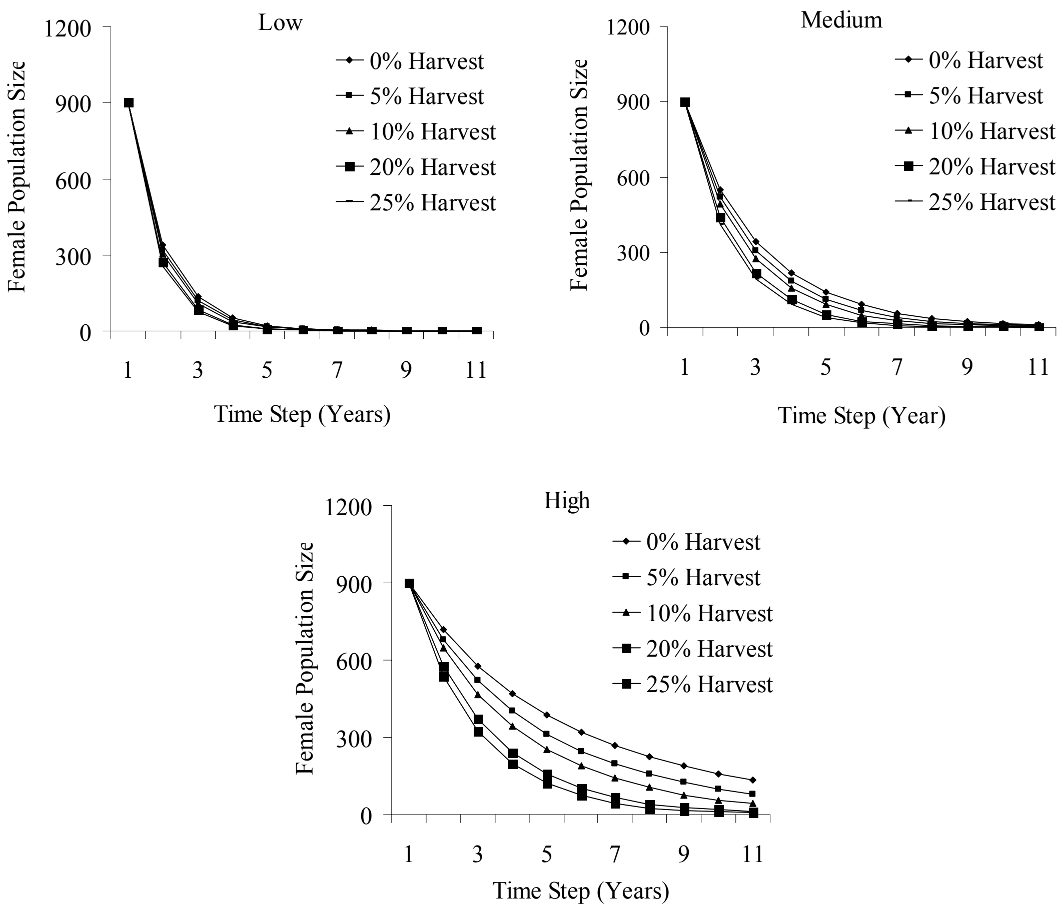

Fig. 4.1. Population trajectories of female lesser prairie-chicken (*Tympanuchus pallidicinctus*) population size after 10 years with varying harvest rates (0, 5, 10, 20, and 25%) using low, medium, and high parameter estimates, Texas Panhandle, 2007.

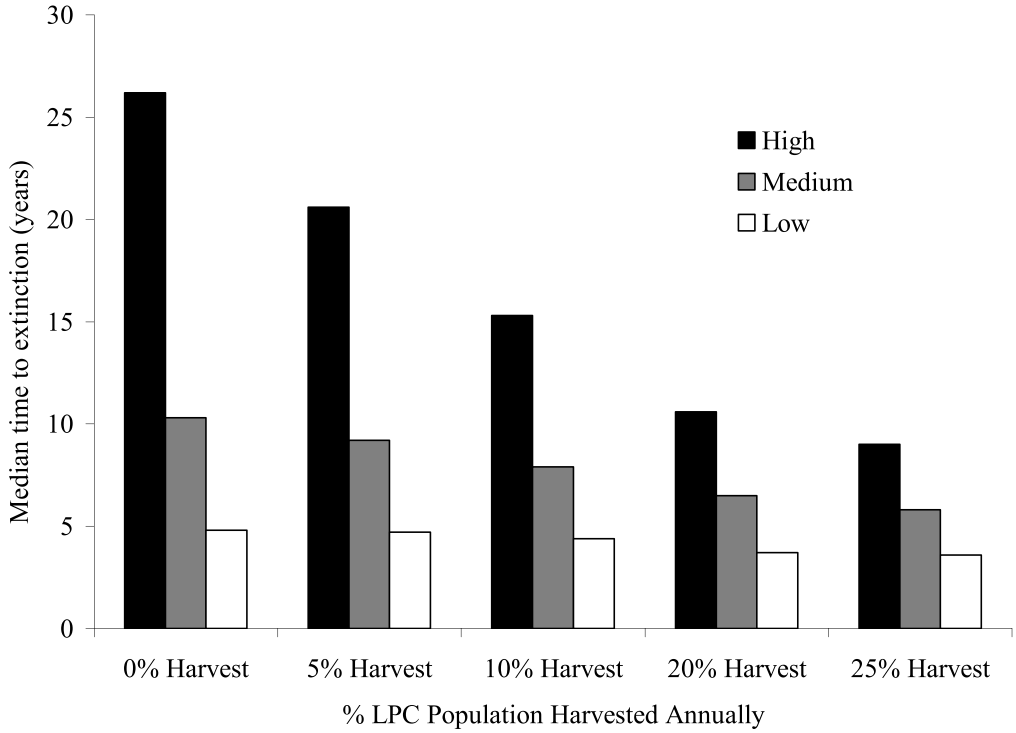

Fig. 4.2. Population persistence of lesser prairie-chicken (*Tympanuchus pallidicinctus*) populations with varying harvest rates (0, 5, 10, 20, and 25%) using low, medium and high parameter estimates, Texas Panhandle, 2007. Persistence is expressed as median time to extinction in years.

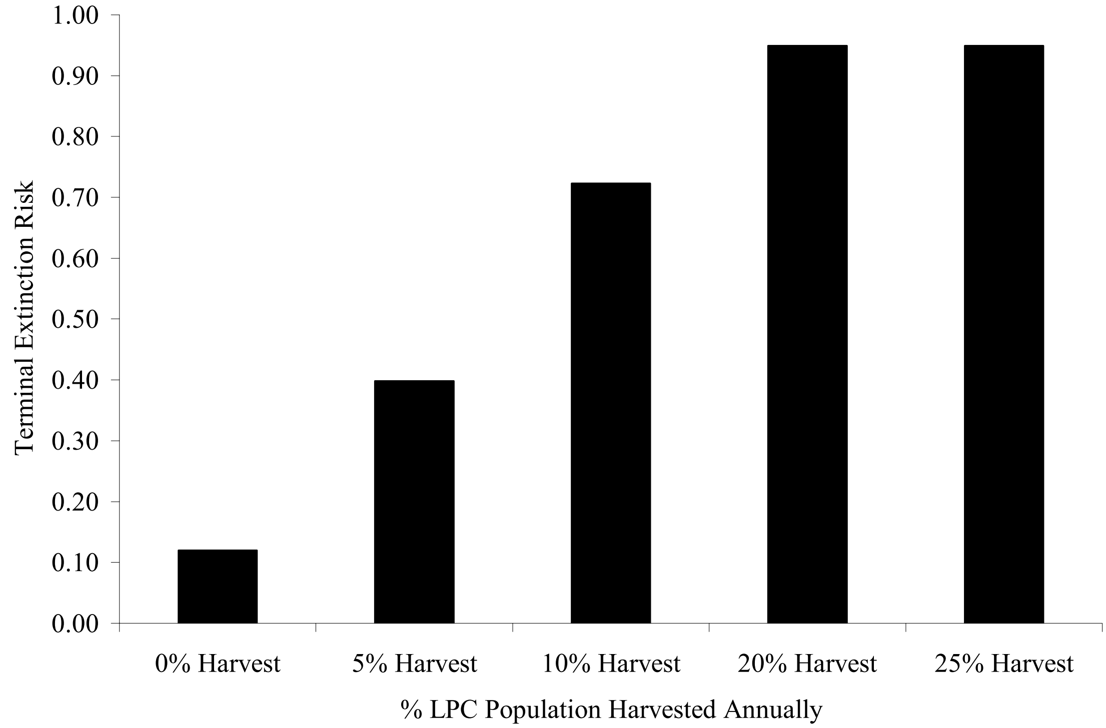

Fig. 4.3. Effects of varying harvest rates (0, 5, 10, 20, and 25%) on risk of extinction of lesser prairie-chicken (*Tympanuchus pallidicinctus*) populations using high parameter estimates, Texas Panhandle, 2007. Risk of extinction is expressed as terminal extinction risk.

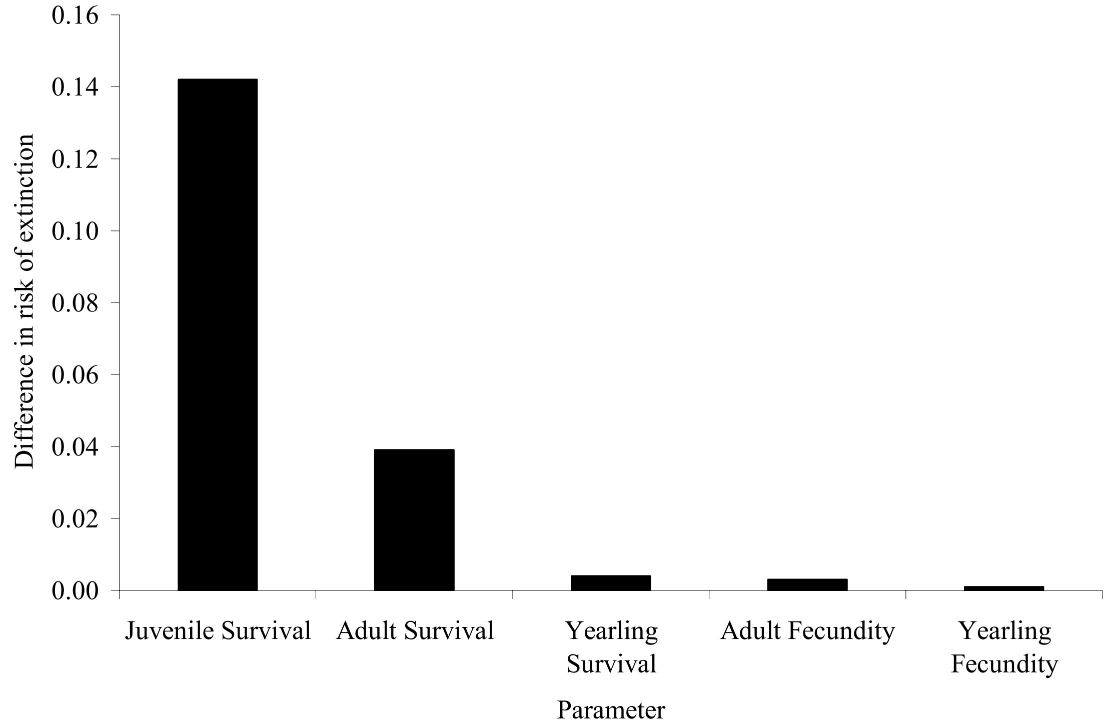

Fig. 4.4. Sensitivity (difference in risk estimates between high and low parameter values) of model results to parameter estimates for lesser prairie-chicken (*Tympanuchus pallidicinctus*) populations, Texas Panhandle, 2007. Population viability is expressed as terminal extinction risk.

DISCUSSION

Lesser prairie-chickens in Texas are at a high risk of extinction with model results suggesting extinction times of 10–20 years. Simulations suggest harvest exacerbated decline and reduced viability of lesser prairie-chicken populations in Texas. Classical approaches applied to harvest management included the generalization that harvest was compensatory as opposed to additive (Errington and Hamerstrom 1935).

Hagen et al. (2007) reported limited harvest by hunters should not impact lesser prairie-chicken populations in Kansas (<5% of all current mortality), however, populations in Kansas are increasing. Conversely, Taylor and Guthery (1980) reported hunter harvest of small populations during times of population lows may increase population declines, and recent studies on other species of upland game birds demonstrated negative effects of harvest regardless of population size (Johnson and Braun 1999, Peterson and Perez 2000, Guthery 2002). Although 2005 TPWD regulation changes precluded hunting of lesser prairie-chickens in Texas except on properties involved in a TPWD approved wildlife management plan, the potential exists for harvest levels to return to levels recorded prior to harvest policy changes if all previously hunted areas get approved wildlife management plans. I modeled multiple scenarios using past estimates of harvest rates of lesser prairie-chickens in Texas (Litton 1978) to account for greater uncertainty in annual harvest rates.

Hagen et al. (2004) suggested that although lesser prairie-chicken declines have slowed, their continuation is probably a result of poor habitat quality and quantity negatively affecting vital rates. My results indicated population persistence was lower in the southwest compared to the northeast region and differences between vegetation types in the Texas Panhandle probably influenced demographic rates. Deficiencies in shinnery oak vegetation types (i.e., less cover) compared to sand sagebrush vegetation types negatively affected demographic parameters such as survival and reproductive (Chapter II and III). Pitman (2003) and Hagen (2003) both found that increased cover by sand sagebrush may increase juvenile survival in Kansas. Johnson and Braun (1999) found adult and juvenile survival to be the most limiting factor in population growth of greater sage grouse, and also found these parameters respond clearly to habitat manipulation, especially brush manipulation (Johnson and Braun 1999).

Model estimates used in this study fall within the range from the published literature for lesser prairie-chickens (Campbell 1972, Merchant 1982, Hagen et al. 2005), although Haukos (1988) reported lower (4.1%) in Texas while Jamison (2000) estimated higher annual survival (0.57) in Kansas. While accurate or total counts may allow managers to predict potential extinction of species, as done with Attwater's prairie-chickens (Silvy et al. 2004), sparse data often are associated with endangered species biology and management, and model parameters are often known as ranges instead of single value estimates (Akçakaya 2000). Reed et al. (2002) suggested the most appropriate use of population viability analyses is to compare the relative effects of potential management actions on population growth or persistence. Predicting possible extinction risk and identifying factors relevant to decline of lesser prairie-chicken in Texas is imperative because trends in population declines by counties indicate that lesser prairie-chickens are in a steeper decline than the endangered Attwater's prairie-chicken

(Silvy et al. 2004). The most appropriate use of my model is to investigate the current status of lesser prairie-chicken in Texas and to evaluate the effects of current management and past-harvest scenarios (i.e., hunting) on a declining species. Akçakaya (2004) demonstrated that viability of other grouse species is determined by demographic factors such as fecundity and survival as well as the dynamics of a changing landscape. My results show that increasing survival of juvenile and adult lesser prairie-chickens is important if not imperative, to the short-term conservation and long-term recovery of lesser prairie-chickens in Texas. Relevant conservation efforts such as habitat management to increase lesser prairie-chicken usable space (Silvy et al. 2004) are one possibility to improve lesser prairie-chicken populations in Texas.

CHAPTER V

SUMMARY AND MANAGEMENT IMPLICATIONS

The purpose of this chapter is to summarize research findings from this dissertation and provide management recommendations. This chapter will begin by summarizing research findings from previous chapters in the dissertation. Management recommendations for maintaining lesser prairie-chicken populations in the Texas Panhandle will be derived from research findings.

RESEARCH FINDINGS

Survival

Multiple mechanisms have been hypothesized for the decline in lesser prairie-chickens in Texas including overgrazing and habitat loss and fragmentation (Taylor and Guthery 1980). This habitat loss and fragmentation has forced lesser prairie-chickens into marginal habitats dominated primarily by sand sagebrush in the northeast and shinnery oak in the southwest. I hypothesized that survival would be lower in the shinnery oak compared to the sand sagebrush vegetation type. Study results confirmed that annual survival of lesser prairie-chickens was lower in shinnery oak dominated areas compared to sand sagebrush areas (Chapter II). Study results also confirmed that survival was lower in the breeding season compared to the non-breeding season suggesting that lack of cover during the breeding season exacerbated mortality in the shinnery oak dominated areas.

Nest success

I also hypothesized that nest success would be lower in shinnery dominated areas because of less cover for nest concealment. Study results confirmed nest success to be lower in the shinnery oak dominated areas compared to sand sagebrush areas (Chapter III). Given that survival of birds was lower during the breeding season than the non-breeding season, it is evident that vegetation structure and composition and nesting cover played an important role in successful nesting. Model selection indicated differences in nest success were due mostly to differences in vegetation characteristics rather than region or year.

Population viability

Demographic parameters for survival (Chapter II) and reproduction (Chapter III) were used to construct a population viability analysis. The northeastern population of lesser prairie-chickens was traditionally the stronghold of the overall population in Texas (N. J. Silvy, personal communication.) Population viability analysis indicated that the northeastern population would continue to persist for at least 30 years while the southwestern population would go extinct more quickly. Overall declines in the population would continue and all levels of harvest negatively affected the overall viability of lesser prairie-chickens in Texas.

MANAGEMENT IMPLICATIONS

Population management

1. Higher survival of birds in the northeastern region compared to the southwestern region illustrated the need to manage for habitat components such as sand sagebrush and residual bunchgrasses as opposed to shinnery oak.
2. Higher survival of birds during the non-breeding season compared to the breeding season illustrated the need to manage for vegetation components such as sand sagebrush and residual bunchgrasses as opposed to shinnery oak that mitigate predation during the breeding season.
3. Higher nest success in the sand sagebrush compared to the shinnery oak vegetation type demonstrated this vegetation type provided more of the cover requirements necessary for successful nests.

Monitoring and research

1. Continue collecting demographic data using radio telemetry on lesser prairie-chickens in Texas. Long term data sets are lacking and are useful for evaluating population changes of lesser prairie-chickens in Texas.
2. Conduct census to ascertain accurate population estimates for lesser prairie-chickens in both regions of the Texas Panhandle.
3. Collect demographic data using radio-telemetry on lesser prairie-chickens in suitable and marginal habitats to quantify the rate of decline in each habitat type.
4. Changes in shinnery oak age, composition, and structure may account for lower survival and declining lesser prairie-chicken populations in the southwestern

Texas Panhandle. A need to understand the effect of shinnery oak on the population dynamics of lesser prairie-chickens is imperative to the recovery of the species and long-term monitoring programs are essential to maintaining viable lesser prairie-chicken populations.

5. Evaluate the importance of micro-habitat variables within vegetation types on survival and nest success.
6. Other lesser prairie-chicken management needs include estimating the habitat suitability bounds for various cover components of lesser prairie-chicken habitat and the amount of acreage (i.e., usable space) to sustain viable lesser prairie-chicken populations.

Conservation

1. A need to understand the dynamics of declining populations now existing as metapopulations is imperative and the use of techniques such as simulation models are recommended.
2. Collect demographic data using radio telemetry on juvenile survival, and yearling survival and reproduction. These data are lacking from previous studies in Texas (Sell 1979, Haukos 1988, Chapters II and III). Current reproductive data are important for refining the population viability analysis model (Chapter IV).
3. Continue to collect data on harvest rates of lesser prairie-chickens in Texas. Harvest exacerbated decline of lesser prairie-chickens and accurate rates will aid in refining the population viability analysis model.

4. Refine population viability analysis by incorporating spatial aspects such as patch size and immigration and emigration between patches into the model. These data will be useful in refining the model.

CONCLUSION

Historically, lesser prairie-chickens in Texas occupied rangelands dominated by short and mid grass prairies and loss of these habitats mirrors loss of lesser prairie-chickens. They now occupy marginal habitats composed of mostly woody vegetation and dominated in some areas by a monoculture of shinnery oak. As a result of preferred habitat being lost, improvements to remaining marginal habitats must be made. Future management for lesser prairie-chickens will be habitat management. Habitat restoration of remaining grasslands (i.e., intersperse CRP areas with native grasses) and creation of patchy habitats in shinnery oak dominated areas with the use of herbicides are just 2 possibilities for increasing habitat for lesser prairie-chickens.

The future of lesser prairie-chickens across their range and throughout Texas is bleak. Even as current research is adopted into management strategies, lesser prairie-chickens continue to decline. If current trends continue, the lesser prairie-chicken in Texas will follow in the footsteps of the Attwater's prairie-chicken and the Heath Hen. Continued research may be useful for answering questions on rates and possible mechanisms of population declines in Texas. However, without changes in policies and attitudes towards recovery of the species by scientists and agencies (McCleery et al. 2007) the lesser prairie-chicken will continue their decline towards extinction in Texas.

LITERATURE CITED

Amman, G. A. 1944. Determining age and sex of pinnated and sharp-tailed grouse. Journal of Wildlife Management 8:170–171.

Akçakaya, H. R. 1991. A method for simulating demographic stochasticity. Ecological Modeling 54:133–136.

Akçakaya, H. R. 2000. Population viability analyses with demographically and spatially structured models. Ecological Bulletins 48:23–38.

Akçakaya, H. R., and P. Sjögren-Gulve. 2000. Population viability analyses in conservation planning: an overview. Ecological Bulletins 48:9–21.

Akçakaya, H. R., V. C. Radeloff, D. J. Mladenoff, and H. S. He. 2004. Integrating landscape and metapopulation modeling approaches: viability of the sharp-tailed grouse in a dynamic landscape. Conservation Biology 18:526–537.

Bailey, J. A., and S. O. Williams, III. 2000. Status of the lesser prairie-chicken in New Mexico, 1999. Prairie Naturalist 32:157–168.

Bergerud, A. T. 1988. Population ecology of North American grouse. Pages 578–685 *in* A. T. Bergerud and M. W. Gratson, editors. Adaptive strategies and population ecology of northern grouse. Wildlife Management Institute, Washington, D.C., USA.

Boag, D. A., and M. A. Schroeder. 1992. Spruce Grouse (*Falcipennis canadensis*), Account 005 *in* A. Poole and F. Gill, editors. The Birds of North America, The Academy of Natural Science, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington D.C., USA.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodal inference: a practical information theoretic approach. 2nd Edition Springer, New York, USA.

Campbell, H. 1972. A population study of lesser prairie-chickens in New Mexico. Journal of Wildlife Management 36:689–699.

Caizergues, A., and L. N. Ellison. 1997. Survival of black grouse *Tetrao tetrix* in the French Alps. Wildlife Biology 3:177–186.

Connelly, J. W., M. W. Gratson, and K. P. Reese. 1998. Sharp-tailed grouse (*Tympanuchus phasianellus*). Account 354 *in* A. Poole and F. Gill, editors. The Birds of North America, The Academy of Natural Science, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington D.C., USA.

Copelin, F. F. 1963. The lesser prairie-chicken in Oklahoma. Oklahoma Wildlife Conservation Department Technical Bulletin 6. Oklahoma City, USA, 57 pp.

Crawford, J. A. 1980. Status, problems, and research needs of the lesser prairie-chickens. Pages 1–7 *in* P. A. Vohs, Jr., and F. L. Knopf, editors. Proceedings of the Prairie Grouse Symposium, Oklahoma State University, Stillwater, USA.

Errington, P. L., and F. N. Hamerstrom, Jr. 1935. Bobwhite winter survival on experimentally shot and unshot areas. Iowa State College Journal of Science 9:250–262.

Federal Register. 1998. Endangered and threatened wildlife and plants; 12-month finding for a petition to list the lesser prairie-chicken as threatened and designate critical habitat. Federal Register 63:31400–31406.

Giesen, K. M., and C. A. Hagen. 2005. Lesser prairie-chicken (*Tympanuchus pallidicinctus*). Account 364 *in* A. Poole and F. Gill, editors. The Birds of North America, The Academy of Natural Science, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington D.C., USA.

Giesen, K. M. 1994. Movements and nesting habitat of lesser prairie-chicken hens in Colorado. Southwestern Naturalist 39:96–98.

Giesen, K. M. 2000. Population status and management of lesser prairie-chicken in Colorado. Prairie Naturalist 32:137–148.

Ginzburg, L.R., S. Ferson, and H. R. Akçakaya. 1990. Reconstructibility of density dependence and conservative assessment of extinction risk. Conservation biology 4:63–70.

Gould, F. W. 1960. Texas plants–a checklist and ecological summary. Texas Agricultural Experiment Station, Bulletin, MS-585, College Station, USA.

Grant, W. E., and P. B. Thompson. 1997. Integrated ecological models: simulation of socio-cultural constraints on ecological dynamics. Ecological Modeling 100:43–59.

Guthery, F. S. 2002. The technology of bobwhite management: the theory behind the practice. Iowa State University Press, Ames, USA.

Hagen, C. A. 2003. A demographic analysis of lesser prairie-chicken populations in southwestern Kansas: survival, population viability, and habitat use. Dissertation, Kansas State University, Manhattan, USA.

Hagen, C. A., B. E. Jamison, K. E. Giesen, and T. Z. Riley. 2004. Guidelines for managing lesser prairie-chicken populations and their habitats. Wildlife Society Bulletin 31:69–82.

Hagen C. A., J. C. Pitman, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2005. Age-specific variation in apparent survival rates of male lesser prairie-chickens. Condor 107:77–86.

Hagen, C. A., B. K. Sandercock, J. C. Pitman, R. J. Robel, and R. D. Applegate. 2006. Radio-telemetry survival estimates of lesser prairie-chickens in Kansas: Are there transmitter biases? Wildlife Society Bulletin 34:1064–1069.

Hagen, C. A., J. C. Pitman, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2007. Age-specific survival and probable causes of mortality in female lesser prairie-chickens. Journal of Wildlife Management 71:518–525.

Hannon. S. J., R. C. Gruys, and J. O. Schieck. 2003. Differential seasonal mortality of the sexes in willow ptarmigan *Lagopus lagopus* in northern British Columbia, Canada. Wildlife Biology 9:317–326.

Haukos, D. A. 1988. Reproductive ecology of lesser prairie-chickens in west Texas. Thesis, Texas Tech University, Lubbock, USA.

Henika, F. S. 1940. Present status and future management of the prairie chicken in Region 5. Division Wildlife Restoration Project 1-R special report, Texas Game, Fish, and Oyster Commission, Austin, USA.

Horton, R. E. 2000. Distribution and abundance of lesser prairie-chicken in Oklahoma. Prairie Naturalist 32:189–195.

IUCN 2004. 2004. Red list of threatened species. Accessed at:http://www.redlist.org. 1 January 2008.

Jackson, A. S., and R. DeArment. 1963. The lesser prairie-chicken in the Texas Panhandle. Journal of Wildlife Management 27:733–737.

Jamison, B. E. 2000. Lesser prairie-chicken chick survival, adult survival, and habitat selection and movements in fragmented rangelands of southwestern Kansas. Thesis, Kansas State University, Manhattan, USA.

Jensen, W. E., D. A. Robinson, Jr., and R. D. Applegate. 2000. Distribution and population trend of lesser prairie-chicken in Kansas. Prairie Naturalist 32:169–175.

Johnsgard, P. A. 1983. The grouse of the world. University of Nebraska, Lincoln, USA.

Johnsgard, P. A. 2002. Grassland grouse and their conservation. Smithsonian Institution Press, Washington, D.C., USA.

Johnson, K. H., and C. E. Braun. 1999. Viability and conservation of an exploited sage grouse population. Conservation Biology 13:77–84.

Kirsch, L. M. 1974. Habitat management considerations for prairie chickens. Wildlife Society Bulletin 2:124–129.

Leupin, E, E. 2003. Status of the Sharp-tailed Grouse (*Tympanuchus phasianellus*) in British Columbia. (Wildlife bulletin (British Columbia. Biodiversity Branch), B-104).

Litton, G. W. 1978. The lesser prairie-chicken and its management in Texas. Booklet 7000–025, Texas Parks and Wildlife Department, Austin, USA.

Litton, G.W., R. L. West, D. F. Dvorak, and G. T. Miller. 1994. The lesser prairie-chicken and its management in Texas. Booklet 7100–025, Texas Parks and Wildlife Department, Austin, USA.

Liu, J. G. 2001. Integrating ecology with human demography, behavior, and socioeconomics: needs and approaches. Ecological Modeling 140:1–8.

Marks, J. S. and V. S. Marks. 1988. Winter habitat use by Columbian sharp-tailed grouse in western Idaho. Journal of Wildlife Management 52:743–746.

McCleery, R. A., R. R. Lopez, and N. J. Silvy. 2007. Transferring research to endangered species management. Journal of Wildlife Management 71:2134–2141.

Merchant, S. S. 1982. Habitat-use, reproductive success, and survival of female lesser prairie-chickens in two years of contrasting weather. Thesis, New Mexico State University, Las Cruces, USA.

National Oceanic and Atmospheric Administration [NOAA]. 2005 Nov 15. NOAA home page. http://www.noaa.gov/. Accessed 2005 Nov 15.

Oberholser, H. C. 1974. The bird life of Texas. The University of Texas, Austin, USA.

Patten, M. A., D. H. Wolfe, E. Shochat, and S. K. Sherrod. 2005*a*. Effects of microhabitat and microclimate on adult survivorship of the lesser prairie-chicken. Journal Wildlife Management 36:1270–1278.

Patten, M. A., D. H. Wolfe, E. Shochat, and S. K. Sherrod. 2005*b*. Habitat fragmentation, rapid evolution, and population persistence. Evolutionary Ecology Research 7: 235–249.

Peterson, M. J., and N. J. Silvy. 1996. Reproductive stages limiting productivity of the endangered Attwater's prairie-chicken. Conservation Biology 4:1264–1276.

Peterson, M. J., W. F. Grant, and N. J. Silvy. 1998. Simulation of reproductive stages limiting productivity of the endangered Attwater's prairie chicken. Ecological Modeling 111:283–295.

Peterson, M. J., and R. M. Perez. 2000. Is quail hunting self-regulatory? Northern bobwhite and scaled quail abundance and quail hunting in Texas. Pages 85–91 *in* L. A. Brennan, W. E. Palmer, L. W. Burger, Jr., and T. L. Pruden, editors. Quail IV: proceeding of the fourth national quail symposium. Tall Timbers Research Station, Tallahassee, USA.

Pitman, J. C. 2003. Lesser prairie-chicken nest site selection and nest success, juvenile gender determination and growth, and juvenile survival and dispersal in southwestern Kansas. Thesis, Kansas State University, Manhattan, USA.

Pitman, J. C., C. A. Hagen, B. E. Jamison, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2006*a*. Survival of juvenile lesser prairie-chickens in Kansas. Wildlife Society Bulletin 34:675–981.

Pitman, J. C., C. A. Hagen, B. E. Jamison, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2006*b*. Nesting ecology of lesser prairie-chickens in sand sagebrush prairie of southwestern Kansas. Wilson Journal of Ornithology 118:23–35.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7–15.

Reed, J. M., L. S. Mills, J. B. Dunning Jr., E. S. Menges, K. S. McKelvey, R. Frye, S. R. Beissinger, M. Anstett, and P. Miller. 2002. Emerging issues in population viability analysis. Conservation Biology 16:7–19.

Riley, T. Z., C. A. Davis, M. Ortiz, and M. J. Wisdom. 1992. Vegetative characteristics of successful and unsuccessful nests of lesser prairie-chickens. Journal of Wildlife Management 56:383–387.

Schroeder, M. A. and L A. Robb. 1993. Greater prairie-chicken (*Tympanuchus cupido*). Account 36 *in* A. Poole and F. Gill, editors. The Birds of North America, The Academy of Natural Science, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington D.C., USA

Sell, D. L. 1979. Spring and summer movements and habitat use by lesser prairie-chicken females in Yoakum County, Texas. Thesis, Texas Tech University, Lubbock, USA, 41 pp.

Silvy, N. J., M. E. Morrow, E. Shanley, Jr., and R. D. Slack. 1990. An improved drop net for capturing wildlife. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 44:374–378.

Silvy, N. J., C. P. Griffin, M. A. Lockwood, M. E. Morrow, and M. J. Peterson. 1999. Attwater's prairie-chicken: a lesson in conservation biology research. Pages 153–162 *in* W. D. Svedarsky, R. H., Hier, and N. J. Silvy, editors; The greater prairie-chicken: a national look. Minnesota Agricultural Experiment Station, Miscellaneous Publication 99–1999, St. Paul, USA.

Silvy, N. J., and C. A. Hagen. 2004. Introduction: Management of imperiled prairie grouse species and their habitat. Wildlife Society Bulletin 32:2–5.

Silvy, N. J., M. J. Peterson, and R. R. Lopez. 2004. The cause of the decline of pinnated grouse: the Texas example. Wildlife Society Bulletin 32:16–21.

Simonoff, J. S. 2003. Analyzing categorical statistics. Springer-Verlag, New York, USA.

Storch, I. 2007. Conservation status of grouse worldwide: an update. Wildlife Biology 13 (Supplement 1):5–12.

Sullivan, R. M., J. P. Hughes, and J. E. Lionberger. 2000. Review of the historical and present status of the lesser prairie-chicken (*Tympanuchus pallidicinctus*) in Texas. Prairie Naturalist 32:177–188.

Taylor, M. A., and F. S. Guthery. 1980. Status, ecology, and management of the lesser prairie-chicken. Technical Report RM77, Forest Service General Rocky Mountain Forest and Range Experiment Station, United States Department of Agriculture, Fort Collins, USA.

Toole, B. E. 2005. Survival, seasonal movements, and cover use by lesser prairie-chickens in the Texas Panhandle. Thesis, Texas A&M University, College Station, USA, 39pp.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, California, USA.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird study 46 (supplement):120–139.

Wiebe, K. L., and K. Martin. 1998. Cost and benefits of nest cover for ptarmigan: change within and between years. Animal Behaviour 56:1137–1144.

Winterstein, S. R., K. H. Pollock, and C. M. Bunck. 2001. Analysis of survival data from telemetry studies. Pages 351–380 *in* J. Millspaugh and J. Marzluff, editors; Radio tracking and animal populations. Academic Press, San Diego, California, USA.

Wisdom, M. L., and L. S. Mills. 1997. Sensitivity analysis to guide population recovery: prairie-chickens as an example. Journal of Wildlife Management 61:302–312.

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