# BREEDING SEASON DEMOGRAPHICS OF A LESSER PRAIRIE-CHICKEN (*TYMPANUCHUS PALLIDICINCTUS*) POPULATION IN THE NORTHEASTERN TEXAS PANHANDLE

by

R.Douglas Holt, B.S. M.S.

A Dissertation

In

WILDLIFE SCIENCE

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

DOCTOR OF PHILOSOPHY

Approved

Dr. Clint Boal
Chair of Committee

Dr. Philip Gipson

Dr. Nancy McIntyre

Dr. David Haukos

Dr. Randall DeYoung

Dominick Casadonte
Interim Dean of the Graduate School

December 2012

# ACKNOWLEDGEMENTS

I want to first thank my family for their support and encouragement throughout this endeavor. I would like to acknowledge my late advisor, Dr. Warren Ballard, who gave me this opportunity and helped to get me going on the proper path to complete this degree. You have been missed. I offer my gratitude to Dr. Clint Boal for stepping in and taking over advising responsibilities and helping me push this to the end. I want to thank all of my committee members for being patient with me as I pushed things to the final deadlines.

I would also like to thank Dr. Matthew Butler for his help and assistance throughout this project. You have been a great help in data analyses and dealing with the pursuit of this degree in spite of the other things that life throws at us during the process. I am especially thankful for your friendship.

This project was completed entirely on private property and, as such, would not have been possible without the graciousness of all the landowners that I worked with in Gray and Hemphill counties. The Turley Ranch in Durham, Oklahoma provided a inexpensive place to stay throughout the project and it was the best field housing I have ever seen.

I would be remiss without thanking my friend, Blake Grisham and his lovely wife Elizabeth. I really want to thank you guys for taking me in on holidays when I was stuck in town. I really want to thank Blake for looking over my shoulder when I was attempting to analyze data using tests that I really didn’t know anything about and keeping me headed in the right direction.

# TABLE OF CONTENTS

# ABSTRACT

Lesser prairie-chicken (*Tympanuchus pallidicinctus*) populations have declined across their range since 1900 and are a candidate for listing as Threatened under the Endangered Species Act. The historic lesser prairie-chicken range included all of the Texas panhandle. Currently, lesser prairie-chickens are found in 2 distinct populations in the northeastern and southwestern Texas panhandle. I conducted a 3-year study of breeding season demographics of lesser prairie-chickens on private properties in Gray and Hemphill counties (1 March-31 August, 2008-2010).

I estimated male and female breeding bird survival, nest survival, and chick survival. I used demographic data collected during this study to conduct a population viability analysis and estimate time until extinction in the northeastern Texas panhandle. I assessed the efficacy of traditional road-based lek surveys to monitor lesser prairie-chicken populations in the Rolling Plains and High Plains ecoregions of Texas.

Male survival differed between seasons and age-classes. Juvenile male survival was 1.00 (SE=0.00) during the lekking season and 0.88 (SE=0.62) during the nesting season. Adult male survival was 0.51 (SE=0.10) during the lekking season and 0.82 (SE=0.08) during the nesting season. Female survival did not differ with respect to season or age and was 0.55 (SE=0.13) for the entire breeding season. Nest survival was 0.36 (SE=0.05) during my study. Chick survival was lower between hatch and 14 days post hatch (0.18; SE=0.01) than 15-63 days post-hatch (0.55; SE=0.16). Results of a population viability analysis indicated low population growth rate ($\lambda$=0.44) and time to extinction was 3.5 years under baseline conditions based on field data. Management practices resulting in higher vital rates across the annual cycle resulted in higher population growth rates and longer times until extinction. The probability of detecting an active lek during road-based lek surveys was affected by wind speed, wind direction, and ecoregion. Current assumptions of detectability of active leks are likely too great and should be adjusted based on environmental conditions.

Due to the drastic reduction in lesser prairie-chicken population across their range, listing as threatened is likely. As such, it is important to collect demographic data and establish management plans for species recovery. The results of analyses based on the data collected during my study suggest that the lesser prairie-chicken population in the northeastern Texas panhandle are on the brink of extripation.

# LIST OF TABLES

# LIST OF FIGURES

# CHAPTER 1

# INTRODUCTION

North American prairie grouse species include greater sage-grouse (*Centrocercus urophasianus*), Gunnison sage-grouse (*C. minimus*), sharp-tailed grouse (*Tympanuchus phasianellus*), greater prairie-chicken (*T. cupido*), and lesser prairie-chicken (*T. pallidicinctus*) (American Ornithologists' Union 1998). Species of prairie grouse in North America have declined sharply over the past 3 to 4 decades (Silvy and Hagen 2004). Indeed, one sub-species of the greater prairie-chicken, the heath hen (*T. c. cupido*), has been extinct since 1932 (Johnsgard 2002) and another subspecies, the Attwater's prairie-chicken (*T. c. attwateri*), is listed as endangered in accordance with section 4(f)(1) of the Endangered Species Act of 1973 (ESA), as amended (16 U.S.C. 1531 *et seq.*).

The U. S. Fish and Wildlife Service was petitioned to list lesser prairie-chicken as threatened under the ESA in 1995 (U. S. Fish and Wildlife Service 1998). The U. S. Fish and Wildlife Service determined that listing was warranted but precluded due to higher priority species (U. S. Fish and Wildlife Service 1998). The U. S. Fish and Wildlife Service use a listing priority matrix to assign listing priorities to species to be considered for protection under the ESA (U. S. Fish and Wildlife Service 1983; Table 1.1). After reviewing the petition, lesser prairie-chickens were assigned a listing priority of 8 (U. S. Fish and Wildlife Service 1998). Recently, the listing priority for lesser prairie-chickens was increased to 2 (U. S. Fish and Wildlife Service 2008), which indicates that listing for this species is likely imminent.

The lesser prairie-chicken has experienced large-scale population declines throughout its range. Lesser prairie-chickens are endemic to mixed-grass and short-grass prairies of North America (Patten et al. 2005*b*) dominated by sand shinnery oak (*Quercus havardii*) and sand sagebrush (*Artemisia filifolia*) (Giesen 1998). Historic lesser prairie-chicken range included portions of southwestern Kansas, southeastern Colorado, westernern Oklahoma, eastern New Mexico, and the Texas panhandle (Sullivan et al. 2000). As fragmentation of native prairie habitats progressed, lesser prairie-chicken populations became more isolated and at increased risk of inbreeding depression (Sullivan et al. 2000). Winter et al. (2006) reported that greater prairie-chickens were more sensitive to fragmentation of habitats than other bird species, but lesser prairie-chickens were not included in their analysis. Patch sizes as large as 10,000 ha of native rangeland may be necessary for lesser prairie-chicken population persistence (Davis et al. 2008). Fewer large patches of intact native habitat have been associated with declining populations of lesser prairie-chickens in Oklahoma and Texas compared to stable populations observed in other parts of the species' range (Fuhlendorf 2002). The cause of this precipitous decline in lesser prairie-chicken populations is thought to be due to changes in land-use practices (Aldrich 1963, Jackson and DeArment 1963, Sullivan et al. 2000, Woodward et al. 2001) and exacerbated by droughts (Jackson and DeArment 1963, Hagen et al. 2004).

Lesser prairie-chickens were thought to have been widespread prior to the settlement of Texas (Woodward et al. 2001). However, records of this species' occurrence are incomplete and make determinations of population size prior to the early 1900's difficult to assess accurately. Additionally, early distinctions between lesser and greater prairie-chickens were not made and the two species were likely sympatric in parts of their ranges (Jackson and DeArment 1963). Lesser prairie-chickens currently occur in two distinct populations in the Texas panhandle (Jackson and DeArment 1963, Taylor and Guthery 1980, Corman 2011), which may represent a 92 percent decrease from population levels of the 1800's (Taylor and Guthery 1980, Sullivan et al. 2000).

Lesser prairie-chickens exhibit a clumped polygynous mating system (Bergerud 1988), where males gather at communal display grounds known as leks. Females select a mate from the number of males displaying on the lek. Generally, females select the most dominant males on the lek and, as such, only a few males have the majority of breeding opportunities (Giesen 1998). Males show high site fidelity to leks (Campbell 1972), and lek site fidelity increases with age (Hagen et al. 2005*a*). However, Pitman et al. (2006*b*) observed radio-marked sub-adult males at multiple leks during their first breeding season. Given the clumped polygynous mating system and lek site fidelity of lesser prairie-chickens, natal dispersal is the likely mechanism for gene flow across populations (Pitman et al. 2006*b*). Juvenile dispersal and male use of multiple leks, during and across breeding seasons, may provide insight to gene flow within lesser prairie-chicken populations.

Nesting season fitness is the most critical parameter driving prairie grouse population trajectories (Wisdom and Mills 1997, Peterson and Silvy 1996). Nesting habitat may be increasingly fragmented due to anthropogenic changes to the landscape (Sullivan et al. 2000). These changes are the result of conversion of native grassland to croplands, increased petroleum exploration and extraction, infrastructure associated with these activities, and increased pressure on native rangelands for grazing (Sullivan et al. 2000, Pitman et al. 2005). Hagen et al. (2007) reported that lesser prairie-chicken ranges were primarily restricted to native prairie habitats. Lesser prairie-chicken females in Kansas avoided anthropogenic features when selecting nesting locations (Robel et al. 2004, Pitman et al. 2005) and all adults avoided anthropogenic features within their home range (Robel et al. 2004). Increased landscape fragmentation may also lead to an increase in interspecific competition for nesting resources (Hagen et al. 2002, 2007) or result in disturbance as a result of physical interactions (Holt et al. 2010).

Sand sagebrush has been identified as a critical vegetative component surrounding successful nests in Kansas (Pitman et al. 2005). However, Riley et al. (1992) reported greater nest survival when lesser prairie-chickens selected sand bluestem (*Andropogon hallii*) as nesting cover compared to nests established in sand sagebrush in New Mexico. Johnson et al. (2004) reported nesting females selected areas dominated by sand shinnery oak compared to sites treated with herbicide in New Mexico.

Female lesser prairie-chickens have been observed to attempt a second nest if the first nest fails early in the season (Giesen 1998). Fields et al. (2006) reported declining nest survival as nest age increased in Kansas. Along with nest success, brood survival is an important component to lesser prairie-chicken population persistence (Sullivan et al. 2000, Fields et al. 2006, Pitman et al. 2006*a*). Chicks are precocial and leave the nest on the day they hatch to follow the female to foraging habitat (Giesen 1998). Previous studies have used flush counts at regular intervals (Fields et al. 2006, Pitman et al 2006*a*) to monitor brood survival. Fields et al. (2006) reported that brood survival increased with brood age and Pitman et al. (2006*a*) reported >50% of total brood losses occurred prior to 14 days post-hatch. Brood mixing of radio-marked chicks has been observed (Pitman et al 2006*a*). However, chicks in this study were radio-marked at 30 days post hatch so it was not possible to detect brood-mixing prior to 30 days post hatch.

Hagen et al. (2005*b*) reported a strong relationship between invertebrate biomass and lesser prairie-chicken brood-use and that brood areas had greater visual obstruction readings (Robel et al. 1970) compared to non-use areas. Previous studies have reported that arthropods are essential to survival of gray partridge (*Perdix perdix*) chicks (Dahlgren 1990) and densities of gray partridge broods were greater in areas with greater insect abundance (Panek 1997). Hill (1985) reported home range sizes were smaller and survival was greater for ring-necked pheasant (*Phasianus colchicus*) broods in areas where invertebrate abundance was greater. At greater density, vegetation may provide screening cover (Kopp et al. 1998) and increase brood survival. If invertebrate abundance is related to vegetation density, habitat management to increase vegetation density may increase brood fitness by adding cover and invertebrate biomass. An increase in life history needs at the brood stage could result in smaller brood ranges and reduced exposure to predators (Hill 1985).

Many studies of animal ecology focus on habitat use relative to availability under the presumption that selective use reflects greater habitat quality or relative value (Garshelis 2000). These studies often use statistical tests (e.g. chi-square tests, compositional analysis, etc.) to detect disproportionate or non-random use for the purpose of making inferences about habitat selction (Dixon et al. 1996). Although this approach may reflect habitat selection, it does not necessarily reflect habitat quality as measured by fitness (Van Horne 1983). Inferences regarding habitat quality require knowledge of relationships among habitat composition, structure, and fitness components (e.g., survival, reproduction).

Some studies have qualitatively related habitat composition to survival (Hines 1987, Klinger et al. 1989, Loegering and Fraser 1995), but few have made quantitative estimations of survival in relation to habitat composition and structure. Landscape structure and composition has been quantitatively related to nesting season (Schmitz and Clark 1999) and winter (Perkins et al. 1997) survival rates for ring-necked pheasants and nesting season survival for northern bobwhite (*Colinus virginianus*) (Taylor et al. 1999). Only one published report has related lesser prairie-chicken habitat selection to survivorship (Patten et al. 2005*a*).

The bulk of knowledge regarding lesser prairie-chicken ecology has been the result of short-term graduate studies (Giesen 1998) conducted largely in sand shinnery oak and sand sagebrush communities (Hagen et al. 2004). Studies in Kansas were conducted in areas with large enrollment in the Conservation Reserve Program where lesser prairie-chicken populations are stable and may be increasing (Fields et al. 2006).

Lesser prairie-chicken seasonal habitat preference has been listed as a research priority (Giesen 1998). Collecting natural history data is crucial to developing plans for conservation of prairie grouse species (Bell et al. 2007). As such, the objective of my study was to provide baseline demographic data for a population of lesser prairie-chickens in the northeastern Texas panhandle.

Collection of demographic data for this study was carried out during the breeding seasons (March 1-August 31) 2008-2010 in Gray and Hemphill counties, Texas, USA (Figure 1.1). I present assessments of survival and cause-specific mortality rates for radiomarked breeding aged male and female lesser prairie-chickens (Chapter 2). I present assessments of nest and chick survival and vegetative characteristics at nest sites (Chapter 3). I use the assessments of demographic rates presented in Chapters 2 and 3 along with over-winter survival estimates for radiomarked female lesser prairie-chicken collected during a concurrent study (Kukal 2010) to develop Population Viability Analysis models to predict population persistence in Gray and Hemphill counties under baseline and hypothetical conditions (Chapter 4). I present an assessment of the efficacy of road-based lek surveys (Chapter 5) using data collected in Cochran, Gray, Hemphill, and Yoakum counties, Texas, USA (Figure 1.1). I formatted Chapters 2-5 of the following dissertation to be independent manuscripts to facilitate publication of the results contained here. As such, there are redundancies within each chapter, particularly in the introduction and study area sections. The format of these chapters follows the guidelines for The Journal of Wildlife Management (Block et al. 2011). However, for this dissertation, chapters are written in the first person. Chapters will be changed to third person and appropriate co-authors will be added when submitted for publication.

## LITERATURE CITED

Aldrich, J. W. 1963. Geographic orientation of American Tetraonidae. Journal of Wildlife Management 27:528-545.

American Ornithologists' Union. 1998. Check-list of North American Birds, 7th ed. American Ornithologists' Union, Washington, D.C., USA.

Bell, L. A., J. C. Pitman, M. A. Patten, D. H. Wolfe, S. K. Sherrod, and S. D. Fuhlendorf. 2007. Juvenile lesser prairie-chicken growth and development in southeastern New Mexico. The Wilson Journal of Ornithology 119:386-391.

Bergerud, A. T. 1988. Mating systems in grouse. *in* A. T. Bergerud and M. W. Gratson, editors. Adaptive Strategies and Population Ecology of Northern Grouse, Volume II: Theory and Synthesis. University of Minnesota Press, Minneapolis, MN, USA.

Block, W. M., F. R. Thompson, D. Hanseder, A. Cox, and A. Knipps. 2011. Journal of Wildlife Management Guidelines. The Wildlife Society, Bethesda, Maryland, USA.

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

Corman, K. S. 2011. Conservation and landscape genetics of Texas lesser prairie-chicken: population structure and differentiation, genetic variability, and effective size. M. S. Thesis. Texas A&M University-Kingsville, Kingsville, USA.

Dahlgren, J. 1990. The significance of arthropods in the partridge diet. Pages 203-213 *in* K. E. Church, R. E. Warner, and S. J. Brady, editors. Perdix V: gray partridge and ring-necked pheasant workshop. Kansas Department of Wildlife and Parks, Emporia, Kansas, USA.

Davis, D. M., R. E. Horton, E. A. Odell, R. D. Rodgers, and H. A. Whitlaw. 2008. Lesser prairie-chicken conservation initiative. Lesser Prairie-chicken Interstate Working Group. Unpublished Report. Colorado Division of Wildlife, Fort Collins, USA.

Dixon, K. R., M. A. Horner, S. R. Anderson, W. D. Henriques, D. Durham, and R. J. Kendall. 1996. Northern bobwhite habitat use and survival on a South Carolina plantation during winter. Wildlife Society Bulletin 24:627-635.

Fields, T. L., G. C. White, W. C. Gilbert, and R. D. Rodgers. 2006. Nest and brood survival of lesser prairie-chickens in west central Kansas. Journal of Wildlife Management 70:931-938.

Fuhlendorf, S. D., A. J. W. Woodward, D. M. Leslie, Jr., and J. S. Shackford. 2002. Multi-scale effects of habitat loss and fragmentation on lesser prairie-chicken populations of the US southern great plains. Landscape Ecology 17:617-628.

Garshelis, D. L. 2000. Delusions in habitat evaluation: measuring use, selection, and importance. Pages 111-164 *in* L. Boitani and T.K. Fuller, editors. Research techniques in animal ecology: controversies and consequences. Columbia University Press, New York, USA.

Giesen, K. M. 1998. *Tympanuchus pallidicinctus*, lesser prairie-chicken. *in* A. Poole and F. Gill. editors. The Birds of North America, No. 364. Cornell Laboratory of Ornithology, Ithaca, NY, USA, and The Academy of Natural Sciences, Philadelphia, PA, USA.

Hagen, C. A., B. E. Jamison, K. M. Giesen, and T. Z. Riley. 2004. Guidelines for managing lesser prairie-chicken populations and their habitats. Wildlife Society Bulletin 32:69-82.

Hagen, C. A., B. E. Jamison, R. J. Robel, and R. D. Applegate. 2002. Ring-necked pheasant parasitism of lesser prairie-chicken nests in Kansas. The Wilson Bulletin 114:522-524.

Hagen, C. A., J. C. Pitman, R. J. Robel, T. M. Loughlin, and R. D. Applegate. 2007. Niche partitioning by lesser prairie-chicken *Tympanuchus pallidicinctus* and ring-necked pheasant *Phasianus colchicus* in southwestern Kansas. Wildlife Biology 13:Supplement 1:1-8.

Hagen, C. A., J. C. Pitman, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2005*a*. Age-specific variation in apparent survival rates of male lesser prairie-chickens. The Condor 1074:78-86.

Hagen, C. A., G. C. Salter, J. C. Pitman, R. J. Robel, and R. D. Applegate. 2005*b*. Lesser prairie-chicken brood habitat in sand sagebrush: invertebrate biomass and vegetation. Wildlife Society Bulletin 33:1080-1091.

Hill, D. A. 1985. The feeding ecology and survival of pheasant chicks on arable farmland. Journal of Applied Ecology 22:645-654.

Hines, J. E. 1987. Winter habitat relationships of blue grouse on Hardwicke Island, British Columbia. Journal of Wildlife Management 51:426-435.

Holt, R. D., M. J. Butler, W. B. Ballard, C. A. Kukal, and H. Whitlaw. 2010. Disturbance of lekking Lesser Prairie-Chickens (*Tympanuchus pallidicinctus*) by Ring-necked Pheasants (*Phasianus colchicus*). Western North American Naturalist 70:241-244.

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

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

Johnson, K., B. H. Smith, G. Sadoti, T. B. Neville, and P. Neville. 2004 Habitat use and nest site selection by nesting lesser prairie-chickens in southeastern New Mexico. The Southwestern Naturalist 49:334-343.

Klinger, R. C., M. J. Kutilek, and H. S. Shellhammer. 1989. Population responses of black-tailed deer to prescribed burning. Journal of Wildlife Management 53:863-871.

Kopp, S. D., F. S. Guthery, N. D. Forrester, and W. E. Cohen. 1998. Habitat selection modeling for northern bobwhites on subtropical rangeland. Journal of Wildlife Management 62:884-895.

Kukal, C. A. 2010. The over-winter ecology of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in the northeast Texas panhandle. M. S. Thesis, Texas Tech University, Lubbock, USA.

Loegering, J. P. and J. D. Fraser. 1995. Factors affecting piping plover chick survival in different brood-rearing habitats. Journal of Wildlife Management 59:646-655.

Panek, M. 1997. The effect of agricultural landscape structure on food resources and survival of grey partridge *Perdix perdix* chicks in Poland. Journal of Applied Ecology 34:787-792.

Patten, M. A., D. H. Wolfe, E. Shochat, and S. K. Sherrod. 2005*a*. Effects of microhabitat and microclimate selection on adult survivorship of the lesser prairie-chicken. Journal of Wildlife Management 69:1270-1278.

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

Perkins, A. J., W. R. Clark, T. Z. Riley, and P. A. Vohs. 1997. Effects of landscape and weather on winter survival of ring-necked pheasant hens. Journal of Wildlife Management 61:634-644.

Peterson, M. J., and N. J. Silvy. 1996. Reproductive strategies limiting productivity of the endangered Attwater's prairie-chicken. Ecological Modeling 111:283-295.

Pitman, J. C., C. A. Hagen, B. E. Jamison, R. J. Robel, T. M. Loughlin, and R. D. Applegate. 2006*a*. Survival of juvenile lesser prairie-chickens in Kansas. Wildlife Society Bulletin 34:675-681.

Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughlin, and R. D. Applegate. 2005. Location and success of lesser prairie-chicken nests in relation to vegetation and human disturbance. Journal of Wildlife Management 69:1259-1269.

Pittman, J. C., B. E. Jamison, C. A. Hagen, and R. D. Applegate. 2006*b*. Brood break-up and juvenile dispersal of lesser prairie-chicken in Kansas. The Prairie Naturalist 38:85-99.

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.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Robel, R. J., J. A. Harrington, Jr., C. A. Hagen, J. C. Pitman, and R. R. Reker. 2004. Effect of energy development and human activity on the use of sand sagebrush habitat by lesser prairie chickens in southwestern Kansas. Transactions of the 69th North American Wildlife and Natural Resources Conference 69:251-266.

Schmitz, R. A. and W. R. Clark. 1999. Survival of ring-necked pheasant hens duringspring in relation to landscape features. Journal of Wildlife Management 63:147-154.

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

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. The Prairie Naturalist 32:177-188.

Taylor, J. S., K. E. Church, D. H. Rusch, and J. R. Cary. 1999. Macrohabitat effects on summer survival, movements, and clutch success of northern bobwhites in Kansas. Journal of Wildlife Management 63:675-685.

Taylor, M. A. and F. S. Guthery. 1980. Status, ecology, and management of the lesser prairie-chicken. United States Department of Agriculture Forest Service Technical Report RM-77. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado, USA.

U. S. Fish and Wildlife Service. 1983. Endangered and threatened species listing and recovery guidelines. Federal Register. 48:43098-43105.

U. S. Fish and Wildlife Service. 1998. Endangered 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.

U. S. Fish and Wildlife Service. 2008. Endangered and threatened wildlife and plants; review of native species that are candidates for listing as endangered or threatened; annual notice of findings on resubmitted petitions; annual description of progress on listing actions. Federal Register. 73:75176-75244.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893-901.

Winter, M., D. H. Johnson, and J. A. Shafer. 2006. Does body size affect a bird's sensitivity to patch size and landscape structure? The Condor 10:808-816.

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

Woodward, A. J. W., S. D. Fuhlendorf, D. M. Leslie, Jr., and J. Shackford. 2001. Influence of landscape composition and change on lesser prairie-chicken (*Tympanicus pallidicinctus*) populations. American Midland Naturalist 145:261-274.

Table 1.1. Priority ranking matrix used to determine listing priority for species considered for protection under the Endangered Species Act by the U. S. Fish and Wildlife Service (adapted from U. S. Fish and Wildlife Service 1983).

| Threat | | Taxonomy | Priority |
|---|---|---|---|
| Magnitude | Immediacy | | |
| High | Imminent | Monotypic genus | 1 |
| | | Species | 2 |
| | | Subspecies | 3 |
| | Non-imminent | Monotypic genus | 4 |
| | | Species | 5 |
| | | Subspecies | 6 |
| Moderate to low | Imminent | Monotypic genus | 7 |
| | | Species | 8 |
| | | Subspecies | 9 |
| | Non-imminent | Monotypic genus | 10 |
| | | Species | 11 |
| | | Subspecies | 12 |

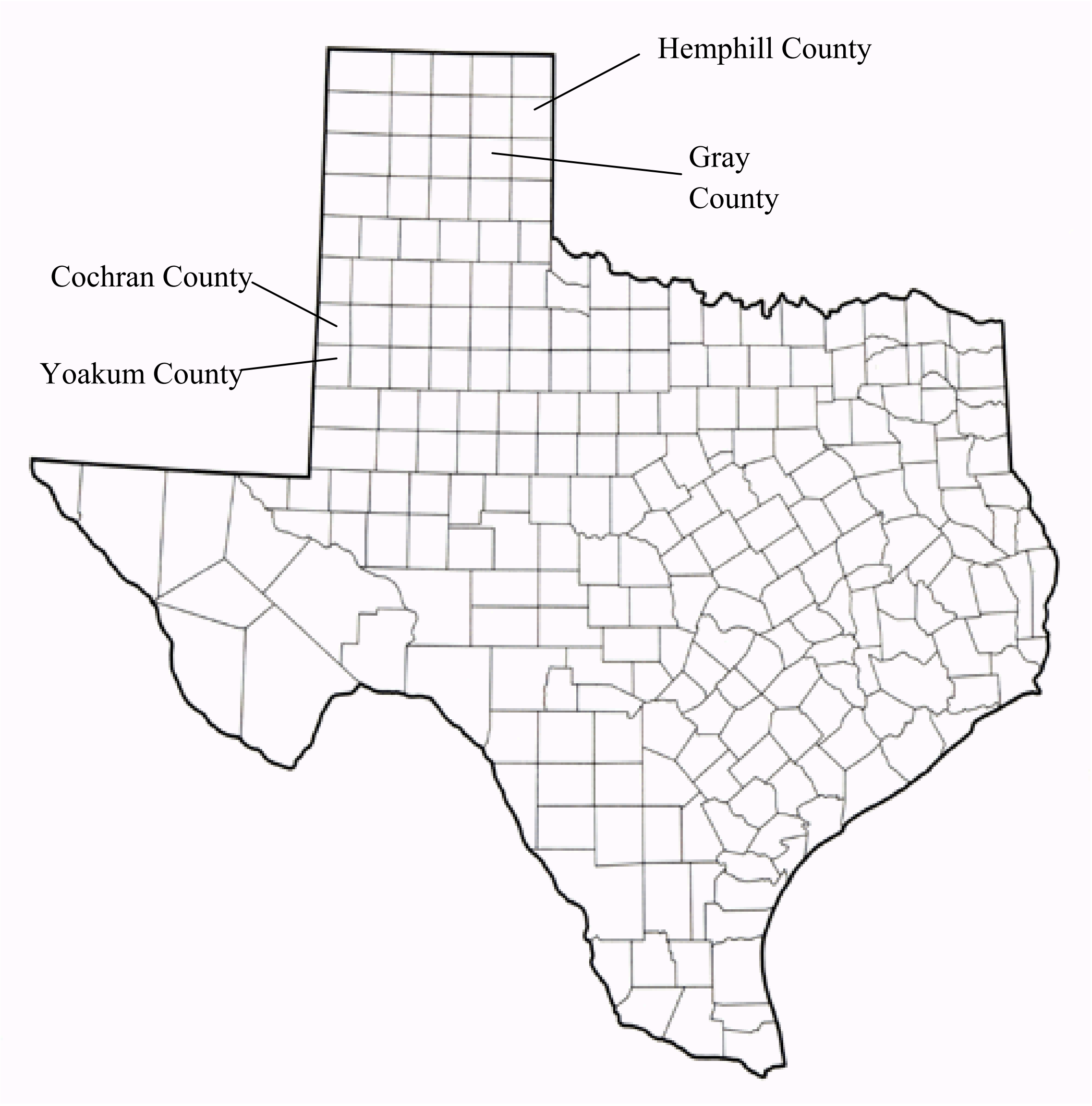


Figure 1.1 Location of Cochran, Gray, Hemphill, and Yoakum counties, Texas, USA.

# CHAPTER 2

## SURVIVAL AND CAUSE-SPECIFIC MORTALITY OF LESSER PRAIRIE-CHICKENS (*TYMPANUCHUS PALLIDICINCTUS*) DURING THE BREEDING SEASON IN THE NORTHEASTERN TEXAS PANHANDLE

All species of prairie grouse have declined sharply over the past 3 to 4 decades (Silvy and Hagen 2004). Large-scale declines of lesser prairie-chicken (*Tympanuchus pallidicinctus*) populations have been observed since 1900 on the Great Plains (Litton et al. 1978). Lesser prairie-chickens are endemic to mixed-grass and short-grass prairies of North America (Aldrich 1963, Patten et al. 2005), and prefer grasslands dominated by sand shinnery oak (*Quercus havardii*) and sand sagebrush (*Artemisia filifolia*) (Giesen 1998). Historic range of lesser prairie-chickens included portions of southwestern Kansas, southeastern Colorado, western Oklahoma, eastern New Mexico, and the Texas Panhandle (Sullivan et al. 2000).

It is estimated that two-thirds of the historic range of lesser prairie-chickens occurred in the Texas panhandle (U. S. Fish and Wildlife Service 2010), with as many as 2 million birds present prior to 1900 (Litton et al. 1978). Currently, lesser prairie-chickens are found in at least 2 distinct populations in the Texas panhandle (Jackson and DeArment 1963, Taylor and Guthery 1980, Corman 2011), with a distribution representing up to a 92% reduction of occupied area (Sullivan et al. 2000). Furthermore, the Texas range has declined by as much as 78% since 1940 (Taylor and Guthery 1980).

The cause of the large-scale population decline observed in lesser prairie-chickens is attributed to changes in land use (Aldrich 1963, Jackson and DeArment 1963, Sullivan

et al. 2000) and habitat fragmentation (Crawford 1980, Samson 1980, Braun et al. 1994). Changing land-use practices include the conversion of native grasslands to cultivation (Jackson and DeArment 1963, Crawford and Bolen 1976, Braun et al. 1994), over-grazing (Riley 1992, Giesen 1998), and oil and gas extraction (Pitman et al. 2005*b*). Effects of anthropogenic land-use changes may be exacerbated by periodic droughts (Jackson and DeArment 1963, Hagen et al. 2004*a*).

Knowledge of population vital rates is critical to assess the efficacy of management activities. Survival estimates have been reported for lesser prairie-chickens in Kansas (Hagen et al. 2005, Hagen et al. 2007), New Mexico (Campbell 1972), and Texas (Lyons et al. 2009). Causes of mortality have also been reported for studies conducted in Kansas (Hagen et al. 2007) and Oklahoma and New Mexico (Wolfe et al. 2007). Estimates of survival and cause of mortality have recently been reported for the southwestern Texas panhandle population for reproductive (Grisham 2012) and over-winter (Pirius 2011) seasons. One study has assessed survival estimates during the reproductive season (Lyons et al. 2009) and one study has assessed survival and cause-specific mortality during the over-winter season (Kukal 2010) for the northeastern Texas panhandle.

The land cover in the southwestern Texas panhandle is dominated by sand shinnery oak (McCleery et al. 2007), whereas rangelands in the northeastern Texas panhandle are characterized by lower densities of sand shinnery oak. McCleery et al. (2007) argued that since most studies of lesser prairie-chicken ecology have been conducted in areas where sand shinnery oak is dominant, a paradigm has taken hold that sand shinnery oak is crucial to management for persistence of lesser prairie-chickens. Furthermore, McCleery et al. (2007) hypothesized that sand shinnery oak is dominated landscapes represent suboptimal habitat. The land cover in the southwestern Texas panhandle is dominated by sand shinnery oak (McCleery et al. 2007), whereas rangelands in the northeastern Texas panhandle are less dominated by sand shinnery oak. Estimates of local vital rates in different cover types are necessary to guide management across the current range of lesser prairie-chickens and could provide insight into what constitutes optimal cover types. My objectives were to estimate survival and cause-specific mortality rates for lesser prairie-chickens in the northeastern Texas panhandle and compare the results to estimates reported from across their range.

## STUDY AREA

The study area was on private lands in Gray and Hemphill counties, Texas, USA. The Gray county site was located in the High Plains ecoregion and the Hemphill County site was in the Rolling Plains ecoregion (Bender et al. 2005). Primary land uses were cattle ranching interspersed with oil and gas development and some Conservation Reserve Program lands, center-pivot and dry-land agricultural crops (McRoberts 2009).

The Gray county site was at the eastern edge of the Caprock Escarpment, with elevations from 850-900 m. Elevations on the Hemphill county site were from 750-800 m. Mean annual precipitation and temperatures were similar between the sites. Mean annual precipitation was 52 cm; mean low temperature was -5° C (January) and mean high temperature was 35° C (July).

Native land-cover types were similar for both sites and vegetation was dominated by grassland interspersed with areas of dense shrubs. Grasses included little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), switchgrass (*Panicum virgatum*), and Indiangrass (*Sorghastum nutans*; Jackson and DeArment 1963). Common forbs found in grasslands included common broomweed (*Amphiachyris dracunculoides*), Indian blanket (*Gaillardia pulchella*), and western ragweed (*Ambrosia psilostachya*). Shrubs, including sand sagebrush (*Artemisia filifolia*) and soapweed yucca (*Yucca glauca*), were sparsely scattered throughout grasslands. Patches of dense (>50% cover) sand shinnery oak (*Quercus havardii*) were present throughout the area and contained mottes consisting of sand shinnery oak-post oak (*Q. stellata*) hybrids ≤ 6 m tall (Peterson and Boyd 1998).

## METHODS

I defined the reproductive season as between 1 March-31 August. I further defined the lekking season (1 March-31 May) and the nesting season (1 June-31 August) as distinct components of the reproductive season. The lekking season was characterized by attendance at leks for the purposes of breeding, and nesting season was characterized by nest initiation, incubation, and brood-rearing by females. I defined these seasons at the conclusion of my study based on observations of behavior of birds on my study sites. Due to logistics and distance between study sites, monitoring activities at the Gray county site were reduced in 2009 and were not conducted in 2010.

### Capture

Birds were captured on leks during spring 2008-2010 using walk-in funnel traps (Haukos et al. 1990, Schroeder and Braun 1991) and rocket nets. All leks were trapped continuously throughout the lekking period. Upon capture, each bird was weighed, fitted with a serially numbered monel leg band, and classified by gender and age (Ammann 1944, Pitman et al. 2005*a*). Males were identified by the presence of eye combs and esophageal sacs (Giesen 1998). Birds were classified as juvenile (first breeding year) or adult (after first breeding year) based on the pattern of spotting on the 9th and 10th primaries (Ammann 1944, Copelin 1963). Birds captured as juveniles and that survived until the end of the season in which they were captured were promoted to adults on 1 September. Birds > 700 g were fitted with a 14 g, necklace-style radio transmitter with 12-hour mortality switches. I selected 700 g as a minimum mass so that radio transmitters were not greater than 2% of the bird mass (Venturato 2009). I captured additional birds outside of the primary trapping season near water sources and by trapping at leks during the fall lekking period. Capture and handling of live animals for research was approved by the Texas Tech University Institutional Animal Care and Use Committee (Animal Care and Use Protocol 07050-08).

### Effects of Radiomarking

I assumed that radio transmitters had no chronic effect on survival (Hagen et al. 2006). I tested for an acute effect of time since capture, handling, and radiomarking using a hierarchical model-selection procedure (Holt et al. 2009) based on Akaike's Information Criterion (AIC; Akaike 1973, Burnham and Anderson 1998). I tested 13 *a* *priori* models (Table 2.1) to describe survival over a 64-day period starting 22 February 2008-2010. This interval included most of trapping effort during spring each year. The best model that described survival during the trapping period was used as the base model to test acute effects of trapping, handling, and radiomarking for intervals lasting between 1 and 28 days post-release.

### Survival

Animals were entered into the risk set following an appropriate adjustment period. I attempted to monitor radiomarked birds ≥ 5 days/week. I used the nest model (Dinsmore et al. 2002) in Program MARK (White and Burnham 1999) to estimate daily survival rates. The use of the nest model in Program MARK is appropriate for ragged telemetry data if monitoring intervals are irregular (Hartke et al. 2006) or exact date of loss is unknown (Hagen et al. 2007). I changed daily survival estimates to interval survival estimates and approximated interval survival variances using the delta method (Powell 2007). I developed a set of 12 and 15 *a priori* models (Table 2.1) to describe survival for radiomarked male and female lesser prairie-chickens, respectively. I assessed survival for male and female lesser prairie-chickens separately because of differences in the number of each gender captured and because I intended to use female survival estimates to develop a female-based life-stage analysis model.

### Cause-specific Mortality

When a mortality signal was received, I homed to the signal and inspected the remains to assign a probable cause of mortality (Dumke and Pils 1973, Small et al. 1991). Accurate determination of true mortality factors can be affected in the presence of scavenging, particularly if there is lag-time between a mortality event and recovery of remains (Bumann and Stauffer 2002). I attempted to make more accurate estimates of cause of mortality by inspecting remains immediately upon receiving a mortality signal to reduce scavenging opportunities. I estimated cause-specific mortality (Schaub and Pradel 2004, Heisey and Patterson 2006) using Package *wild1* (Sargeant 2011) in Program R (R Development Core Team 2012). I classified mortalities as the result of avian predation, mammalian predation, or due to an unknown cause. I estimated season-specific, cause-specific mortality rates based on the best explanatory models for lesser prairie-chicken survival as outlined above.

## RESULTS

### Capture

I monitored 92 radiomarked lesser prairie-chickens during the reproductive seasons of 2008-2010 (Table 2.2). The number of birds tracked varied between seasons due to trapping methods used outside of the main trapping effort.

### Effects of Radiomarking

There were 4 competitive models ($\Delta AIC_c \leq 2$) for survival during the trapping period (Table 2.3). Of these models, 3 included a within-year linear trend and 1 included a within-year quadratic trend. The beta parameter estimates for all parameters except the within -year linear trend in all competing models were not statistically significant (Table 2.4). I selected the top model that included only a within-year linear trend as the best base model. When covariates for time since capture, handling, and radiomarking between 1 and 28 days post -release were added to the best base model, there was no clear best model (Table 2.5). I examined the beta parameter estimates for the effect of time since capture, handling, and radiomarking (Table 2.6). Effects of time since capture, handling, and radiomarking were significant from 1 to 17 days post-release. Therefore I entered birds into the risk set on the 18th day following capture to avoid biased survival estimates that may result from the stress of capture, handling, and radiomarking.

Survival

There were 2 competing models ($\Delta AIC_c \leq 2$) describing survival of radiomarked male lesser prairie-chickens, both of which included an age and season interaction effect (Table 2.7). The second best model included a within-season linear trend, but the 95% confidence interval for the beta parameter estimate for that covariate included zero (-0.001 ± 0.016). I concluded that male survival was best estimated by the model that included an age and season interaction effect only. Daily and seasonal survival estimates were lower for adult males during the lekking season than during the nesting season or juvenile survival during either season (Table 2.9). Juvenile survival was greater during the lekking season than the nesting season (Table 2.9). During the 3 years of this study, I observed no mortality of a radiomarked juvenile male lesser prairie-chicken during the lekking season. Male daily and seasonal survival estimates were greater for juveniles than for adults during the lekking and nesting seasons (Table 2.9).

There were 5 competing models ($\Delta AIC_c \leq 2$) describing the survival of radiomarked female lesser prairie-chickens (Table 2.8). The top models included the intercept-only model (i.e., no effect of any measured covariates on survival), a model with an across-year linear trend, a model with an age effect, a model with a within-year linear trend, and a model with a season effect (Table 2.8). However, in all models with a covariate effect, the 95% confidence intervals on the beta parameter estimate overlapped zero (Table 2.10). Survival of radiomarked female lesser prairie-chickens did not differ by age, season, or year. The daily survival estimate was 0.997 (SE = 0.001) and the survival estimate for the entire reproductive season was 0.545 (SE = 0.125).

### Cause-specific Mortality

Based on the results of the survival modeling, I estimated cause-specific mortality rates for males by age and season and females were pooled by age and season (Table 2.11). I pooled years for both genders. Mortality of adult males due to avian predation was greater than that of other causes during the lekking season. Mortality of both adult and juvenile males due to mammalian predation was greater than other causes during the nesting season. No mortalities of juvenile males were observed during the lekking season during this study. Cause-specific mortality rates from unknown causes for adult males were similar to that due to mammalian predation during both seasons. There were 3 mortalities of adult males during the lekking season attributed to an unknown cause. In 2 of these instances, the entire carcass was found intact with no sign of injury. However, carcasses were incorrectly stored and did not permit additional analysis of the cause of mortality (i.e., disease). Cause-specific mortality rates for females across the reproductive seasons of 2008-2010 were similar for both avian and mammalian predators (Table 2.11).

## DISCUSSION

The goal of this study was to estimate survival and cause-specific mortality for a radiomarked sample of lesser prairie-chickens on private land in the northeastern Texas panhandle. As such, I assumed that the sample of radiomarked birds was representative of the population from which they were drawn. Lack of lek attendance by juvenile males could bias survival or cause-specific mortality estimates in this study, especially if non-attendance leads to increased survival (Hagen et al. 2005). The survival estimate reported in my study will be biased low if many juveniles do not attend leks and have resulting greater survival. Conversely, the survival estimate of juvenile males could be biased high if mortalities of certain juveniles are not detected because they did not attend a lek and were unavailable for capture.

Schroeder and Braun (1992) reported that juvenile greater prairie-chickens (*T. cupido*) visited more leks compared to adults. Ballard and Robel (1974) observed that male greater prairie-chickens with established lek territories actively excluded other males, presumably juveniles, from the lek under observation. Furthermore, Ballard and Robel (1974) reported that removal of the dominant male from a lek resulted in establishment of territories on the lek by males that had not previously attended the lek. Daily lek attendance variation in greater sage grouse (*Centrocercus urophasianus*) has been reported (Jenni and Hartzler 1978, Emmons and Braun 1984) where overall male attendance peaks after the peak of female attendance. Emmons and Braun (1984) captured and radiomarked greater sage grouse on leks and by spotlighting on roads and reported average lek attendance of juveniles was 86% over 2 years. Hagen et al. (2005)

reported that lek site fidelity increased with age in male lesser prairie-chickens, but they did not specifically address lack of lek attendance by juveniles. Behney (2009) reported that some males captured on leks in the southwestern Texas panhandle never established territories on any observed lek.

If lek attendance by subordinate males is restricted by social interactions, then the probability of capture for juveniles will be lower than that for adults because juveniles would attend leks less often. A decrease in aggression towards subordinate juvenile males as the lekking season progresses could be the result of 2 causes. First, decreased aggression following the peak of female attendance could simply be a strategy to reduce energetic costs of lek territory defense due to reduced breeding opportunities. Alternatively, the energetic cost involved with display and defense of a lek territory causes dominant males to have poorer body condition and become susceptible to predation.

The proportion of radiomarked juveniles to adults varied during the study (Table 2.2). This might indicate that juveniles in the population were less available for capture during the final 2 years of the study. Alternatively, this might point to decreased recruitment in the population at large as the study progressed. I surveyed intensively to find leks for capture, and all known leks were trapped continuously. Therefore, if juvenile males in the population I studied visit multiple leks, it is likely that they would have encountered traps on any lek they attended. My capture methods were consistent with other reported studies of lesser prairie-chicken survival (Hagen et al. 2005, Patten et al. 2005, Lyons et al. 2009), so valid comparisons across studies are still possible.

I found no reports of differential lek attendance by females of any prairie grouse species based on age. The proportion of juvenile to adult females, based on captures, was greater in 2008 and 2010 and equal in 2009 (Table 2.2). This indicates that, unless there were many more juvenile than adult females in the population, there is no difference in female lek attendance based on age.

Hagen et al. (2005) reported annual apparent survival, so comparisons of season-specific survival estimates are not possible with this study. Patten et al. (2005) reported survival times for populations of lesser prairie-chickens in Oklahoma and New Mexico in relation to vegetative cover and microclimate, but did not report survival estimates by age, gender, or season, so comparison to my study was inappropriate.

I used a 17-day adjustment period to take into account any mortality that may have resulted from stress due to capture, handling, and marking. Other studies either did not report the use of an adjustment period (Hagen et al. 2005, Patten et al. 2005), or reported using an *ad hoc* 14-day adjustment period (Hagen et al. 2007, Lyons et al. 2009, Grisham 2012). It is unlikely that use of a 14-day adjustment period in other studies (Hagen et al. 2007, Lyons et al. 2009, Grisham 2012) would significantly affect comparisons of survival estimates. Studies that lacked an adjustment period (Hagen et al. 2005, Patten et al. 2005) may underested survival if capture, handling, and radiomarking had an acute effect that was not taken into account.

Lesser prairie-chicken reproductive season ecology was studied on the southwestern Texas panhandle population at the same time as my study (Grisham 2012) and provides the most appropriate comparison to my results. In contrast to my study, Grisham (2012) found no evidence of differential male survival as a function of age but reported differential survival with respect to season. Grisham (2012) also estimated that male survival was greater early in the breeding season, which is counter to the results on my study areas. However, the overall reproductive season survival estimates reported for male lesser prairie-chickens in the southwestern Texas panhandle (Grisham 2012) were greater than the estimates for my study during the same period. The survival rate I estimated for female lesser prairie-chickens in my study were during the reproductive season was lower (0.54; SE=0.13) than the lowest estimate reported during the same period in the southwestern Texas panhandle (0.71; SE=0.14; Grisham 2012). This suggests that there may be distinct differences between the two disjunct populations of lesser prairie-chickens in the Texas.

Lyons et al. (2009) estimated survival of lesser prairie-chickens approximately 64 km north of my Hemphill County study site and on some of the same sites in the southwestern Texas panhandle as Grisham (2012). Estimates from the southwestern and northeastern Texas panhandle were pooled by age and gender, and breeding season survival was reported to be 0.71 (Lyons et al. 2009). However, Lyons et al. (2009) stated that their reported breeding season survival estimate was for a 4-month period but did not define the period so it is impossible to compare with any of my 3- or 6-month periods as I have defined as seasons. Additionally, given the distinct differences between the results of my study and those of Grisham (2012), it may have been inappropriate to pool study areas.

Hagen et al. (2007) reported survival estimates for radiomarked female lesser prairie-chickens in Kansas from 1998-2002 during the reproductive season and used methods similar to mine. Female survival estimates pooled by age ranged between 0.571 and 0.855 in Kansas over 4 years (Hagen et al. 2007). The estimates from my study over 3 years were lower and could be the result of regional differences in land-use or land cover or temporal differences, as my study began 6 years following the end of the Kansas study (Hagen et al. 2007).

Mortality in lesser prairie-chickens is primarily due to predation. Predation of lesser prairie-chickens is acknowledged as important, and lists of predators presumed to have an impact on lesser prairie-chicken populations are published (Giesen 1998, Schroeder and Baydack 2001), but cause-specific mortality is rarely addressed. Furthermore, little is known about the timing of predation throughout the annual cycle (Schroeder and Baydack 2001). Cause-specific mortality takes into account the probability of a death occurring from a given mortality factor in the presence of other factors or surviving (Heisey and Patterson 2006); this is important in conservation because of the potential influence specific causes of mortality on population dynamics (Schaub and Pradel 2004, Heisey and Patterson 2006). Because telemetry studies are usually designed to allow for staggered entry of individual animals (i.e., left-censoring), cause-specific mortality estimates are more appropriate than expressing specific mortality factors as a percentage of all mortalities. Reports of mortality factors as a percentage of overall mortality in telemetry can lead to biased estimates when animals are added to the risk set throughout the study, because animals that died early are not available for sampling and mortality estimates are sensitive to periods when more radiomarked animals are in the risk set (Heisey and Fuller 1985).

Wolfe et al. (2007) reported that male mortality was greater in the lekking season compared to the rest of the year and did not differ with age. My results showed a similar pattern for adult males, but there was a difference between age classes during the lekking season (Table 2.9). I observed greater cause-specific mortality of male lesser prairie-chickens due to avian predators during the lekking season than any other mortality factor (Table 2.11). This might lead to the conclusion that males are more conspicuous during the lekking season and more vulnerable to predation while on the lek (Hartzler 1974). However, I recovered no remains of lesser prairie-chickens on the lek. This is consistent with the findings of Behney et al. (2011). It is possible that the energetic cost of displaying on leks results in poorer condition and makes males more susceptible to predation when away from the lek. Alternatively, predation that occurred on the lek may not have been observed as such if predators carried the carcass away from the lek following the predation event. The difference between mortalities of adult and juvenile males during the lekking season could indicate that adults spend more energy defending a territory on the lek and as such have poorer condition. Cause-specific mortality rates are similar for adult and juvenile males during the nesting season (Table 2.11). Loss of body mass has been recorded as the lekking season progresses in lesser prairie-chickens (Hagen et al. 2004*b*) and greater sage grouse (Vehrencamp et al. 1989).

Because female survival did not differ between ages or seasons, I estimated female cause-specific mortality pooled by ages and seasons. There was no significant difference in mortality due to avian or mammalian predators for radiomarked females during this study. In contrast, Hagen et al. (2007) reported the majority of female mortalities were the result of mammalian predation. However, Hagen et al. (2007) also attributed several female mortalities to snakes. I observed no predation by snakes on either females or males during my study. Grisham (2012) pooled mortality factors across the entire reproductive season and for age classes and reported numbers of mortalities due to specific factors for males and females. If I examined mortalities in the same manner as Grisham 2012, the results for both Texas populations during the same period were similar.

The survival I observed during my study was lower in comparison to other reported lesser prairie-chicken studies but it is difficult to make meaningful comparisons because most studies report annual survival. However, because annual survival rates are the product of seasonal survival rates, even much greater survival outside of the reproductive season would result in survival estimates lower than those reported elsewhere for all females and adult males (Giesen 1998, U.S. Fish and Wildlife Service 2010). I found no evidence that any mortality factor that I observed had a greater impact on survival than did another.

## MANAGEMENT IMPLICATIONS

Management efforts may be most effective if focus is on improving overall survival through habitat manipulation. My observations suggest that depredation occurs away from the lek. Management practices that provide cover away from leks may provide refugia for males during the lekking season when away from the lek. These findings support the idea that different management activities may be required across the current range of lesser prairie-chickens. That is, there may not be a single management approach that will result in a positive population response if applied to the entire occupied range of lesser prairie-chickens.

## LITERATURE CITED

Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Page 267-281 *in* B. N. Petran and F. Csaki, editors. International Symposium on Information Theory. Second Edition. Akademiai Kiado, Budapest, Hungary.

Aldrich, J. W. 1963. Geographic orientation of American Tetraonidae. Journal of Wildlife Management 27:529-545.

Ammann, G. A. 1944. Determining age of pinnate and sharp-tailed grouses. Journal of Wildlife Management 8:170-171.

Ballard, W. B. and R. J. Robel. 1974. Reproductive importance of dominant male greater prairie chickens. The Auk 91:75-85.

Behney, A. C. 2009. Predation and reproductive behavior of lesser prairie-chickens at leks in the Texas Southern High Plains. M. S. Thesis, Texas Tech University, Lubbock, USA.

Behney, A. C., C. W. Boal, H. A. Whitlaw, and D. R. Lucia. 2011. Interations of raptors and lesser prairie-chickens at leks in the Texas Southern High Plains. The Wilson Journal of Ornithology 123:332-338.

Bender, S., S. Shelton, K. C. Bender, and A. Kalmbach, editors. 2005. Texas comprehensive wildlife conservation strategy: 2005-2010. Texas Parks and Wildlife Department. Austin, USA.

Braun, C. E., K. Martin, T. E. Remington, and J. R. Young. 1994. North American grouse: issues and strategies for the 21st century. Transactions of the North American Wildlife and Natural Resource Conference 59:428-437.

Bumann, G. B., and D. F. Stauffer. 2002. Scavenging of ruffed grouse in the Appalachians: influences and implications. Wildlife Society Bulletin 30:853-860.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and multimodel inference: a practical information-theoretic approach. Springer. New York, USA.

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

Copelin, F. F. 1963. The lesser prairie chicken in Oklahoma. Technical Bulletin 6. Oklahoma Department of Wildlife, Oklahoma City, USA.

Corman, K. S. 2011. Conservation and landscape genetics of Texas lesser pairie-chicken: population structure and differentiation, genetic variability, and effective size. M. S. Thesis. Texas A&M University-Kingsville, Kingsville, USA.

Crawford, J. A. 1980. Status, problems, and research needs of the lesser prairie chicken. Pages 1-7 *in* Proceedings of the Prairie Grouse Symposium. 17-18 September 1980. Stillwater, Oklahoma, USA.

Crawford, J. A., and E. G. Bolen. 1976. Effects of land use on lesser prairie-chickens in Texas. Journal of Wildlife Management 40:96-104.

Dinsmore, S. J., G. C. White, and F. L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476-3488.

Dumke, R. T., and C. M. Pils. 1973. Mortality of radio-tagged pheasants on the Waterloo Wildlife Area. Technical Bulletin 72. Wisconsin Department of Natural Resources, Madison, USA.

Emmons, S. R., and C. E. Braun. 1984. Lek attendance of male sage grouse. Journal of Wildlife Management 48:1023-1028.

Giesen, K. M. 1998. Lesser prairie-chicken (*Tympanuchus pallidicinctus*), No. 364. *in* A. Poole and F. Gill, editors. The Birds of North America. The Birds of North America, Inc. Philadelphia, Pennsylvania, USA.

Grisham, B. A. 2012. The ecology of lesser prairie-chickens in shinnery oak-grassland communities in New Mexico and Texas with implications toward habitat management and future climate change. Ph.D. Dissertation, Texas Tech University, Lubbock, USA.

Hagen, C.A., B.E. Jamison, K.M. Griesen, and T.Z. Riley. 2004*a*. Guidelines for managing lesser prairie-chicken populations and their habitats. Wildlife Society Bulletin 32:69-82.

Hagen, C. A., J. C. Pitman, R. J. Robel, and R. D. Applegatge. 2004*b*. Morphology of lesser prairie-chickens in Kansas. The Prairie Naturalist 36:95-101.

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. The Condor 107:78-86.

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.

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

Hartke, K. M., J. B. Grand, G. P. Hepp, and T. H. Folk. 2006. Sources of variation in survival of breeding female wood ducks. The Condor 108:201-210.

Hartzler, J. E. 1974. Predation and the daily timing of sage grouse leks. The Auk 91:532-536.

Haukos, D. A., L. M. Smith, and G. S. Broda. 1990. Spring trapping lesser prairie-chickens. Journal of Field Ornithology 61:20-25.

Heisey, D. M., and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. Journal of Wildlife Management 49:668-674.

Heisey, D. M., and B. R. Patterson. 2006. A review of methods to estimate cause-specific mortality in presence of competing risks. Journal of Wildlife Management 70:1544-1555.

Holt, R. D., L. W. Burger, Jr., S. J. Dinsmore, M. D. Smith, S. J. Szukaitis, and K. D. Godwin. 2009. Estimating duration of short-term acute effects of capture handling and radiomarking. Journal of Wildlife Management 73:989-995.

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

Jenni, D. A., and J. E. Hartzler. 1978. Attendance at a sage grouse lek: implications for spring census. Journal of Wildlife Management 42:46-52.

Kukal, C. A. 2010. The over-winter ecology of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in the northeast Texas panhandle. M. S. Thesis, Texas Tech University, Lubbock, USA.

Litton, G., R. L. West, D. F. Dvorak, and G. T. Miller. 1978 The lesser prairie chicken and its management in Texas. Texas Parks and Wildlife Department Booklet N7000-25. Austin, USA.

Lyons, E. K., B. A. Collier, N. J. Silvy, R. R. Lopez, B. E. Toole, R. S. Jones, and S. J. DeMaso. 2009. Breeding and non-breeding survival of lesser prairie-chickens *Tympanuchus pallidicinctus* in Texas, USA. Wildlife Biology 15:89-96.

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

McRoberts, J.T. 2009. Aerial surveys for lesser prairie-chicken leks: detectability and disturbance response. M. S. Thesis, Texas Tech University, Lubbock, USA.

Patten, M. A., D. H. Wolfe, E. Shochat, and S. K. Sherrod. 2005. Habitat fragementation, rapid eveloution and population persistence. Evolutionary Ecology Research 7:235-249.

Peterson, R. S., and C. S. Boyd. 1998. Ecology and management of sand shinnery communities: a literature review. U. S. Department of Agriculture Forest Service General Technical Report RMRS-GTR-16. Rock Mountain Research Station, Fort Collins, Colorado, USA.

Pirius, N. E. 2011. The non-breeding season ecology of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in the Southern High Plains of Texas. M. S. Thesis, Texas Tech University, Lubbock, USA.

Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2005*a*. Gender identification and growth of juvenile lesser prairie-chickens. The Condor 107:87-96.

Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2005*b*. Location and success of lesser prairie-chicken nests in relation to vegetation and human disturbance. Journal of Wildlife Management 69:1259-1269.

Powell, L. A. 2007. Approximating variance of demographic parameters using the delta method: a reference for avian biologists. The Condor 109:949-954.

R Development Core Team. 2012. R: a language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria.

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.

Samson, F. B. 1980. Island biogeography and the conservation of prairie birds. Proceedings of the North American Prairie Conference 7:293-305.

Sargent, G. A. 2011. wild1: R tools for wildlife research and management. R package version 1.09. U. S. Geological Survey Northern Prairie Wildlife Research Center. Jamestown, North Dakota, USA. <http://cran.r-project.org/web/packages/wild1/index.html>.

Schaub, M., and R. Pradel. 2004. Assessing the relative importance of different sources of mortality from recoveries of marked animals. Ecology 85:930-938.

Schroeder, M. A., and R. K. Baydack. 2001. Predation and the management of prairie grouse. Wildlife Society Bulletin 29:24-32.

Schroeder, M. A., and C. E. Braun. 1991. Walk-in funnel traps for capturing greater prairie-chickens on leks. Journal of Field Ornithology 62:378-385.

Schroeder, M. A., and C. E. Braun. 1992. Greater prairie-chicken attendance at leks and stability of leks in Colorado. The Wilson Bulletin 104:273-284.

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

Small, R. J., J. C. Holzwart, and D. H. Rusch. 1991. Predation and hunting mortality of ruffed grouse in central Wisconsin. Journal of Wildlife Management 55:512-520.

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. The Prairie Naturalist 32:177-188.

Taylor, M.A., and F.S. Guthery. 1980. Status, ecology, and management of the lesser prairie-chicken. U.S. Department of Agriculture Forest Service Technical Report RM-77. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado, USA.

U. S. Fish and Wildlife Service. 2010. U. S. Fish and Wildlife Service species assessment and listing priority assignment form. <http://ecos.fws.gov/docs/candidate/assessments/2010/r2/B0AZ_V01.pdf>. Accessed 11 May 2011.

Vehrencamp, S. L., J. W. Bradbury, and R. M. Gibson. 1989. The energetic cost of display in male sage grouse. Animal Behaviour 38:885-896.

Venturato, E., P. Cavallini, P. Banti, and F. Dessi-Fulgheri. 2009. Do radio collars influence mortality and reproduction? A case with ring-neck pheasants (*Phasianus colchicus*) in central Italy. European Journal of Wildlife Research 55:547-551.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:S120-S139.

Wolfe, D. H., M. A. Patten, E. Shochat, C. L. Pruett, and S. K. Sherrod. 2007. Causes and patterns of mortality in lesser prairie-chickens *Tympanuchus pallidicinctus* and implications for management. Wildlife Biology 13(Supplement 1):95-104.

Table 2.1. Model description for models for assessment of duration of adjustment period following capture, handling, radio-marking, and release of lesser prairie-chickens captured over a 64-day period beginning 22 February 2008-2010 and for survival estimates on private lands in Gray and Hemphill counties, Texas, USA.

| Model | Description | Radio Effects Base Models | Male Survival Models | Female Survival Models |
|---|---|---|---|---|
| $S_{.}$ | no effect (intercept only model) | ✓ | ✓ | ✓ |
| $S_{\text{age}}$ | age effect | ✓ | ✓ | ✓ |
| $S_{\text{gender}}$ | gender effect | ✓ | | |
| $S_{\text{year}}$ | year effect | ✓ | ✓ | ✓ |
| $S_{\text{season}}$ | season (lekking or breeding) effect | | ✓ | ✓ |
| $S_{\text{t}}$ | within year linear trend | ✓ | ✓ | ✓ |
| $S_{\text{tt}}$ | within year quadratic trend | ✓ | ✓ | ✓ |
| $S_{\text{T}}$ | across year linear trend | | ✓ | ✓ |
| $S_{\text{TT}}$ | across year quadratic trend | | ✓ | ✓ |
| $S_{\text{age + t}}$ | age effect + within year linear trend | ✓ | | |
| $S_{\text{age + tt}}$ | age effect + within year quadratic trend | ✓ | | ✓ |
| $S_{\text{age + year}}$ | age and year additive effect | | | ✓ |
| $S_{\text{age x year}}$ | age and year interaction effect | | ✓ | |
| $S_{\text{age + season}}$ | age and season additive effect | | | ✓ |
| $S_{\text{age x season}}$ | age and season additive effect | | ✓ | |
| $S_{\text{gender + age}}$ | gender effect + age effect | ✓ | | |
| $S_{\text{gender + t}}$ | gender effect + within year linear trend | ✓ | | |
| $S_{\text{gender + tt}}$ | gender effect + within year quadratic trend | ✓ | | |
| $S_{\text{year + t}}$ | year effect + within year linear trend | ✓ | ✓ | ✓ |
| $S_{\text{year + tt}}$ | year effect + within year quadratic trend | ✓ | | |
| $S_{\text{year x season}}$ | year and season interaction effect | | | ✓ |
| $S_{\text{season + t}}$ | season effect + within season linear trend | | | ✓ |
| $S_{\text{season + tt}}$ | season effect + within season quadratic trend | | | ✓ |
| $S_{\text{age x season + t}}$ | age and season additive effect + within season linear trend | | ✓ | |

✓ indicates used in model set.

Table 2.2. Radio-marked lesser prairie-chickens by gender, age, year, and season used for survival estimation on private lands in Gray and Hemphill counties, Texas, USA, during the reproductive season 2008-2010.

| Year | Gender | Season | No. Adults | No. Juveniles |
|---|---|---|---|---|
| 2008 | Female | Lekking | 1 | 5 |
| | | Nesting | 2 | 5 |
| | Male | Lekking | 5 | 8 |
| | | Summer | 6 | 12 |
| 2009 | Female | Lekking | 4 | 4 |
| | | Nesting | 3 | 4 |
| | Male | Lekking | 19 | 13 |
| | | Summer | 10 | 11 |
| 2010 | Female | Lekking | 3 | 4 |
| | | Nesting | 2 | 3 |
| | Male | Lekking | 17 | 3 |
| | | Summer | 11 | 3 |

Table 2.3. Base models for assessment of duration of adjustment period following capture, handling, radio-marking, and release of lesser prairie-chickens captured over a 64-day period beginning 22 February 2008-2010 on private lands in Gray and Hemphill counties, Texas, USA.

| Model[a] | $AIC_c$[b] | $\Delta AIC_c$ | $\omega$[c] | Model Likelihood | K[d] | Deviance |
|---|---|---|---|---|---|---|
| $S_t$ | 174.09 | 0.00 | 0.33 | 1.00 | 2 | 170.09 |
| $S_{gender + t}$ | 175.36 | 1.27 | 0.17 | 0.53 | 3 | 169.35 |
| $S_{age + t}$ | 175.84 | 1.75 | 0.14 | 0.42 | 3 | 169.83 |
| $S_{tt}$ | 176.06 | 1.97 | 0.12 | 0.37 | 3 | 170.05 |
| $S_{year + t}$ | 177.24 | 3.14 | 0.07 | 0.21 | 4 | 169.22 |
| $S_{gender + tt}$ | 177.34 | 3.25 | 0.06 | 0.20 | 4 | 169.33 |
| $S_{age + tt}$ | 177.80 | 3.71 | 0.05 | 0.16 | 4 | 169.79 |
| $S_{year + tt}$ | 179.21 | 5.12 | 0.03 | 0.08 | 5 | 169.19 |
| $S_{age}$ | 181.94 | 7.85 | 0.01 | 0.02 | 2 | 177.93 |
| $S_.$ | 182.13 | 8.04 | 0.01 | 0.02 | 1 | 180.13 |
| $S_{gender}$ | 182.86 | 8.77 | 0.00 | 0.01 | 2 | 178.85 |
| $S_{gender + age}$ | 182.92 | 8.83 | 0.00 | 0.01 | 3 | 176.91 |
| $S_{year}$ | 185.24 | 11.14 | 0.00 | 0.00 | 3 | 179.23 |

[a] Model descriptions detailed in table 2.1

[b] Models were evaluated by sample-size-corrected Akaike's Information Criterion

[c] Akaike weight

[d] No. of parameters in each model

Table 2.4. Beta parameter estimates for competing models in base model set for assessment of duration of adjustment period following capture, handling, radio-marking, and release of lesser prairie-chickens captured over a 64-day period beginning 22 February 2008-2010 on private lands in Gray and Hemphill counties, Texas, USA.

| Model | Parameter | Beta Estimate | SE | L95 CI | U95 CI | Significant |
|---|---|---|---|---|---|---|
| $S_t$ | t | 0.05 | 0.02 | 0.02 | 0.08 | yes |
| $S_{gender + t}$ | gender | 0.61 | 0.77 | -0.89 | 2.12 | no |
| | t | 0.05 | 0.02 | 0.02 | 0.08 | yes |
| $S_{age + t}$ | age | -0.34 | 0.69 | -1.70 | 1.02 | no |
| | t | 0.05 | 0.02 | 0.01 | 0.08 | yes |
| $S_{tt}$ | tt | < 0.01 | < 0.01 | < -0.01 | < 0.01 | no |

Table 2.5. Effect models for assessment of duration of adjustment period following capture, handling, radio-marking, and release of lesser prairie-chickens captured over a 64-day period beginning 22 February 2008-2010 on private lands in Gray and Hemphill counties, Texas, USA.

| Model[a] | $\text{AIC}_c$[b] | $\Delta\text{AIC}_c$ | $\omega$[c] | Model Likelihood | K[d] | Deviance |
|---|---|---|---|---|---|---|
| $S_{t + 4 \text{ day effect}}$ | 171.30 | 0.00 | 0.06 | 1.00 | 3 | 165.29 |
| $S_{t + 5 \text{ day effect}}$ | 171.42 | 0.12 | 0.06 | 0.94 | 3 | 165.41 |
| $S_{t + 3 \text{ day effect}}$ | 171.62 | 0.32 | 0.05 | 0.85 | 3 | 165.61 |
| $S_{t + 6 \text{ day effect}}$ | 171.72 | 0.42 | 0.05 | 0.81 | 3 | 165.71 |
| $S_{t + 8 \text{ day effect}}$ | 172.06 | 0.76 | 0.04 | 0.68 | 3 | 166.05 |
| $S_{t + 7 \text{ day effect}}$ | 172.08 | 0.78 | 0.04 | 0.68 | 3 | 166.07 |
| $S_{t + 9 \text{ day effect}}$ | 172.14 | 0.85 | 0.04 | 0.66 | 3 | 166.14 |
| $S_{t + 12 \text{ day effect}}$ | 172.18 | 0.88 | 0.04 | 0.64 | 3 | 166.17 |
| $S_{t + 11 \text{ day effect}}$ | 172.20 | 0.90 | 0.04 | 0.64 | 3 | 166.19 |
| $S_{t + 13 \text{ day effect}}$ | 172.21 | 0.92 | 0.04 | 0.63 | 3 | 166.21 |
| $S_{t + 1 \text{ day effect}}$ | 172.26 | 0.96 | 0.04 | 0.62 | 3 | 166.25 |
| $S_{t + 14 \text{ day effect}}$ | 172.28 | 0.98 | 0.04 | 0.61 | 3 | 166.27 |
| $S_{t + 10 \text{ day effect}}$ | 172.29 | 0.99 | 0.04 | 0.61 | 3 | 166.28 |
| $S_{t + 15 \text{ day effect}}$ | 172.37 | 1.07 | 0.04 | 0.58 | 3 | 166.36 |
| $S_{t + 16 \text{ day effect}}$ | 172.48 | 1.18 | 0.04 | 0.55 | 3 | 166.47 |
| $S_{t + 17 \text{ day effect}}$ | 172.60 | 1.30 | 0.03 | 0.52 | 3 | 166.59 |
| $S_{t + 18 \text{ day effect}}$ | 172.72 | 1.42 | 0.03 | 0.49 | 3 | 166.71 |
| $S_{t + 19 \text{ day effect}}$ | 172.84 | 1.55 | 0.03 | 0.46 | 3 | 166.84 |
| $S_{t + 20 \text{ day effect}}$ | 172.97 | 1.67 | 0.03 | 0.43 | 3 | 166.96 |
| $S_{t + 2 \text{ day effect}}$ | 173.10 | 1.80 | 0.03 | 0.41 | 3 | 167.09 |
| $S_{t + 21 \text{ day effect}}$ | 173.10 | 1.80 | 0.03 | 0.41 | 3 | 167.09 |
| $S_{t + 22 \text{ day effect}}$ | 173.22 | 1.92 | 0.02 | 0.38 | 3 | 167.21 |
| $S_{t + 23 \text{ day effect}}$ | 173.34 | 2.04 | 0.02 | 0.36 | 3 | 167.33 |
| $S_{t + 24 \text{ day effect}}$ | 173.46 | 2.16 | 0.02 | 0.34 | 3 | 167.45 |
| $S_{t + 25 \text{ day effect}}$ | 173.57 | 2.27 | 0.02 | 0.32 | 3 | 167.56 |
| $S_{t + 26 \text{ day effect}}$ | 173.68 | 2.38 | 0.02 | 0.30 | 3 | 167.67 |
| $S_{t + 27 \text{ day effect}}$ | 173.78 | 2.48 | 0.02 | 0.29 | 3 | 167.77 |
| $S_{t + 28 \text{ day effect}}$ | 173.88 | 2.58 | 0.02 | 0.28 | 3 | 167.87 |
| $S_t$ | 174.09 | 2.79 | 0.02 | 0.25 | 2 | 170.09 |

[a] Model descriptions detailed in table 2.1

[b] Models were evaluated by sample-size-corrected Akaike's Information Criterion

[c] Akaike weight

[d] No. of parameters in each model

Table 2.6. Beta parameter estimates for effect models for assessment of duration of adjustment period following capture, handling, radio-marking, and release of lesser prairie-chickens captured over a 64-day period beginning 22 February 2008-2010 on private lands in Gray and Hemphill counties, Texas, USA.

| Parameter | Beta Parameter Estimate | SE | Lower 95% Confidence Interval | Upper 95% Confidence Interval | Significant * |
|---|---|---|---|---|---|
| 1 day effect | -1.88 | 0.78 | -3.42 | -0.35 | yes |
| 2 day effect | -0.85 | 0.41 | -1.65 | -0.04 | yes |
| 3 day effect | -0.63 | 0.25 | -1.12 | -0.14 | yes |
| 4 day effect | -0.47 | 0.18 | -0.83 | -0.11 | yes |
| 5 day effect | -0.36 | 0.15 | -0.65 | -0.08 | yes |
| 6 day effect | -0.29 | 0.12 | -0.52 | -0.05 | yes |
| 7 day effect | -0.23 | 0.10 | -0.43 | -0.03 | yes |
| 8 day effect | -0.20 | 0.09 | -0.37 | -0.02 | yes |
| 9 day effect | -0.17 | 0.08 | -0.33 | -0.02 | yes |
| 10 day effect | -0.15 | 0.07 | -0.29 | -0.01 | yes |
| 11 day effect | -0.14 | 0.06 | -0.26 | -0.01 | yes |
| 12 day effect | -0.12 | 0.06 | -0.24 | -0.01 | yes |
| 13 day effect | -0.11 | 0.05 | -0.22 | -0.01 | yes |
| 14 day effect | -0.10 | 0.05 | -0.20 | -0.01 | yes |
| 15 day effect | -0.09 | 0.05 | -0.18 | -0.01 | yes |
| 16 day effect | -0.09 | 0.04 | -0.17 | -0.01 | yes |
| 17 day effect | -0.08 | 0.04 | -0.16 | -0.01 | yes |
| 18 day effect | -0.07 | 0.04 | -0.15 | 0.01 | no |
| 19 day effect | -0.07 | 0.04 | -0.14 | 0.01 | no |
| 20 day effect | -0.06 | 0.03 | -0.13 | 0.01 | no |
| 21 day effect | -0.06 | 0.03 | -0.12 | 0.01 | no |
| 22 day effect | -0.05 | 0.03 | -0.11 | 0.01 | no |
| 23 day effect | -0.05 | 0.09 | -0.11 | 0.01 | no |
| 24 day effect | -0.05 | 0.03 | -0.10 | 0.01 | no |
| 25 day effect | -0.04 | 0.03 | -0.10 | 0.01 | no |
| 26 day effect | -0.04 | 0.03 | -0.09 | 0.01 | no |
| 27 day effect | -0.04 | 0.02 | -0.09 | 0.01 | no |
| 28 day effect | -0.04 | 0.02 | -0.08 | 0.01 | no |

* Based on 95% confidence interval overlapping zero; overlap of zero is not significant

Table 2.7. Survival model results for radio-marked male lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas USA during the reproductive season 2008-2010.

| Model[a] | $AIC_c$[b] | $\Delta AIC_c$ | $\omega$[c] | Model Likelihood | K[d] | Deviance |
|---|---|---|---|---|---|---|
| $S_{age\ x\ season}$ | 232.24 | 0.00 | 0.67 | 1.00 | 3 | 226.24 |
| $S_{age\ x\ season + t}$ | 234.22 | 1.98 | 0.25 | 0.37 | 4 | 226.21 |
| $S_{age}$ | 238.14 | 5.90 | 0.04 | 0.05 | 2 | 234.14 |
| $S_{age\ x\ year}$ | 239.30 | 7.06 | 0.02 | 0.03 | 5 | 229.29 |
| $S_{season}$ | 240.67 | 8.43 | 0.01 | 0.01 | 2 | 236.67 |
| $S_t$ | 240.93 | 8.68 | 0.01 | 0.01 | 2 | 236.92 |
| $S_{tt}$ | 242.61 | 10.37 | 0.00 | 0.01 | 3 | 236.61 |
| $S_{year + t}$ | 244.56 | 12.32 | 0.00 | 0.00 | 4 | 236.56 |
| $S_.$ | 244.65 | 12.41 | 0.00 | 0.00 | 1 | 242.65 |
| $S_T$ | 246.35 | 14.11 | 0.00 | 0.00 | 2 | 242.35 |
| $S_{year}$ | 248.15 | 15.91 | 0.00 | 0.00 | 3 | 242.14 |
| $S_{TT}$ | 248.15 | 15.91 | 0.00 | 0.00 | 3 | 242.14 |

[a] Model descriptions detailed in table 2.1

[b] Models were evaluated by sample-size-corrected Akaike's Information Criterion

[c] Akaike weight

[d] No. of parameters in each model

Table 2.8. Survival model results for radio-marked female lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA, during the reproductive season 2008-2010.

| Model[a] | $AIC_c$[b] | $\Delta AIC_c$ | $\omega$[c] | Model Likelihood | K[d] | Deviance |
|---|---|---|---|---|---|---|
| $S_{.}$ | 86.53 | 0.00 | 0.23 | 1.00 | 1 | 84.53 |
| $S_{T}$ | 87.26 | 0.73 | 0.16 | 0.69 | 2 | 83.25 |
| $S_{age}$ | 88.28 | 1.75 | 0.09 | 0.42 | 2 | 84.27 |
| $S_{t}$ | 88.37 | 1.84 | 0.09 | 0.40 | 2 | 84.36 |
| $S_{season}$ | 88.50 | 1.97 | 0.08 | 0.37 | 2 | 84.49 |
| $S_{year}$ | 89.13 | 2.60 | 0.06 | 0.27 | 3 | 83.12 |
| $S_{TT}$ | 89.13 | 2.60 | 0.06 | 0.27 | 3 | 83.12 |
| $S_{tt}$ | 89.30 | 2.77 | 0.06 | 0.25 | 3 | 83.29 |
| $S_{age+season}$ | 90.19 | 3.66 | 0.04 | 0.16 | 3 | 84.18 |
| $S_{season+t}$ | 90.30 | 3.77 | 0.03 | 0.15 | 3 | 84.29 |
| $S_{age+year}$ | 90.53 | 4.00 | 0.03 | 0.14 | 4 | 82.51 |
| $S_{year+t}$ | 91.10 | 4.57 | 0.02 | 0.10 | 4 | 83.08 |
| $S_{year \times season}$ | 91.56 | 5.03 | 0.02 | 0.08 | 5 | 81.53 |
| $S_{year+tt}$ | 92.21 | 5.68 | 0.01 | 0.06 | 5 | 82.18 |
| $S_{season+tt}$ | 92.28 | 5.75 | 0.01 | 0.06 | 4 | 84.26 |

[a] Model descriptions detailed in table 2.1

[b] Models were evaluated by sample-size-corrected Akaike's Information Criterion

[c] Akaike weight

[d] No. of parameters in each model

Table 2.9. Daily and seasonal survival estimates for radiomarked male lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA, during the reproductive season 2008-2010.

| Age | Season | Daily Survival Estimate | SE | Seasonal Survival Estimate | SE |
|---|---|---|---|---|---|
| Adult | Lekking | 0.99 | < 0.01 | 0.51 | 0.09 |
| | Nesting | 0.99 | < 0.01 | 0.82 | 0.08 |
| Juvenile | Lekking | 1.00 | 0.00 | 1.00 | 0.00 |
| | Nesting | 0.99 | < 0.01 | 0.88 | 0.62 |

Table 2.10. Beta parameter estimates for competing models describing survival of female lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA, during the reproductive season 2008-2010.

| Model | Parameter | Beta Parameter Estimate | SE | Lower 95% Confidence Interval | Upper 95% Confidence Interval |
|---|---|---|---|---|---|
| $S_T$ | T | 0.56 | 0.51 | -0.44 | 1.56 |
| $S_{age`}$ | age | -0.38 | 0.77 | -1.88 | 1.12 |
| $S_t$ | t | < -0.01 | 0.01 | -0.02 | 0.01 |
| $S_{season}$ | season | 0.14 | 0.77 | -1.36 | 1.64 |

Table 2.11. Cause-specific mortality estimates for radiomarked lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas USA during the reproductive season 2008-2010.

| Gender | Season-Age | Mortality Factor | n | Cause-specific Mortality Estimate | SE |
|---|---|---|---|---|---|
| Male | Adult Lekking Season | Mammalian Predator | 4 | 0.15 | 0.09 |
| | | Avian Predator | 7 | 0.23 | 0.08 |
| | | Unknown | 3 | 0.12 | 0.08 |
| | Juvenile Lekking Season | Mammalian Predator | 0 | 0.00 | 0.00 |
| | | Avian Predator | 0 | 0.00 | 0.00 |
| | | Unknown | 0 | 0.00 | 0.00 |
| | Adult Nesting | Mammalian Predator | 2 | 0.08 | 0.06 |
| | | Avian Predator | 1 | 0.04 | 0.04 |
| | | Unknown | 1 | 0.08 | 0.08 |
| | Juvenile Nesting | Mammalian Predator | 2 | 0.08 | 0.06 |
| | | Avian Predator | 1 | 0.04 | 0.04 |
| | | Unknown | 0 | 0.00 | 0.00 |
| Female | Seasons & Ages Pooled | Mammalian Predator | 3 | 0.16 | 0.09 |
| | | Avian Predator | 3 | 0.16 | 0.08 |
| | | Unknown | 1 | 0.06 | 0.06 |

## CHAPTER 3

# NEST AND CHICK SURVIVAL OF LESSER PRAIRIE-CHICKENS (*TYMPANUCHUS PALLIDICINCTUS*) IN THE NORTHEASTERN TEXAS PANHANDLE

All species of prairie grouse have declined sharply over the past 3 to 4 decades (Silvy and Hagen 2004). Large-scale declines of lesser prairie-chicken (*Tympanuchus pallidicinctus*) populations have been observed since 1900 on the Great Plains (Litton et al. 1978). Lesser prairie-chickens are endemic to mixed-grass and short-grass prairies of North America (Aldrich 1963, Patten et al. 2005), and prefer grasslands dominated by sand shinnery oak (*Quercus havardii*) and sand sagebrush (*Artemisia filifolia*) (Giesen 1998). Historic range of lesser prairie-chickens included portions of southwestern Kansas, southeastern Colorado, western Oklahoma, eastern New Mexico, and the Texas Panhandle (Sullivan et al. 2000).

It is estimated that two-thirds of the historic range of lesser prairie-chickens occurred in the Texas panhandle (U. S. Fish and Wildlife Service 2010), with as many as 2 million birds present prior to 1900 (Litton et al. 1978). Currently, lesser prairie-chickens are found in at least 2 distinct populations in the Texas panhandle (Jackson and DeArment 1963, Taylor and Guthery 1980, Corman 2011), with a distribution representing up to a 92% reduction of occupied area (Sullivan et al. 2000). Furthermore, the Texas range has declined by as much as 78% since 1940 (Taylor and Guthery 1980).

The cause of the large-scale population decline observed in lesser prairie-chickens is attributed to changes in land use (Aldrich 1963, Jackson and DeArment 1963, Sullivan

et al. 2000) and habitat fragmentation (Crawford 1980, Samson 1980, Braun et al. 1994). Changing land-use practices include the conversion of native grasslands to cultivation (Jackson and DeArment 1963, Crawford and Bolen 1976, Braun et al. 1994), over-grazing (Riley 1992, Giesen 1998), and oil and gas extraction (Pitman et al. 2005*b*). Effects of anthropogenic land-use changes may be exacerbated by periodic droughts (Jackson and DeArment 1963, Hagen et al. 2004).

Poor recruitment, as a result of low nest and chick survival, has been identified as a limiting factor in prairie grouse populations, including Attwater's prairie-chickens (*T. cupido attwaterii*; Peterson and Silvy 1996), greater sage grouse (*T. cupido*; Wisdom and Mills 1997), and lesser prairie-chickens (Hagen et al. 2009). An understanding of the factors influencing nest and brood survival is critical to develop meaningful management plans for lesser prairie-chicken populations (Pitman et al. 2006*a*, Davis 2009).

I monitored nests of radiomarked and unmarked female lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA, during 2008-2010, measured vegetative characteristics of nests, and assessed nest survival. I followed radiomarked female lesser prairie-chickens after successful nesting attempts to assess chick survival. The objectives of this study were to relate vegetative cover characteristics to nest site selection and nest success, and estimate chick survival. I compared the results of this study to published reports of similar studies throughout the range of lesser prairie-chickens.

## STUDY AREA

The study area was on private lands in Gray and Hemphill counties, Texas, USA. The Gray county site was located in the High Plains ecoregion and the Hemphill County site was in the Rolling Plains ecoregion (Bender et al. 2005). Primary land uses were cattle ranching interspersed with oil and gas development and some Conservation Reserve Program lands, center-pivot and dry-land agricultural crops (McRoberts 2009).

The Gray county site was at the eastern edge of the Caprock Escarpment, with elevations from 850-900 m. Elevations on the Hemphill county site were from 750-800 m. Mean annual precipitation and temperatures were similar between the sites. Mean annual precipitation was 52 cm; mean low temperature was -5° C (January) and mean high temperature was 35° C (July).

Native land-cover types were similar for both sites and vegetation was dominated by grassland interspersed with areas of dense shrubs. Grasses included little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), switchgrass (*Panicum virgatum*), and Indiangrass (*Sorghastum nutans*; Jackson and DeArment 1963). Common forbs found in grasslands included common broomweed (*Amphiachyris dracunculoides*), Indian blanket (*Gaillardia pulchella*), and western ragweed (*Ambrosia psilostachya*). Shrubs, including sand sagebrush (*Artemisia filifolia*) and soapweed yucca (*Yucca glauca*), were sparsely scattered throughout grasslands. Patches of dense (>50% cover) sand shinnery oak (*Quercus havardii*) were present throughout the area and contained mottes consisting of sand shinnery oak-post oak (*Q. stellata*) hybrids ≤ 6 m tall (Peterson and Boyd 1998).

## METHODS

Due to logistics and distance between study sites, monitoring activities at the Gray county site were reduced in 2009 and were not conducted in 2010.

### Capture

I captured birds on leks during spring 2008-2010 with walk-in funnel traps (Haukos et al. 1990, Schroeder and Braun 1991) and rocket nets. All leks were trapped continuously throughout the lekking period. Upon capture, each bird was weighed to the nearest gram, fitted with a serially numbered monel leg band, and categorically classified by age (Ammann 1944, Pitman et al. 2005*a*). Females were differentiated from males by the lack of eye combs and esophageal sacs (Giesen 1998). Birds were classified as juvenile (first breeding year) or adult (after first breeding year) based on the pattern of spotting on the 9th and 10th primaries (Ammann 1944, Copelin 1963). Birds that were captured as juveniles and survived until the end of the season in which they were captured were promoted to adults on 1 September. Birds that weighed > 700 g were fitted with a 14-g, necklace-style radio transmitter with a 12-hour mortality switch. I selected 700 g as a minimum mass so that radio transmitters were not greater than 2% of the bird's mass (Venturato 2009). I captured additional birds outside of the primary trapping season by setting traps near and trapping at leks during the fall lekking period. I assumed that capture, handling, and radiomarking had no chronic negative effect on survival (Hagen et al. 2006) or behavior. The monitoring period for nest and brood survival was well after any published adjustment period (i.e., 14 days post-capture) relative to the peak of female capture for this study. I did not assess acute effects of capture, handling, and radiomarking. Capture and handling of live animals for research was approved by the Texas Tech University Institutional Animal Care and Use Committee (Animal Care and Use Protocol 07050-08).

### Nest Location and Monitoring

I located nests by daily monitoring of radiomarked female lesser prairie-chickens. When locations did not differ for 3 consecutive days, I homed to the radio signal and flushed the hen to confirm the presence of a nest in the incubation stage. Upon locating a nest, I recorded the number of eggs present and the location of the nest using a handheld GPS receiver. Each consecutive day following the initial location of a nest for a radiomarked hen, I determined if the nest was active by listening for the hen's unique radio signal from a known location. I assumed the nest was active if the direction and strength of the signal remain unchanged. When hens were detected away from the nest, I returned 2 hours later to recheck the hen location. If the hen was away on the second nest check, I navigated to the nest's GPS coordinates to inspect the nest and determine success or failure. I took this approach to minimize disturbance around active nests.

I classified nests as successful if ≥ 1 whole egg cap or detached shell membrane was present. I classified probable cause of nest failure following Sargeant et al. (1998). However, accurate assignment of specific causes of nest failure can be difficult due to scavenging (Coates et al. 2008) and because many signs used to assign cause of failure are similar for different species of the same taxonomic family (Lariviere 1999). Because there is overlap of both range and habitat use of coyotes (*Canis latrans*), red foxes (*Vulpes vulpes*), gray foxes (*Urocyon cinereoargenteus*), badgers (*Taxidea taxus*), eastern spotted skunks (*Spilogale putorius*), and striped skunks (*Mephitis mephitis*; Davis and Schmidly 1994) on my study sites, I broadly classified nest failure by taxonomic family (i.e., Canidae or Mustelidae). I assumed scavenging of depredated nests was minimal because nest status was monitored daily and nest fate was determined within 2 hours of the first observation of a hen away from the nest. I classified nests as abandoned if the clutch was intact, the hen was not present, and the eggs were cold to the touch. When I suspected nest abandonment, I returned to the monitoring location for a specific nest between 00:00-03:00 hours and checked for the presence of the hen. If the hen was not present between these hours, I visited the nest to determine if eggs were cold to the touch. I classified the cause of nest failure as unknown when there was no evidence of specific causes of nest failure and there was no evidence of a brood with the incubating hen.

I located nests of unmarked hens in 2009 by rope-dragging (Green 1985). Rope-dragging was conducted in native prairie cover types in potential nest habitat, based on nest location data from the 2008 season. I conducted rope-dragging efforts during dates when ≥ 85% of radiomarked hens were incubating. A 50-m length of 3-cm diameter rope with 60 cm strips of fabric attached every 50 cm was dragged on parallel paths between 2 observers. A third observer followed at a distance of 5 m centered on the rope, watching for lesser prairie-chickens to flush from under the rope or adjacent to the observers dragging the rope. When a lesser prairie-chicken flushed, the immediate area of the flush was inspected for the presence of a nest. When a nest was located, the location was recorded with a handheld GPS receiver. Nests of unmarked hens were marked with pin flags inserted to ground-level 10 m due north and east of the nest. The number of eggs was counted and 4 eggs were floated to estimate time since onset of incubation (Westerskov 1950, Liebezeit 2007) using lukewarm bottled water. Methods for determining stage of incubation developed for other species have been reported to be accurate for greater prairie-chickens (*T. cupido*; McNew et al. 2009). I assumed that floating eggs did not affect hatchability (Alberico 1995). To gain a more accurate estimation of incubation stage, eggs in nests of unmarked hens were floated again 3 days after initial detection. Following the 3-day visit, nests of unmarked hens were visited every 7 days until it was determined the nest was successful or failed. Nest status was determined by examination with binoculars to avoid flushing hens from active nests when possible.

### Nest Vegetation Characteristics

I measured vegetation characteristics at nest sites and at a paired random location within 48 hours of hatch or failure. Random sites were within 360 m of the nest site. Random locations were determined by blindly spinning a compass rosette twice. The result of the first blind spin was the distance (m) from the nest and the second blind spin was the azimuth away from the nest.

At each nest and random location, I estimated percent cover of bare ground, litter, forb, grass, and shrub. I defined bare ground as visible mineral soil, litter as residual vegetation from previous growing seasons, grasses as vegetation with hollow stems and long leaves with parallel veins growing from nodes attached to the stem (Brown 1979), forbs as herbaceous growth other than grass, and shrubs as multi-stemmed woody plants. I estimated percent cover using a grid-quadrat frame (Bonham 1989). I selected this method because grid-quadrat methods 1) provide objective estimates, 2) are more expedient than other methods with similar reliability, and 3) provide for replication (Bonham 1989). The grid-quadrat frame I used consisted of 25 cross points 7.5 cm apart in 5 rows with 5 points in each row. I placed the frame at a height of 20 cm, which is roughly equivalent to the height of a full-grown lesser prairie-chicken (Bell et al. 2010). I looked directly from above the frame and recorded the first type of vegetation, bare ground, or litter that was below each point of the frame. I recorded proportion of each cover type at the nest bowl for used sites, plot-center for random sites, and every 1 m in each cardinal direction for 4 m. I measured visual obstruction at each cardinal direction towards the nest bowl or plot center from 4 m away and from a height of 1 m (Robel et al. 1970). I recorded the height (dm) of 100% (Robel pole completely covered) and 0% (no vegetation covering any part of the Robel pole) visual obstruction and calculated the mean reading from measurements in the 4 cardinal directions. I measured litter depth (mm) every 0.5 m from the nest in each cardinal direction.

I tested for differences in vegetative characteristics between used (nest site) and random points using a Wilcoxon Signed Rank test (Wilcoxon 1945, Zar 2010). I elected to use the Wilcoxon Signed Rank test because it is nonparametric and requires no assumption of the distribution (Zar 2010) and data were collected in pairs. Furthermore, I conducted fourth-order (Johnson 1980) compositional analysis (Aebischer et al. 1993) using package *adehabitatHS* (Calenge 2006) in Program R (R Development Core Team 2012). The proportion of all cover types across used and random sites represented available habitat and the proportion of each used site represented used habitat in these compositional analyses.

### Nest Survival

I estimated nest survival using the logit-link function in the nest model (Dinsmore et al. 2002, Rotella et al. 2004) in Program MARK (White and Burnham 1999). I developed 11 *a priori* models to explain nest survival (Table 3.1). The age of the incubating hen was used in 3 models (Table 3.1). Hen age for radiomarked lesser prairie-chickens was based on classification used during capture and time since radiomarking; age of unmarked hens was classified as unknown. I did not use interaction models in my analysis due to the small sample size. I further developed 5 exploratory models following analyses of vegetative composition at nest and random locations based of difference between vegetative characteristics at used and random points (Table 3.1). I added these exploratory models to the model set to examine the influence of within-patch nest site selection on nest survival. I converted daily survival estimates to interval survival estimates and approximated interval survival variances using the delta method (Powell 2007).

### Chick Survival

I conducted brood counts for all successful nests of radiomarked hens. I approached radiomarked brood hens 3 days post-hatch 1 hour before sunrise and attempted to capture the hen and brood using a long-handled dip net (Labisky 1968, Pitman et al. 2006*c*) during the 2008 season. I attached serially numbered monel tags to the patagial flap of captured chicks (Hannon et al. 1990, Carver at al. 1999). I approached radiomarked brood hens at 0.5 hours before sunrise and counted the number of chicks in the brood 5 days post-hatch in 2009 and 2010. I conducted weekly flush counts of all broods beginning at 14 days post-hatch by approaching radiomarked brood hens 15 minutes before sunrise and flushing broods when there was enough ambient light to see and count flushing chicks. I surveyed the area of the flush to make sure no chicks were missed during the flush count. I recorded the number of chicks during each brood count.

I estimated survival of individual chicks using the young survival from marked adults model (Lukacs 2004) in Program MARK (White and Burnham 1999). This approach is a likelihood-based extension of the Cormack-Jolly-Seber model (Cormack 1964, Jolly 1965, Seber 1965) and relaxes the assumption of an accurate count of surviving chicks in a brood required by other methods (Flint et al. 1995, Manly and Schmutz 2001). However, this technique does require that the initial size of the brood is known. I estimated initial brood size based on the number hatched eggs observed at the nest site for each successful nest. I developed 6 *a priori* models to describe daily chick survival (Table 3.2). Because I followed few broods over the course of this study, I pooled years and did not develop any models including additive or interactive effects. Because the broods were located with radiomarked brood hens, I did not include any models that included variable detection probabilities and assumed that detection probability = 1 for all models.

## RESULTS

### Capture

I captured 6 female lesser prairie-chickens (5 juvenile, 1 adult) in 2008, 8 female lesser prairie-chickens (4 juvenile, 4 adult) in 2009, and 7 female lesser prairie-chickens (4 juvenile, 3 adult) in 2010. After a female lesser-prairie chicken was observed using a water source for livestock in 2008, I set traps at the water source and captured 1 adult female lesser prairie-chicken. I lost contact with a radiomarked adult female lesser prairie-chicken in 2008 prior to locating a nest. Three radiomarked female lesser prairie-chickens (1 adult in 2009, 1 juvenile in 2010, and 1 adult in 2010) died prior to the onset of incubation.

### Nest Location and Monitoring

I located 24 nests during the 2008-2010 nesting seasons. I located 7 nests of radiomarked hens in 2008, 1 of which was a second nest attempted after nest failure. I located 9 nests of radiomarked hens in 2009, 2 of which were second nest attempts after first nest attempts had failed. I also located 2 nests of unmarked hens in 2009 as the result of rope-dragging. I classified 1 of these unmarked nests as a first nest attempt and the other as a second nest attempt based on the stage of incubation relative to the time of the season. I located 5 nests of radiomarked hens in 2010, 1 of which was a second nest attempt after a first nest attempt had failed. Although I did not conduct rope-dragging in 2010, I located a nest of an unmarked hen while conducting other field work.

Two nests failed due to mortality of the hen away from the nest in 2009 (Table 3.3). In each case, the nest appeared undisturbed and clutch intact. I classified a total of

5 nest failures as due to unknown causes (Table 3.3). In all cases, I extensively searched the area near the nest for eggshell fragments and found none. I observed only 1 nest abandonment, which was a second nest attempt in 2009 (Table 3.3).

### Nest Vegetation Characteristics

I observed differences between used (nest site) and paired random points for 100% visual obstruction, 0% visual obstruction, bare ground cover at the nest or random plot center, and forb cover within 2 m of the nest or plot center (Table 3.4). Nest sites had greater mean 100% and 0% visual obstruction, less bare ground, and more forb cover within 2 m than did random sites (Table 3.5). However, because a large portion of the center at the nest site included the actual nest bowl, which is constructed of residual vegetation from previous growing seasons, the difference in proportion of bare ground could be spurious.

Compositional analysis indicated that lesser prairie-chickens selected against shrub cover within 4 m when selecting nest sites (Table 3.6). Additionally, lesser prairie-chickens selected for vegetative cover (forbs and grass) other than shrubs slightly over litter and bare ground (Table 3.7). Since I did not differentiate between the orientation of litter (vertical vs. horizontal) these results do not provide insight into the use of vertical litter (i.e., dead, standing vegetation) as screening cover.

### Nest Survival

I assessed nest survival using a set of 11 *a priori* and 5 exploratory models (Table 3.1). Based on model weights, there was a degree of model uncertainty (Table 3.8). Therefore, I estimated daily nest survival by model averaging. Model-averaged daily nest survival rates were 0.96 (SE = 0.01). Incubation for lesser prairie-chickens is 24-26 days (Giesen 1998). The observed incubation time of radiomarked lesser prairie-chickens was, on average, 26 days during this study. Therefore, I derived interval nest survival rates through the incubation period ($0.96^{26}$) to be 0.36 (SE = 0.05). The top 5 models all included clutch size, and 2 of the top 3 models included 100% visual obstruction (Table 3.8). In fact, the highest weighted model was the one that included an additive effect of clutch size and 100% visual obstruction (Table 3.8). I obtained a predictive beta parameter estimate by model averaging across all models (Anderson 2008). I excluded models with a year effect because year had very little weight relative to other models in the model set. Furthermore, there was no evidence of changes in nest daily survival rates as a function of year. The resulting weighted predictive beta parameter estimate was:

> *Logit daily nest survival rate* = (0.17) (*clutch size*) + (0.24) (*100% visual obstruction*) – ($0.01^{-1}$) (*incubation date*) + ($0.03^{-2}$) (*hen age*) + ($0.04^{-1}$) (*% bare ground at nest*) + ($0.03^{-3}$) (*within season linear trend*) + ($0.09^{-1}$) (*0% visual obstruction*) – ($0.01^{-3}$) (*within season quadratic trend*) – ($0.04^{-3}$) (*% forb cover within 2 m of nest*) + 0.47

Based on multimodel inference and the weighted beta parameter estimates (Anderson 2008), clutch size and 100% visual obstruction had the most influence on daily nest survival given the model set I used. Furthermore, both increases in clutch size and 100% visual obstruction had positive effects on daily nest survival estimates.

### Chick Survival

The year with the greatest chick survival was 2008, when 2 broods had chicks past 35 days post-hatch and 1 brood had chicks past 63 days post-hatch. No chicks were observed in broods past 14 days post-hatch in 2009 or 2010. A hen with a brood during 2010 lost her radio collar 3 days following hatch; assessment of chick survival for that brood was impossible past that point. I placed patagial tags on 16 3-day old chicks in 2008 but found no patagial tags on birds captured on leks in 2009 or 2010.

Lesser prairie-chicken chick survival was a function of brood age based on developed models (Table 3.9). Daily chick survival estimates were 0.88 (SE = 0.02) between hatch and 14 days post-hatch and 0.99 (SE = 0.01) between 15 and 63 days post-hatch. This resulted in interval survival estimates of 0.18 (SE = 0.01) between hatch and 14 days post-hatch and 0.55 (SE = 0.16) between 15 and 63 days post-hatch.

## DISCUSSION

Coyotes and snakes have been identified as the primary causes of lesser prairie-chicken nest failure in 2 published studies (Pitman et al. 2005*b*, Grisham 2012). In contrast, under the broader classification of nest failure I used, the primary cause of nest failure due to depredation was attributed to members of the mustelidae family. Although no surveys of predator community composition were conducted during my study, anecdotal observations indicate that striped skunks or badgers were the most likely causes of nest depredation. However, I attributed the same number of nest failures to unknown causes as attributed to mustelidae depredation. Because the determination of unknown cause of nest failure was made when no evidence was present, it is possible that other nest predators, such as bullsnakes (*Pituophis* spp.) or ravens (*Corvus* spp.), could be the cause of nest failure (e.g., Pitman et al. 2005*b*, Grisham 2012). However, there is disagreement with respect to the impact of snake predation on bird nests (Marini and Melo 1998, Weatherhead and Blouin-Demers 2004), so speculation would be unwarranted.

I found evidence that, at the nest site scale, lesser prairie-chickens select sites based on screening cover as measured by visual obstruction (Table 3.4), while avoiding shrubs (Tables 3.6 and 3-7). This indicates that density and height of grass, forb, and standing residual vegetation are important to nest site selection. My findings that lesser prairie-chickens select for greater screening cover (i.e., greater 100% visual obstruction measurements) are consistent with other studies (Giesen 1994, Pitman et al. 2005*b*, Davis 2009, Grisham 2012). Some published studies have reported nest site selection in herbaceous cover (Haukos and Smith 1989, Riley 1992) whereas others have reported selection in shrub cover (Giesen 1994, Pitman et al. 2005*b*, Davis 2009, Grisham 2012). All of these studies reported vegetative characteristics at used compared to random sites and none reported avoidance of any vegetative characteristics as the result of compositional analysis. Because lesser prairie-chickens in different ecoregions have different vegetation available to select from (Silvy 2006), differences in findings between studies support the need for location-specific information from across the range of lesser prairie-chickens (Pitman et al. 2006*a*).

I used vegetation components of used compared to random sites as the basis for exploratory analysis of nest survival on my study site. I did not find support for an effect of maximum vegetation height (0% visual obstruction), proportion of bare ground at the nest site, or proportion of forb cover within 2 m of the nest. I found a positive effect of clutch size and height of complete visual obstruction on nest survival. Grisham (2012) found a positive effect of clutch size on nest survival and attributed this to annual variation in precipitation and available moisture required to produce larger clutches. Grisham (2012) used clutch size as a surrogate for hen condition as a result of moisture in a more arid region than where my study was conducted. This is logical and can be supported by my findings. If hens in better condition are able to produce larger clutches, it stands to reason that they would be better able to defend their nest and spend more time at the nest vs. foraging. The combination of greater screening cover and hens in better condition would lead to greater nest survival. If this is the case, availability of resources prior to the breeding season are important to overall breeding season success at the population level.

Nest survival is the probability that a nest will survive a given interval and nest success is the proportion of nests that produce at least 1 chick (Dinsmore et al. 2002, Rotella et al. 2004). However, some lesser prairie-chicken nesting ecology studies reported nest success (Pitman et al. 2006*a*, Davis 2009). Comparisons between my study and those that report apparent nest success are possible, but the difference in estimation of the vital rate should be noted. My nest survival estimate of 36% was far less than the apparent nest success of 76% reported by Davis (2009) for a population of lesser prairie-chickens in New Mexico, and greater than the apparent nest success on 26% reported by Pitman et al. (2006*a*) in Kansas. Nest survival estimates were reported by Fields et al. (2006) for a population of lesser prairie-chickens in Kansas and Grisham (2012) for a population in southwestern Texas and east New Mexico. My estimates of nest survival (36%) were lower than the 72% reported by Fields et al. (2006) in Kansas. In contrast, my estimates of nest survival were greater than those reported for a concurrent study in the southwestern Texas panhandle (Grisham 2012) in 2009 (23%) and 2011 (0%), but lower than those reported in 2008 (42%) and 2010 (59%).

The brood is the sample unit when estimating brood survival whereas the individual chick was the sample unit in my analysis. Brood survival, while an important vital rate, can be misleading because a brood is considered to have survived if ≥ 1 chick survived. Estimates of individual chick survival may be more appropriate for management because individual survival reflects recruitment, whereas brood survival does not.

Other studies have reported brood survival (Fields 2006, Davis 2009, Grisham 2012) rather than chick survival. However, these studies reported similar findings to my study in that brood survival was lower during the early brood-rearing period than the late-brood rearing period. Although the number of days until the end of the late-brood rearing period varied slightly among studies, the early brood-rearing period was always hatch to 14 days post-hatch. I found 1 study that reported chick survival for the early and late brood rearing periods (Pitman et al. 2006*b*). Compared to Pitman et al. (2006*b*), the survival rates I observed for chicks between hatch and 14 days were considerably lower, but chick survival during the late brood-rearing period was greater. Overall chick survival from hatch until the end of the late brood-rearing period in my study (0.10) was lower than that reported by Pitman et al. (2006*b*) in Kansas (0.18).

Overall, the estimates of nest and chick survival that I report here are neither the lowest nor highest found in the literature. This indicates that, in terms of biological potential, the population of lesser prairie-chickens that I studied should be capable of greater survival rates for both nest and chick survival than I estimated.

## MANAGEMENT IMPLICATIONS

Pressure from nest depredation can have significant impact on prairie grouse populations, this impact can be mitigated by proper habitat management (Schroeder and Baydack 2001). Habitat management with the goal of improving overall nest survival should be considered. Shrubs were avoided as nesting cover, lending support to habitat management plans that call for shrub control to improve lesser prairie-chicken nesting habitat and providing support for the idea that sand shinnery oak may not be a requirement for lesser prairie-chickens (Silvy 2006), at least during the nesting period. However, I could not precisely estimate daily locations of brooding hens and did not have a land cover GIS layer at the resolution to definitively determine use or avoidance of shrubs during other life stages. As such, complete shrub removal may be unwarranted and have deleterious effects during other life stages. Lesser prairie-chickens appear to have the biological potential for greater nest and chick survival, based on results of other reported studies. As such, targeted management aimed at improving these vital rates is warranted.

# LITERATURE CITED

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313-1325.

Alberico, J. A. R. 1995. Floating to estimate incubation stage does not affect hatchability. Wildlife Society Bulletin 23:212-216.

Aldrich, J. W. 1963. Geographic orientation of American Tetraonidae. Journal of Wildlife Management 27:529-545.

Ammann, G. A. 1944. Determining age of pinnate and sharp-tailed grouses. Journal of Wildlife Management 8:170-171.

Anderson, D. R. 2008. Model based inference in the life sciences: a primer on evidence. Springer. New York, USA.

Bell, L. A., S. D. Fuhlendorf, M. A. Patten, D. H. Wolfe, and S. K. Sherrod. 2010. Lesser prairie-chicken hen and brood habitat use on sand shinnery oak. Rangeland Ecology and Management 63:478-486.

Bender, S., S. Shelton, K. C. Bender, and A. Kalmbach, editors. 2005. Texas comprehensive wildlife conservation strategy: 2005-2010. Texas Parks and Wildlife Department. Austin, USA.

Bonham, C. D. 1989. Measurements for terrestrial vegetation. John C. Wiley and Sons, Inc. New York, USA.

Braun, C. E., K. Martin, T. E. Remington, and J. R. Young. 1994. North American grouse: issues and strategies for the 21st century. Transactions of the North American Wildlife and Natural Resource Conference 59:428-437.

Brown, L. 1979. Grasses: and identification guide. Houghton Mifflin Company, New York, USA.

Calenge, C. 2006. The package adehabitat for the R software: a tool for the analysis of space and habitat use by animals. Ecological Modelling 197:516-519.

Carver, A. V., L. W. Burger, Jr., and L. A. Brennan. 1999. Passive integrated transponders and patagial tag markers for northern bobwhite chicks. Journal of Wildlife Management. 63:162-166.

Coates, P. S., J. W. Connelly, and D. J. Delehanty. 2008. Predators of greater sage-grouse nests identified by video monitoring. Journal of Field Ornithology 79:421-428.

Copelin, F. F. 1963. The lesser prairie chicken in Oklahoma. Technical Bulletin 6. Oklahoma Department of Wildlife, Oklahoma City, USA.

Cormack, R. M. 1964. Estimates of survival from the sighting of marked animals. Biometrics 51:429-438.

Corman, K. S. 2011. Conservation and landscape genetics of Texas lesser prairie-chicken: population structure and differentiation, genetic variability, and effective size. M. S. Thesis. Texas A&M University-Kingsville, Kingsville, USA.

Crawford, J. A. 1980. Status, problems, and research needs of the lesser prairie chicken. Pages 1-7 *in* Proceedings of the Prairie Grouse Symposium. 17-18 September 1980. Stillwater, Oklahoma, USA.

Crawford, J. A., and E. G. Bolen. 1976. Effects of land use on lesser prairie-chickens in Texas. Journal of Wildlife Management 40:96-104.

Davis, D. M. 2009. Nesting ecology and reproductive success of lesser prairie-chickens in shinnery oak-dominated rangelends. The Wilson Journal of Ornithology 121:322-327.

Davis, W. B., and D. J. Schmidly. 1994. The mammals of Texas. Texas Parks and Wildlife Press, Austin, USA.

Dinsmore, S. J., G. C. White, and F. L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476-3488.

Fields, T. L., G. C. White, W. C. Gilbert, and R. D. Rodgers. 2006. Nest and brood survival of lesser prairie-chickens in west central Kansas. Journal of Wildlife Management 70:931-938.

Flint, P. L., K. H. Pollock, D. Thomas, and J. S. Sedinger. 1995. Estimating prefledging survival: allowing for brood mixing and dependence among brood mates. Journal of Wildlife Management 59:448-455.

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

Giesen, K. M. 1998. Lesser prairie-chicken (*Tympanuchus pallidicinctus*), No. 364. *in* A. Poole and F. Gill, editors. The Birds of North America. The Birds of North America, Inc. Philadelphia, Pennsylvania, USA.

Green, R. E. 1985. Estimating the abundance of breeding snipe. Bird Study 32:141-149.

Grisham, B. A. 2012. The ecology of lesser prairie-chickens in shinnery oak-grassland communities in New Mexico and Texas with implications toward habitat management and future climate change. Ph.D. Dissertation, Texas Tech University, Lubbock, USA.

Hagen, C.A., B.E. Jamison, K.M. Griesen, and T.Z. Riley. 2004. Guidelines for managing lesser prairie-chicken populations and their habitats. Wildlife Society Bulletin 32:69-82.

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

Hagen, C. A., B. K. Sandercock, J. C. Pitman, R. J. Robel, and R. D. Applegate. 2009. Spatial variation in lesser prairie-chicken demography: a sensitivity analysis of population dynamics and management alternatives. Journal of Wildlife Management 73:1325-1332.

Hannon, S. J., I. Jonsson, and K. Martin. 1990. Patagial tagging of juvenile willow ptarmigan. Wildlife Society Bulletin. 18:116-119.

Haukos, D. A., and L. M. Smith 1989. Lesser prairie-chicken nest site selection and vegetation characteristics in tebuthiuron-treated and untreated sand shinnery oak in Texas. Great Basin Naturalist 49:624-626.

Haukos, D. A., L. M. Smith, and G. S. Broda. 1990. Spring trapping lesser prairie-chickens. Journal of Field Ornithology 61:20-25.

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

Johnson, D. H. 1980. The comparison of use and availability measurements for evaluating resource preference. Ecology 61:65-71.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic models. Biometrika 64:225-247.

Labisky, R. F. 1968. Nightlighting: its use in capturing pheasants, prairie-chickens, bobwhites, and cottontails. Illinois Natural History Survey Biological Notes. 62.

Lariviere, S. 1999. Reasons why predators cannot be inferred from nest remains. The Condor 101:718-721.

Liebezeit, J. R., P. A. Smith, R. B. Lanctot, H. Schekkerman, I. Tulp. S. J. Kendall, D. M. Tracy, R. J. Rodrigues, H. Meltofte, J. A. Robinson, C. Gratto-Trevor, B. J. McCaffery, J. Morse, and S. W. Zack. 2007. Assessing the development of shorebird eggs using the floatation method: species-specific and generalized regression models. The Condor 109:32-47.

Litton, G., R. L. West, D. F. Dvorak, and G. T. Miller. 1978 The lesser prairie chicken and its management in Texas. Texas Parks and Wildlife Department Booklet N7000-25. Austin, USA.

Lukacs, P. M., V. J. Drietz, F. L. Knopf, and K. P. Burnham. 2004. Estimating survival probabilities of unmarked dependent young when detection is imperfect. The Condor 106:926-931.

Marini, M. A., and C. Melo. 1989. Predators of quail eggs and the evidence of the remains: implications for nest predation studies. The Condor 100:395-399.

Manly, B. F. J., and J. A. Schmutz. 2001. Estimation of brood and nest survival: comparative methods in the presence of heterogeneity. Journal of Wildlife Management 65:258-270.

McNew, L. B., A. J. Gregory, S. M. Wisely, and B. K. Sandercock. 2009. Estimating the stage of incubation for nests of greater prairie-chickens using egg floation: a float curve for grousers. Grouse News 38:12-14.

McRoberts, J.T. 2009. Aerial surveys for lesser prairie-chicken leks: detectability and disturbance response. M. S. Thesis, Texas Tech University, Lubbock, USA.

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

Peterson, M. J., and N. J. Silvy. 1996. Reproductive strategies limiting productivity of the endangered Attwater's prairie-chicken. Conservation Biology 10:1264-1276.

Peterson, R. S., and C. S. Boyd. 1998. Ecology and management of sand shinnery communities: a literature review. U. S. Department of Agriculture Forest Service General Technical Report RMRS-GTR-16. Rock Mountain Research Station, Fort Collins, Colorado, USA.

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

Pitman, J. C., C. A. Hagen, B. E. Jamison, R. J. Robel, T. M. Loughin, and R. D. Applegatge. 2006*b*. Survival of juvenile lesser prairie-chickens in Kansas. Wildlife Society Bulletin 34:675-681.

Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2005*a*. Gender identification and growth of juvenile lesser prairie-chickens. The Condor 107:87-96.

Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2005*b*. Location and success of lesser prairie-chicken nests in relation to vegetation and human disturbance. Journal of Wildlife Management 69:1259-1269.

Pitman, J. C., B. E. Jamison, C. A. Hagen, R. J. Robel, and R. D. Applegate. 2006*c*. Brood break-up and juvenile dispersal of lesser prairie-chickens in Kansas. The Prairie Naturalist 38:85-99.

Powell, L. A. 2007. Approximating variance of demographic parameters using the delta method: a reference for avian biologists. The Condor 109:949-954.

R Development Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria.

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.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management. 23:295-297.

Rotella, J. J., S. J. Dinsmore, and T. L. Shaffer. 2004. Modeling nest-survival data: a comparison of recently developed methods that can be implemented in MARK and SAS. Animal Biodiversity and Conservation 27:187-205.

Samson, F. B. 1980. Island biogeography and the conservation of prairie birds. Proceedings of the North American Prairie Conference 7:293-305.

Sargeant, A. B., M. A. Sovada, and R. J. Greenwood. 1998. Interpreting evidence of depredation of duck nests in the prairie pothole region. U. S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND, USA, and Ducks Unlimited, Memphis, TN, USA.

Schroeder, M. A., and R. K. Baydack. 2001. Predation and the management of prairie grouse. Wildlife Society Bulletin 29:24-32.

Schroeder, M. A., and C. E. Braun. 1991. Walk-in funnel traps for capturing greater prairie-chickens on leks. Journal of Field Ornithology 62:378-385.

Seber, G. A. F. 1965. A note on the multiple recapture census. Biometrika 52:249-259.

Silvy, N. J. 2006. In my opinion: shinnery oak is not a requirement for lesser prairie chicken habitat. pages 138-142 *in* J. W. Cain III and P. R. Krausman (editors). Managing Wildlife in the Southwest: New Challenges for the 21st Century. The Southwest Section of the Wildlife Society, 9-11 August 2005, Alpine, Texas, 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.

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. The Prairie Naturalist 32:177-188.

Taylor, M.A., and F.S. Guthery. 1980. Status, ecology, and management of the lesser prairie-chicken. U.S. Department of Agriculture Forest Service Technical Report RM-77. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado, USA.

U. S. Fish and Wildlife Service. 2010. U. S. Fish and Wildlife Service species assessment and listing priority assignment form. <http://ecos.fws.gov/docs/candidate/assessments/2010/r2/B0AZ_V01.pdf>. Accessed 11 May 2011.

Venturato, E., P. Cavallini, P. Banti, and F. Dessi-Fulgheri. 2009. Do radio collars influence mortality and reproduction? A case with ring-neck pheasants (*Phasianus colchicus*) in central Italy. European Journal of Wildlife Research 55:547-551.

Weatherhead, P. J., and G. Blouin-Demers. 2004. Understanding avian nest predation: why ornithologists should study snakes. Journal of Avian Biology 35:185-190.

Westerkov, K. 1950. Methods for determining the age of game bird eggs. Journal of Wildlife Management 14:56-67.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:S120-S139.

Wilcoxon, F. 1945. Individual comparisons by ranking methods. Biometrics Bulletin 1:80-83.

Wisodm, 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.

Zar, J. H. 2010. Biostatistical Analysis. Fifth edition. Prentice Hall, Upper Saddle River, New Jersey, USA.

Table 3.1. Descriptions of models used to examine nest survival of lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA, 2008-2010.

| Model | Description | AP/EX[a] |
|---|---|---|
| $S_{.}$ | no effect (intercept only model) | AP |
| $S_{\text{year}}$ | year effect | AP |
| $S_{\text{hen age}}$ | hen age (adult or juvenile) effect | AP |
| $S_{\text{incubation date}}$ | date of onset of Incubation effect | AP |
| $S_{\text{clutch size}}$ | clutch size effect | AP |
| $S_{t}$ | within season linear trend | AP |
| $S_{tt}$ | within season quadratic trend | AP |
| $S_{\text{year + t}}$ | year effect + within season linear trend | AP |
| $S_{\text{year + tt}}$ | year effect + within year quadratic trend | AP |
| $S_{\text{hen age + clutch size}}$ | hen age effect + clutch size effect | AP |
| $S_{\text{incubation date + clutch size}}$ | date of onset of Incubation effect + clutch size effect | AP |
| $S_{\text{100\% VOR}}$ | 100% visual obstruction (height of complete visual obstruction at nest bowl) | EX |
| $S_{\text{0\% VOR}}$ | 0% visual obstruction (height of tallest vegetation at nest bowl) | EX |
| $S_{\text{nest bare ground}}$ | percentage of bare ground at nest bowl | EX |
| $S_{\text{2 m forb cover}}$ | percentage of forb cover within 2 m of nest bowl | EX |
| $S_{\text{clutch size + 100\% VOR}}$ | clutch size effect + 100% visual obstruction | EX |

[a] AP = *a priori* model, EX = exploratory model

Table 3.2. Descriptions of models used to examine chick survival of lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA, 2008-2010.

| Model | Description |
|---|---|
| $S_{.}$ | no effect (intercept only model) |
| $S_{\text{brood age}}$ | brood age effect[a] |
| $S_{\text{hatch date}}$ | Julian date of hatch |
| $S_{\text{brood size}}$ | initial brood size |
| $S_{t}$ | within season linear trend |
| $S_{tt}$ | within season quadratic trend |

[a] brood age: 1-14 days post hatch (early brood) or 15-63 days post-hatch (late brood)

Table 3.3. Observational data for nests or radiomarked and unmarked lesser prairie-chickens located on private lands in Gray and Hemphill counties, Texas, USA, 2008-2010.

| Year | Nest_ID | Attempt[a] | Fate | Clutch Size | Hen Age | Cause of Failure |
|---|---|---|---|---|---|---|
| 2008 | 2039N-108 | 1st | Hatch | 13 | Adult | N/A |
| 2008 | 1108N-108 | 1st | Fail | 10 | Adult | Canidae |
| 2008 | 1118N-108 | 1st | Hatch | 12 | Juvenile | N/A |
| 2008 | 1111N-108 | 1st | Hatch | 12 | Juvenile | N/A |
| 2008 | 1109N-108 | 1st | Fail | 10 | Juvenile | Mustelidae |
| 2008 | 1113N-108 | 1st | Fail | 11 | Juvenile | Unknown |
| 2008 | 1108N-208 | 2nd | Fail | 8 | Adult | Mustelidae |
| 2009 | 1118N-109 | 1st | Hatch | 13 | Adult | N/A |
| 2009 | 1019N-109 | 1st | Hatch | 10 | Juvenile | N/A |
| 2009 | 1152N-109 | 1st | Fail | 12 | Juvenile | Mustelidae |
| 2009 | 1321N-109 | 1st | Fail | 9 | Juvenile | Unknown |
| 2009 | 1113N-109 | 1st | Hatch | 13 | Adult | N/A |
| 2009 | 2039N-109 | 1st | Hatch | 12 | Adult | N/A |
| 2009 | 1144N-109 | 1st | Fail | 2 | Adult | Hen Death |
| 2009 | UNM-0901 | 1st | Hatch | 12 | Unknown | N/A |
| 2009 | UNM-0902 | 2nd | Fail | 7 | Unknown | Unknown |
| 2009 | 1152N-209 | 2nd | Fail | 9 | Juvenile | Abandoment |
| 2009 | 1134N-209 | 2nd | Fail | 8 | Juvenile | Hen Death |
| 2010 | 1136N-110 | 1st | Fail | 13 | Juvenile | Mustelidae |
| 2010 | 1334N-110 | 1st | Hatch | 7 | Juvenile | N/A |
| 2010 | 2039N-110 | 1st | Fail | 12 | Adult | Unknown |
| 2010 | 1335N-110 | 1st | Fail | 10 | Juvenile | Mustelidae |
| 2010 | 1136N-210 | 2nd | Fail | 6 | Juvenile | Unknown |
| 2010 | UNM1001 | 2nd | Fail | 9 | Unknown | Canidae |

[a] nest attempt determined by date of onset of incubation and clutch size

Table 3.4. Results of Wilcoxon Signed Rank tests for differences in vegetation at lesser prairie-chicken nests and paired random sites in the northeastern Texas panhandle 2008-2010.

| Vegetation Measurement | Z | p-value | Significant |
|---|---|---|---|
| 100% Visual Obstruction | 92 | < 0.01 | yes |
| 0% Visual Obstruction | 74 | 0.03 | yes |
| 1 m Litter Depth | 49.5 | 0.16 | no |
| 2 m Litter Depth | 37.5 | 0.29 | no |
| 3 m Litter Depth | 48.5 | 0.09 | no |
| 4 m Litter Depth | 31 | 0.32 | no |
| Plot Center Bare Ground | -37 | < 0.01 | yes |
| Plot Center Litter Cover | 23.5 | 0.46 | no |
| Plot Center Grass Cover | -60 | 0.07 | no |
| Plot Center Forb Cover | 43 | 0.23 | no |
| Plot Center Shrub Cover | 9.5 | 0.30 | no |
| 1 m Bare Ground | 5 | 0.88 | no |
| 2 m Bare Ground | 41.5 | 0.21 | no |
| 3 m Bare Ground | 49.5 | 0.16 | no |
| 4 m Bare Ground | 37 | 0.20 | no |
| 1 m Forb Cover | 39.5 | 0.21 | no |
| 2 m Forb Cover | 68.5 | 0.03 | yes |
| 3 m Forb Cover | 62.5 | 0.06 | no |
| 4 m Forb Cover | 55.5 | 0.07 | no |
| 1 m Grass Cover | -25.5 | 0.45 | no |
| 2 m Grass Cover | -35.5 | 0.32 | no |
| 3 m Grass Cover | -36.5 | 0.31 | no |
| 4 m Grass Cover | -28 | 0.44 | no |
| 1 m Litter Cover | 33.5 | 0.35 | no |
| 2 m Litter Cover | 26.5 | 0.43 | no |
| 3 m Litter Cover | 10 | 0.77 | no |
| 4 m Litter Cover | -0.5 | 0.99 | no |
| 1 m Shrub Cover | -8 | 0.68 | no |
| 2 m Shrub Cover | -12.5 | 0.54 | no |
| 3 m Shrub Cover | -15 | 0.41 | no |
| 4 m Shrub Cover | -10 | 0.62 | no |

Table 3.5. Mean values of vegetation data collected at lesser prairie-chicken nest sites and paired random locations in the northeastern Texas panhandle 2008-2010 where differences were significant based on Wilcoxon Signed Rank tests.

| | | Nest Sites | | | | Random Locations | | | |
|---|---|---|---|---|---|---|---|---|---|
| Vegetation Measurement | n | Mean | Minimum | Maximum | SE | Mean | Minimum | Maximum | SE |
| 100% Visual Obstruction[a] | 24 | 1.90 | 0.90 | 3.00 | 0.12 | 1.16 | 0.30 | 3.60 | 0.20 |
| 0% Visual Obstruction[b] | 24 | 4.91 | 2.90 | 8.90 | 0.28 | 3.88 | 1.40 | 8.30 | 0.43 |
| Plot Center Bare Ground[c] | 24 | 1.83 | 0.00 | 20.00 | 0.87 | 9.00 | 0.00 | 44.00 | 2.42 |
| 2 m Forb Cover[c] | 24 | 22.21 | 2.00 | 42.00 | 2.44 | 17.17 | 7.00 | 35.00 | 1.79 |

[a] height (dm) where Robel pole was completely obstructed

[b] height (dm) where Robel pole was completely visible; height of tallest vegetation

[c] measured as percent cover

Table 3.6. Ranking matrix from the results of fourth-order compositional analysis of nests of radio-marked lesser prairie-chickens in the northeastern Texas panhandle 2008-2010.

| | Bare Ground | Forb Cover | Grass Cover | Litter Cover | Shrub Cover |
|---|---|---|---|---|---|
| Bare Ground | 0 | - | - | - | +++ |
| Forb Cover | + | 0 | + | + | +++ |
| Grass Cover | + | - | 0 | + | +++ |
| Litter Cover | + | - | - | 0 | +++ |
| Shrub Cover | --- | --- | --- | --- | 0 |

Table 3.7. Fourth-order compositional analysis ranks for cover types of radio-marked lesser prairie-chicken nests in the northeastern Texas panhandle 2008-2010.

| Forb Cover | Grass Cover | Litter Cover | Bare Ground | Shrub Cover |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

Table 3.8. Nest survival model results for lesser prairie-chicken nests on private lands in Gray and Hemphill counties, Texas, USA, 2008-2010.

| Model[a] | $AIC_c$[b] | $\Delta AIC_c$ | $\omega$[c] | Model Likelihood | K[d] | Deviance |
|---|---|---|---|---|---|---|
| $S_{\text{clutch size + 100\% VOR}}$ | 118.83 | 0.00 | 0.37 | 1.00 | 3 | 112.76 |
| $S_{\text{clutch size}}$ | 120.26 | 1.43 | 0.18 | 0.50 | 2 | 116.23 |
| $S_{\text{100\% VOR}}$ | 120.81 | 1.98 | 0.14 | 0.37 | 2 | 116.77 |
| $S_{\text{clutch size + incubation date}}$ | 121.64 | 2.81 | 0.09 | 0.25 | 3 | 115.57 |
| $S_{\text{clutch size + hen age}}$ | 122.29 | 3.46 | 0.07 | 0.18 | 3 | 116.23 |
| $S_{\text{nest bare ground}}$ | 123.81 | 4.98 | 0.03 | 0.08 | 2 | 119.77 |
| $S_{.}$ | 124.23 | 5.40 | 0.02 | 0.07 | 1 | 122.22 |
| $S_{\text{incubation date}}$ | 124.27 | 5.45 | 0.02 | 0.07 | 2 | 120.24 |
| $S_{t}$ | 124.66 | 5.83 | 0.02 | 0.05 | 2 | 120.63 |
| $S_{\text{0\% VOR}}$ | 124.98 | 6.15 | 0.02 | 0.05 | 2 | 120.94 |
| $S_{tt}$ | 125.65 | 6.83 | 0.01 | 0.03 | 3 | 119.59 |
| $S_{\text{hen age}}$ | 126.20 | 7.37 | 0.01 | 0.03 | 2 | 122.17 |
| $S_{\text{2 m forb cover}}$ | 126.23 | 7.40 | 0.01 | 0.02 | 2 | 122.20 |
| $S_{\text{year}}$ | 127.60 | 8.77 | 0.00 | 0.01 | 3 | 121.54 |
| $S_{\text{year + t}}$ | 128.25 | 9.42 | 0.00 | 0.01 | 4 | 120.14 |
| $S_{\text{year + tt}}$ | 129.62 | 10.79 | 0.00 | 0.00 | 5 | 119.45 |

[a] Model descriptions detailed in table 3.1

[b] Models were evaluated by sample-size-corrected Akaike's Information Criterion

[c] Akaike weight

[d] No. of parameters in each model

Table 3.9. Results of brood survival models for broods of radiomarked lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA, 2008-2010.

| Model[a] | $AIC_c$[b] | $\Delta AIC_c$ | $\omega$[c] | Model Likelihood | K[d] | Deviance |
|---|---|---|---|---|---|---|
| $S_{\text{brood age}}$ | 93.26 | 0.00 | 1.00 | 1.00 | 2 | 88.81 |
| $S_t$ | 106.14 | 12.88 | 0.00 | 0.00 | 2 | 101.69 |
| $S_{tt}$ | 107.51 | 14.25 | 0.00 | 0.00 | 3 | 100.58 |
| $S_{\text{hatch date}}$ | 114.77 | 21.51 | 0.00 | 0.00 | 2 | 110.32 |
| $S_{\text{brood size}}$ | 118.19 | 24.94 | 0.00 | 0.00 | 2 | 113.75 |
| S. | 123.88 | 30.62 | 0.00 | 0.00 | 1 | 121.73 |

[a] Model descriptions detailed in table 3.2

[b] Models were evaluated by sample-size-corrected Akaike's Information Criterion

[c] Akaike weight

[d] No. of parameters in each model

# CHAPTER 4

# A POPULATION VIABILITY ANALYSIS FOR LESSER PRAIRIE-CHICKENS (*TYMPANUCHUS PALLIDICINCTUS*) IN THE NORTHEASTERN TEXAS PANHANDLE

All species of prairie grouse have declined sharply over the past 3 to 4 decades (Silvy and Hagen 2004). Large-scale declines of lesser prairie-chicken (*Tympanuchus pallidicinctus*) populations have been observed since 1900 on the Great Plains (Litton et al. 1978). Lesser prairie-chickens are endemic to mixed-grass and short-grass prairies of North America (Aldrich 1963, Patten et al. 2005), and prefer grasslands dominated by sand shinnery oak (*Quercus havardii*) and sand sagebrush (*Artemisia filifolia*) (Giesen 1998). Historic range of lesser prairie-chickens included portions of southwestern Kansas, southeastern Colorado, western Oklahoma, eastern New Mexico, and the Texas Panhandle (Sullivan et al. 2000).

It is estimated that two-thirds of the historic range of lesser prairie-chickens occurred in the Texas panhandle (U. S. Fish and Wildlife Service 2010), with as many as 2 million birds present prior to 1900 (Litton et al. 1978). Currently, lesser prairie-chickens are found in at least 2 distinct populations in the Texas panhandle (Jackson and DeArment 1963, Taylor and Guthery 1980, Corman 2011), with a distribution representing up to a 92% reduction of occupied area (Sullivan et al. 2000). Furthermore, the Texas range has declined by as much as 78% since 1940 (Taylor and Guthery 1980).

The cause of the large-scale population decline observed in lesser prairie-chickens is attributed to changes in land use (Aldrich 1963, Jackson and DeArment 1963, Sullivan

et al. 2000) and habitat fragmentation (Crawford 1980, Samson 1980, Braun et al. 1994). Changing land-use practices include the conversion of native grasslands to cultivation (Jackson and DeArment 1963, Crawford and Bolen 1976, Braun et al. 1994), over-grazing (Riley 1992, Giesen 1998), and oil and gas extraction (Pitman et al. 2005*b*). Effects of anthropogenic land-use changes may be exacerbated by periodic droughts (Jackson and DeArment 1963, Hagen et al. 2004).

The U. S. Fish and Wildlife Service was petitioned to list lesser prairie-chicken as threatened under the ESA in 1995 (U. S. Fish and Wildlife Service 1998). The U. S. Fish and Wildlife Service determined that listing was warranted but precluded due to higher priority species (U. S. Fish and Wildlife Service 1998). The U. S. Fish and Wildlife Service uses a listing priority matrix to assign listing priorities to species to be considered for protection under the ESA (U. S. Fish and Wildlife Service 1983). After reviewing the petition, lesser prairie-chickens were assigned a listing priority of 8 (U. S. Fish and Wildlife Service 1998). Recently, the listing priority for lesser prairie-chickens was increased to 2 (U. S. Fish and Wildlife Service 2008), which indicates that listing for this species is likely imminent. A directed conservation effort is needed to stop and reverse decline in this species. Management should be directed to improve vital rates that will have the greatest impact on population persistence and growth.

Population viability analysis (PVA) provides insight into population dynamics using data collected from biological systems (Dinsmore and Johnson 2005). Studies using PVA have been criticized as being too generalized (White 2000) and resulting from studies that are too short in duration (Doak et al. 2005). Understanding the limitations of the data prior to analysis can lead to development of more robust models and add to the utility of PVA (White 2000, Doak et al. 2005). In particular, elasticity analyses of population viability models provide guidance for future research and management (Clark et al. 2008). Additionally, Morris et al. (1999) suggested that projection matrix models be used for demographic data collected over 2 or more years.

Elasticity analyses have been used for population assessments of greater (*T. cupido*; Wisdom and Mills 1997, Wisdom et al. 2000) and lesser prairie-chickens (Hagen et al. 2009). Analyses for greater prairie-chickens were based on data collected on previous studies and reported elsewhere (Wisdom and Mills 1997, Wisdom et al. 2000). Hagen et al. (2009) based a PVA on data collected over a 6-year period in Kansas. However, variability in landscape components across the range of lesser prairie-chickens suggests site- or regional-specific examination of the impact of vital-rate changes would provide more meaningful guidance for management activities.

I collected 3 years of radiotelemetry-based demographic data for lesser prairie-chickens in the northeastern Texas panhandle. I developed PVA models based on data collected in the field and then used these models to examine the potential effects of management activities on population growth. The specific objectives of this study were to determine the life stage of lesser prairie-chickens that had the greatest influence on population growth, determine the impact of alteration of vital-rates on population growth, and estimate the potential of population persistence under current and hypothetical management conditions.

## STUDY AREA

The study area was on private lands in Gray and Hemphill counties, Texas, USA. The Gray county site was located in the High Plains ecoregion and the Hemphill County site was in the Rolling Plains ecoregion (Bender et al. 2005). Primary land uses were cattle ranching interspersed with oil and gas development and some Conservation Reserve Program lands, center-pivot and dry-land agricultural crops (McRoberts 2009).

The Gray county site was at the eastern edge of the Caprock Escarpment, with elevations from 850-900 m. Elevations on the Hemphill county site were from 750-800 m. Mean annual precipitation and temperatures were similar between the sites. Mean annual precipitation was 52 cm; mean low temperature was -5° C (January) and mean high temperature was 35° C (July).

Native land-cover types were similar for both sites and vegetation was dominated by grassland interspersed with areas of dense shrubs. Grasses included little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), switchgrass (*Panicum virgatum*), and Indiangrass (*Sorghastum nutans*; Jackson and DeArment 1963). Common forbs found in grasslands included common broomweed (*Amphiachyris dracunculoides*), Indian blanket (*Gaillardia pulchella*), and western ragweed (*Ambrosia psilostachya*). Shrubs, including sand sagebrush (*Artemisia filifolia*) and soapweed yucca (*Yucca glauca*), were sparsely scattered throughout grasslands. Patches of dense (>50% cover) sand shinnery oak (*Quercus havardii*) were present throughout the area and contained mottes consisting of sand shinnery oak-post oak (*Q. stellata*) hybrids ≤ 6 m tall (Peterson and Boyd 1998).

## METHODS

Females were captured using walk-in funnel traps (Haukos et al. 1990, Schroeder and Braun 1991) and rocket-netting on leks. All birds were classified as juvenile (first breeding year) or adult (after first breeding year) based on the pattern of spotting on the 9th and 10th primaries (Ammann 1944, Copelin 1963). Each bird was fitted with a 12-16 g necklace-style radio-transmitter, equipped with a 12-hour mortality switch, operating between 148.000 and 151.999 Mhz, and an individually numbered monel leg band (size 12), and then each bird was released at the capture site. Capture and handling of live animals for research was approved by the Texas Tech University Institutional Animal Care and Use Committee (Animal Care and Use Protocol 07050-08).

Birds were monitored ≥ 5 times per week using radio-telemetry with handheld antennae. I used radiotelemetry data to estimate survival of marked birds (see Chapter 2). Survival was estimated using the Kaplan-Meier approach modified for staggered entry (Pollock et al. 1989). I divided the annual cycle into 2 seasons. I defined the breeding season as 1 March-31 August and the over-winter season as 1 September-the last day of February. I estimated survival rates for adult and juvenile birds separately for the breeding season. Estimates of over-winter survival of radiomarked female lesser prairie-chickens were from a concurrent study (Kukal 2010).

During the peak nesting season, birds were located daily. When the location of the bird was the same for 3 consecutive days, I homed to the signal and flushed the bird to check for signs of nesting. If a nest was detected, clutch size and geographic location were recorded. Radiotelemetry was used to check the status of nests daily during the incubation period. Nests of radiomarked birds were not re-visited unless radio-telemetry indicated the bird was away from the nest. When I determined a bird was away from the nest, I used a handheld Global Positioning System to navigate to the location to verify nest status or identify nest fate. Additional nests were located using rope-dragging (Earl 1950) and incidentally during other field activities. When a nest of an unmarked bird was located (see Chapter 3), nest age was identified by floating eggs (Westerskov 1950, Alberico 1995). Unmarked nests were visited every 7 days following location to identify fate. Nest survival was estimated using the nest survival model in Program MARK (Dinsmore et al. 2002).

I estimated individual chick survival using the young survival from marked adults model (Lukacs 2004) in Program MARK (White and Burnham 1999). I divided the brood-rearing period into two discrete periods. The early brood period was considered to be hatch to 14 days post-hatch. The late brood-rearing period was considered to be 15-63 days post-hatch.

Vital rates calculated from field data were used to develop a stochastic, matrix-based PVA model (Wisdom and Mills 1997, Wisdom et al. 2000, Hagen et al. 2009; Figure 4.1). The PVA model was female only and based on a pre-breeding census. Vital rates were recruitment, juvenile survival, and adult survival. Recruitment was the product of ½ mean clutch size (assuming a female to male ratio of 1:1; K. Corman, unpublished data), nest survival, early brood survival, late brood survival, and over-winter survival. Vital rates contributing to recruitment (nest survival, early and late brood survival, and yearling over-winter survival) were assumed to be equal for all age classes. Juvenile (1st breeding season) survival was the product of juvenile breeding season survival and over-winter. Adult (2nd, 3rd, and 4th breeding seasons) survival was the product of adult breeding season survival and over-winter survival. Survival between 1st and 2nd-year adult and 2nd and 3rd-year adult was equal. Over-winter survival for all age classes were equal. I used 4 stages in the model (Figure 4.2); juvenile, 1st-year adult, 2nd-year adult and 3rd-year adult. Survival rates were drawn from β-distributions and clutch size was drawn from a normal distribution and multiplied by 0.5 to represent number of females in a clutch under a 1:1 gender ratio assumption. I used β-distributions for survival data because the data collected and the associated standard errors were used to determine the shape of the curve from which random values for vital rates were drawn. In this manner, the simulations were more appropriately based on the real data collected I the field. All age classes were able to reproduce.

The base model was developed using vital rates and associated variance estimates from field data described above. Elasticity analysis was performed on the base model to identify the life stage that had the greatest influence on population growth. I increased vital rates by 5, 10, and 15 percentage points above the initial estimates based on field data values and estimated the change in population growth rates (λ) for each model. I assumed that management activities that would result in an increase in one vital rate would have a synergistic effect and also result in an increase in other vital rates. As such, I estimated λ for composite models that included increases in more than 1 vital rate at a time. Each model was run 10,000 times and values for each vital rate were selected from a distribution during each simulation.

I used the results of the PVA models to estimate the probability of quasi-extinction (hereafter, extinction) using a simulation approach in which populations were followed through time. For the probability of extinction models, I used the $\lambda$'s estimated in PVA models and assumed a starting population of 100 females (40 juvenile, 30 1st-year adult, 20 2nd-year adult, and 10 3rd-year adult). I estimated risk of extinction over 50 years for each of the 10,000 iterations. The probability of extinction was the proportion of 10,000 iterations that reached $\leq$ 10 birds within 50 years.

## RESULTS

Every radiomarked female lesser prairie-chicken that I observed during the nesting season made $\geq$1 nest attempt. Therefore, no adjustment for individuals not attempting to nest was needed, and nesting rates for all radiomarked individuals = 1. Estimated baseline vital rates of radiomarked female lesser prairie-chickens during 2008-2010 are presented in Table 4.1.

The PVA component with the greatest elasticity was yearling survival from the beginning of the 1st breeding season to the beginning of the 2nd breeding season (Table 4.2, Figure 4.3). However, because the parameters contributing to recruitment were equal with respect to age class, the elasticity values for all recruitment parameters were added (Table 4.2, Figure 4.4). Similarly, survival estimates were the same for 1st, 2nd, and 3rd-year adults, so survival between these age classes were added (Table 4.2, Figure 4.4). When elasticity values for the parameters with the same value were added, the parameter with the highest elasticity was recruitment (Table 4.2, Figure 4.4).

All models that increased vital rates resulted in higher mean λ estimates (Table 4.3) for 10,000 simulations. Models assuming a synergistic effect resulted in the greatest mean λ values for 10,000 simulations. The model that resulted in the greatest mean λ for 10,000 simulations included a combined 15% point increase in nest and overall brood survival, a 10% point increase in breeding season survival, and a 5% point increase in over-winter survival.

None of the models I examined predicted population persistence on my study sites for 50 years (Table 4.3). The longest time to extinction was 32.2 years when the baseline data were changed with a combined 15% point increase in nest and overall brood survival, a 10% point increase in breeding season survival, and a 5% point increase in over-winter survival. Extinction within a decade was predicted by 19 of the 22 models I examined.

## DISCUSSION

Poor recruitment, as a result of low nest and chick survival, has been identified as a limiting factor in prairie grouse populations, including Attwater's prairie-chickens (*T. cupido attwaterii*; Peterson and Silvy 1996), greater prairie-chickens (Wisdom and Mills 1997), and lesser prairie-chickens (Hagen et al. 2009). Populations of lesser prairie-chickens continue to decline across most portions of their range, including in the northeastern Texas panhandle. Previous lesser prairie-chicken population viability analyses have been reported for a 2 sites in Kansas (Hagen et al. 2009). To my knowledge, this is the first lesser prairie-chicken PVA conducted for the population found in the northeastern Texas panhandle.

The results from these simulations indicate that vital rates associated with recruitment play an important role in lesser prairie-chicken population persistence and growth in the northeastern Texas panhandle. These simulations also indicate that synergistic effects of management that result in increases for more than one vital rate have the best potential for the greatest positive impact. Fortunately, it is likely that factors (i.e., predators) that negatively affect any vital rate operate negatively on other vital rates in a similar manner. Therefore, management with the goal to improve any of the vital rates examined in this study will likely have a positive, synergistic effect on multiple components making the proposed models feasible.

Hagen et al. (2009) conducted similar analyses based on 6 years of field data from 2 populations of lesser prairie-chickens in Kansas. Baseline λ estimates for these 2 populations were greater than my estimate of 0.439 (0.535 for site 1 and 0.739 for site 2; Hagen et al. 2009). However the 95% confidence interval reported by Hagen et al. (2009) for site 1 (0.286-0.845) overlapped my estimate. The results of elasticity analysis reported by Hagen et al. (2009) also indicated that survival from hatch to 1st breeding season likely had the largest impact on λ.

The results of these simulations suggest that the lesser prairie-chicken population in Gray and Hemphill counties is unsustainable under current conditions. Furthermore, the time of extirpation in these counties under current situations may be near. My simulations indicate conservation would be most appropriate with the goal of increasing survival from hatch to the 1st breeding season. However, my findings should be used in conjunction with the results of other research (i.e. habitat related fitness models) to facilitate development of meaningful management decisions.

Without intervention through directed management, the probability of extinction of lesser prairie-chickens in my study area in less than 10 years is predicted by the majority of models. However, my results are based on a relatively short-term study (3 years) and extinction models assume a starting population of 100 females. If there are more than 100 females in the population, the time to extinction that I presented will be longer than predicted. Also, if there were temporal environmental factors that were responsible for suppressing fitness over the length of my study, natural changes resulting in greater fitness would not have been noticed. Additionally, I had no mechanism to account for immigration into the population I studied. However, it is thought that one of the main factors contributing to the decline in lesser prairie-chickens across their range is landscape fragmentation (Crawford 1980, Samson 1980, Braun et al. 1994) as the result of changes in land use (Aldrich 1963, Jackson and DeArment 1963, Sullivan et al. 2000). As fragmentation leads to isolation, immigration could be significantly limited. Alternatively, immigration could be enhanced through improved habitat management and increased connectivity.

## MANAGEMENT IMPLICATIONS

The results of this study are hypothetical models based on field data that show the potential influence of management activities, though no specific management activities were assessed. It is possible to use the results of this study to determine areas where future management should be directed in order to stop or reverse the severe decline of lesser prairie-chickens observed in the northeastern Texas panhandle. Implementation of management practices designed to improve chances for lesser prairie-chicken population growth will require knowledge of the suite of factors influencing components of the PVA that I developed. Extension of studies such as the one presented here and by Hagen et al. (2009) will help determine if regional-specific management is warranted to insure lesser prairie-chicken population persistence across their range.

## LITERATURE CITED

Alberico, J. A. R. 1995. Floating eggs to estimate incubation stage does not affect hatchability. Wildlife Society Bulletin. 23:212-216.

Aldrich, J. W. 1963. Geographic orientation of American Tetraonidae. Journal of Wildlife Management. 27:528-545.

Ammann, G. A. 1944. Determining the age of pinnated and sharp-tailed grouses. Journal of Wildlife Management. 8:170-171.

Bender, S., S. Shelton, K. C. Bender, and A. Kalmbach, editors. 2005. Texas comprehensive wildlife conservation strategy: 2005-2010. Texas Parks and Wildlife Department. Austin, USA.

Braun, C. E., K. Martin, T. E. Remington, and J. R. Young. 1994. North American grouse: issues and strategies for the 21st century. Transactions of the North American Wildlife and Natural Resource Conference 59:428-437.

Clark, W. R., T. R. Bogenschutz, and D. H. Tessin. 2008. Sensitivity analysis of a population projection model of ring-necked pheasants. Journal of Wildlife Management. 72:1605-1613.

Copelin, F. F. 1963. The lesser prairie chicken in Oklahoma. Technical Bulletin 6. Oklahoma Department of Wildlife, Oklahoma City, USA.

Corman, K. S. 2011. Conservation and landscape genetics of Texas lesser pairie-chicken: population structure and differentiation, genetic variability, and effective size. M.S. Thesis. Texas A&M University-Kingsville, Kingsville, USA.

Crawford, J. A. 1980. Status, problems, and research needs of the lesser prairie chicken. Pages 1-7 *in* Proceedings of the Prairie Grouse Symposium. 17-18 September 1980. Stillwater, Oklahoma, USA.

Crawford, J. A., and E. G. Bolen. 1976. Effects of land use on lesser prairie-chickens in Texas. Journal of Wildlife Management 40:96-104.

Dinsmore, S. J., and D. H. Johnson. 2005. Population analysis in wildlife biology. Pages 154-184 *in* C. E. Braun, editor. Techniques for wildlife investigations and management. Sixth edition. The Wildlife Society, Bethesda, Maryland, USA.

Dinsmore, S. J., G. C. White, and F. L. Knopf. 2002. Advanced techniques for modeling avain nest survival. Ecology. 83:3476-3488.

Doak, D. F., K. Gross, and W. F. Morris. 2005. Understanding and predicting the effects of sparse data on demographic analysis. Ecology 86:1154-1163.

Earl, J. P. 1950. Production of Mallards on irrigated land in the Sacramento Valley, California. Journal of Wildlife Management. 14:332-342.

Giesen, K. M. 1998. Lesser prairie-chicken (*Tympanuchus pallidicinctus*), No. 364. *in* A. Poole and F. Gill, editors. The Birds of North America. The Birds of North America, Inc. Philadelphia, Pennsylvania, USA.

Hagen, C. A., B. E. Jamison, K. M. Griesen, and T. Z. Riley. 2004. Guidelines for managing lesser prairie-chicken populations and their habitats. Wildlife Society Bulletin. 32:69-82.

Hagen, C. A., B. K. Sandercock, J. C. Pitman, R. J. Robel, and R. D. Applegate. 2009. Spatial variation in lesser prairie-chicken demography: a sensitivity analysis of population dynamics and management alternatives. Journal of Wildlife Management 73:1325-1332.

Haukos, D. A., L. M. Smith, and G. S. Broda. 1990. Spring trapping of lesser prairie-chickens. Journal of Field Ornithology. 61:20-25.

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

Kukal, C. A. 2010. The over-winter ecology of lesser prairie-chickens (*Tympanuchus pallidicinctus*) in the northeast Texas panhandle. M. S. Thesis, Texas Tech University, Lubbock, USA.

Litton, G., R. L. West, D. F. Dvorak, and G. T. Miller. 1978 The lesser prairie chicken and its management in Texas. Texas Parks and Wildlife Department Booklet N7000-25. Austin, USA.

Lukacs, P. M., V. J. Drietz, F. L. Knopf, and K. P. Burnham. 2004. Estimating survival probabilities of unmarked dependent young when detection is imperfect. The Condor 106:926-931.

McRoberts, J. T. 2009. Aerial surveys for lesser prairie-chicken leks: detectability and disturbance response. M. S. Thesis, Texas Tech University, Lubbock, USA.

Morris, W., D. Doak, M. Groom, P. Kareiva, J. Fieberg, L. Gerber, P. Murphy, and D. Thompson. 1999. A practical handbook for population viability analysis. The Nature Conservancy. Arlington, Virginia, USA.

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

Peterson, M. J., and N. J. Silvy. 1996. Reproductive strategies limiting productivity of the endangered Attwater's prairie-chicken. Conservation Biology 10:1264-1276.

Peterson, R. S., and C. S. Boyd. 1998. Ecology and management of sand shinnery communities: a literature review. U. S. Department of Agriculture Forest Service General Technical Report RMRS-GTR-16. Rock Mountain Research Station, Fort Collins, Colorado, USA.

Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2005. Location and success of lesser prairie-chicken nests in relation to vegetation and human disturbance. Journal of Wildlife Management 69:1259-1269.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry approach. Journal of Wildlife Management. 53:7-14.

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.

Samson, F. B. 1980. Island biogeography and the conservation of prairie birds. Proceedings of the North American Prairie Conference 7:293-305.

Schroeder, M. A., and C. E. Braun. 1991. Walk-in traps for capturing greater prairie-chickens on leks. Journal of Field Ornithology. 62:378-385.

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

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. The Prairie Naturalist. 32:177-188.

Taylor, M. A., and F. S. Guthery. 1980. Status, ecology, and management of the lesser prairie-chicken. U.S. Department of Agriculture Forest Service Technical Report RM-77. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado, USA.

U. S. Fish and Wildlife Service. 1983. Endangered and threatened species listing and recovery guidelines. Federal Register. 48:43098-43105.

U. S. Fish and Wildlife Service. 1998. Endangered 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.

U. S. Fish and Wildlife Service. 2008. Endangered and threatened wildlife and plants; review of native species that are candidates for listing as endangered or threatened; annual notice of findings on resubmitted petitions; annual description of progress on listing actions. Federal Register. 73:75176-75244.

U. S. Fish and Wildlife Service. 2010. U. S. Fish and Wildlife Service species assessment and listing priority assignment form. <http://ecos.fws.gov/docs/candidate/assessments/2010/r2/B0AZ_V01.pdf>. Accessed 11 May 2011.

Westerskov, K. 1950. Methods for determining the age of game bird eggs. Journal of Wildlife Management. 14:56-67.

White, G. C. 2000. Population viability analysis: data requirements and essential analyses. Pages 288-331 *in* L. Boitani, and T. K. Fulled, editors. Research techniques in animal ecology: controversies and consequences. Columbia University Press, New York, USA.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46:S120-S139.

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.

Wisdom, M. L., L. S. Mills, and D. F. Doak. 2000. Life stage simulation analysis: estimating vital-rate effects on population growth for conservation. Ecology 81:628-641.

Table 4.1. Estimates of vital-rates of radiomarked female lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA, 2008-2010.

| PVA Model Component | Vital-rate | Estimate | SE |
|---|---|---|---|
| Recruitment | Clutch Size (C) | 10 | 2.72 |
| | Nest Survival ($S_n$) | 0.36 | 0.05 |
| | Early Brood Survival ($S_e$) | 0.18 | 0.01 |
| | Late Brood Survival ($S_l$) | 0.55 | 0.16 |
| | Over-winter Survival ($S_w$) | 0.75 | 0.15 |
| Juvenile Survival | Over-winter Survival ($S_w$) | 0.75 | 0.15 |
| | Juvenile Breeding Season Survival ($S_j$) | 0.73 | 0.16 |
| Adult Survival | Over-winter Survival ($S_w$) | 0.75 | 0.15 |
| | Adult Breeding Season Survival ($S_a$) | 0.39 | 0.16 |

Table 4.2. Elasticity values of individual and pooled values of vital rates based on baseline data collected from radiomarked female lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA, 2008-2010.

| Parameter | Elasticity | SE |
|---|---|---|
| $r_1$ | 0.13 | < 0.01 |
| $r_2$ | 0.16 | < 0.01 |
| $r_3$ | 0.09 | < 0.01 |
| $r_4$ | 0.07 | < 0.01 |
| $S_{12}$ | 0.32 | < 0.01 |
| $S_{23}$ | 0.16 | < 0.01 |
| $S_{34}$ | 0.07 | < 0.01 |
| r | 0.45 | < 0.01 |
| $S_{juvenile}$ | 0.32 | < 0.01 |
| $S_{adult}$ | 0.23 | < 0.01 |

$r_1$ = recruitment from 1st breeding year birds
$r_2$ = recruitment from 2nd breeding year birds
$r_3$ = recruitment from 3rd breeding year birds
$r_4$ = recruitment from 4th breeding year birds
$S_{12}$ = survival of birds from the beginning of the 1st breeding year to the beginning of the 2nd breeding year
$S_{23}$ = survival of birds from the beginning of the 2nd breeding year to the beginning of the 3rd breeding year
$S_{34}$ = survival of birds from the beginning of the 3rd breeding year to the beginning of the 4th breeding year
r = recruitment from all breeding females
$S_{juvenile}$ = survival of birds from the beginning of the 1st breeding year to the beginning of the 2nd breeding year
$S_{adult}$ = survival of 1st and 2nd year adults

Table 4.3. Mean finite growth rate (λ) and time to quasi-extinction (<10 females) based on 10,000 simulations using differing vital rates for radiomarked female lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA, 2008-2010.

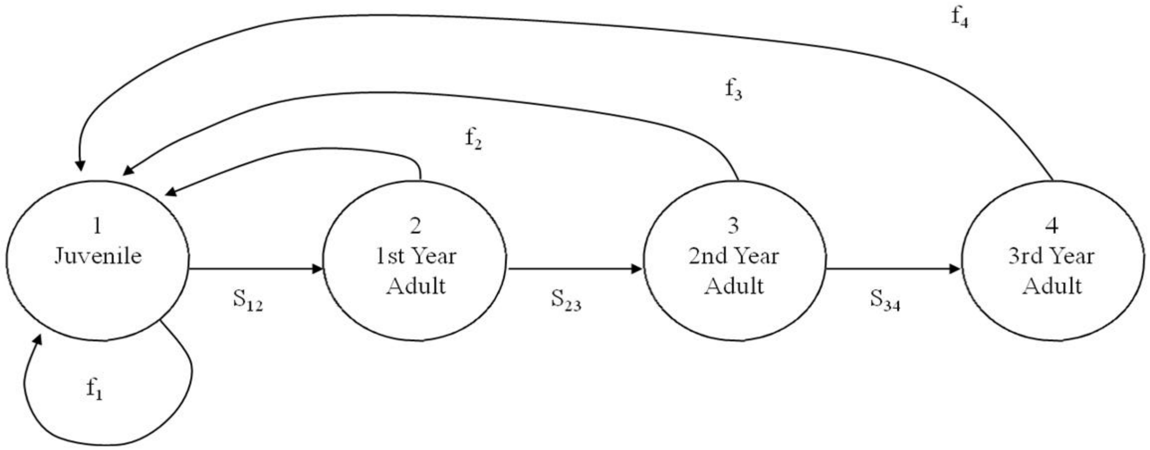
| Model | Mean λ | SE | Mean Time to Quasi-Extinction [a] | SE |
|---|---|---|---|---|
| Baseline | 0.44 | < 0.01 | 3.5 | < 0.01 |
| Late Brood Survival +5% | 0.46 | < 0.01 | 3.6 | < 0.01 |
| Nest Survival +5% | 0.47 | < 0.01 | 3.7 | < 0.01 |
| Late Brood Survival +10% | 0.48 | < 0.01 | 3.7 | < 0.01 |
| Late Brood Survival +15% | 0.49 | < 0.01 | 3.9 | 0.01 |
| Nest Survival +10% | 0.50 | < 0.01 | 3.9 | 0.01 |
| Early Brood Survival +5% | 0.50 | < 0.01 | 3.9 | 0.01 |
| Overall Brood Survival +5% | 0.51 | < 0.01 | 4.1 | 0.01 |
| Nest Survival +15% | 0.52 | < 0.01 | 4.1 | 0.01 |
| Nest and Early Brood Survival +5% | 0.53 | < 0.01 | 4.2 | 0.01 |
| Early Brood Survival +10% | 0.54 | < 0.01 | 4.4 | 0.01 |
| Nest and Overall Brood Survival +5% | 0.55 | < 0.01 | 4.4 | 0.01 |
| Early Brood Survival +15% | 0.59 | < 0.01 | 4.9 | 0.01 |
| Overall Brood Survival +10% | 0.59 | < 0.01 | 5.0 | 0.01 |
| Nest and Early Brood Survival +10% | 0.62 | < 0.01 | 5.2 | 0.02 |
| Overall Brood Survival +15% | 0.67 | < 0.01 | 6.3 | 0.03 |
| Nest and Overall Brood Survival +10% | 0.68 | < 0.01 | 6.4 | 0.03 |
| Nest and Overall Brood Survival +10%; Breeding Season Season Survival +5% | 0.71 | < 0.01 | 7.1 | 0.04 |
| Nest and Early Brood Survival +15% | 0.72 | < 0.01 | 7.3 | 0.05 |
| Nest and Overall Brood Survival +15% | 0.83 | < 0.01 | 12.1 | 0.23 |
| Nest and Overall Brood Survival +15%; Breeding Season Survival +10% | 0.89 | < 0.01 | 18.8 | 0.71 |
| Nest and Overall Brood Survival +15%; Breeding Season Survival +10%; Over-winter Survival +5% | 0.95 | < 0.01 | 32.2 | 1.77 |

[a] starting population size of 100 females (40 1st year, 30 2nd year, 20 3rd year, and 10 4th year breeding females); time in years

$$\lambda = \begin{bmatrix} r_1 & r_2 & r_3 & r_3 \\ s_{12} & 0 & 0 & 0 \\ 0 & s_{23} & 0 & 0 \\ 0 & 0 & s_{34} & 0 \end{bmatrix}$$

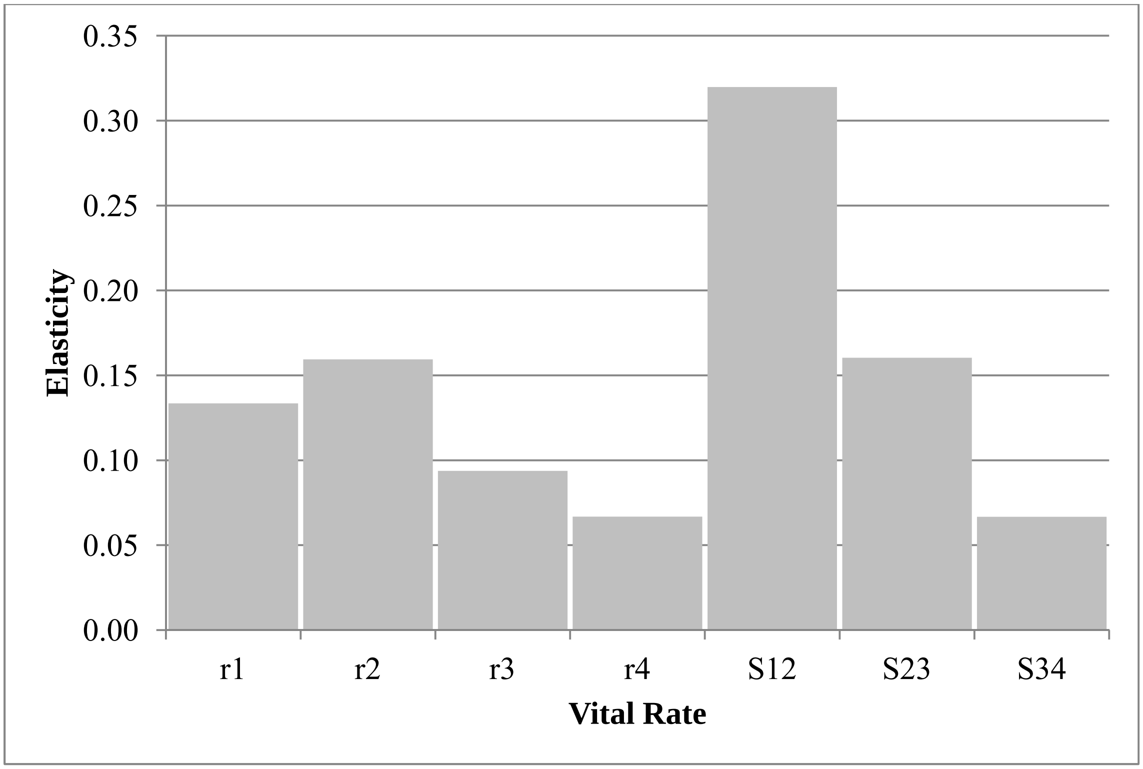
$r_1$ = recruitment from 1st breeding year birds
$r_2$ = recruitment from 2nd breeding year birds
$r_3$ = recruitment from 3rd breeding year birds
$r_4$ = recruitment from 4th breeding year birds
$s_{12}$ = survival of birds from the beginning of the 1st breeding year to the beginning of the 2nd breeding year
$s_{23}$ = survival of birds from the beginning of the 2nd breeding year to the beginning of the 3rd breeding year
$s_{34}$ = survival of birds from the beginning of the 3rd breeding year to the beginning of the 4th breeding year

Figure 4.1. Population viability analysis model matrix for radiomarked female lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA.



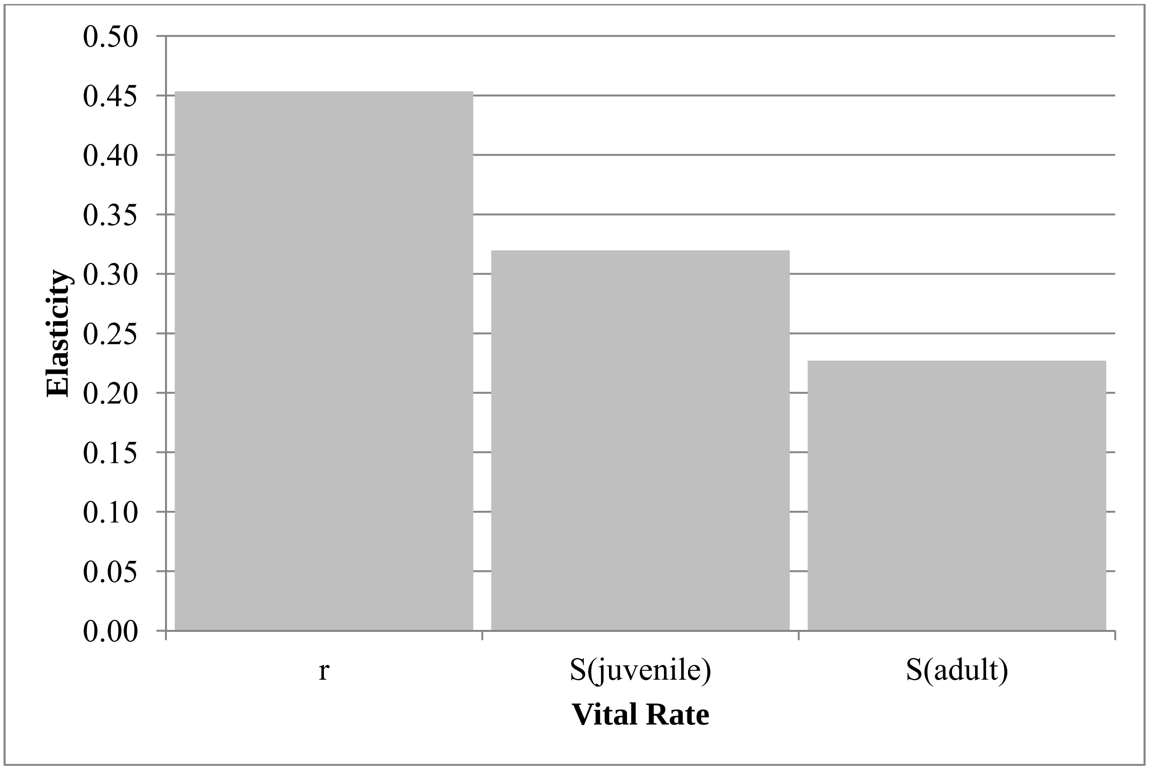
$r_1$ = recruitment from 1st breeding year birds, $r_2$ = recruitment from 2nd breeding year birds, $r_3$ = recruitment from 3rd breeding year birds, $r_4$ = recruitment from 4th breeding year birds, $s_{12}$ = survival of birds from the beginning of the 1st breeding year to the beginning of the 2nd breeding year, $s_{23}$ = survival of birds from the beginning of the 2nd breeding year to the beginning of the 3rd breeding year, $s_{34}$ = survival of birds from the beginning of the 3rd breeding year to the beginning of the 4th breeding year

Figure 4.2. 4-stage model used to develop population viability analysis for radiomarked female lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA.



$r_1$ = recruitment from 1st breeding year birds, $r_2$ = recruitment from 2nd breeding year birds, $r_3$ = recruitment from 3rd breeding year birds, $r_4$ = recruitment from 4th breeding year birds, $s_{12}$ = survival of birds from the beginning of the 1st breeding year to the beginning of the 2nd breeding year, $s_{23}$ = survival of birds from the beginning of the 2nd breeding year to the beginning of the 3rd breeding year, $s_{34}$ = survival of birds from the beginning of the 3rd breeding year to the beginning of the 4th breeding year

Figure 4.3. Elasticity of vital rates based on baseline data collected from radiomarked female lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA 2008-2010.



r = recruitment from all breeding females, S(juvenile) = survival of birds from the beginning of the 1st breeding year to the beginning of the 2nd breeding year, S(adult) = survival of 1st and 2nd year adults

Figure 4.4. Elasticity of pooled vital rates based on baseline data collected from radiomarked female lesser prairie-chickens on private lands in Gray and Hemphill counties, Texas, USA, 2008-2010.

# CHAPTER 5

# FACTORS INFLUENCING THE EFFICACY OF ROAD-BASED LEK SURVEYS TO DETECT LESSER PRAIRIE-CHICKENS (*TYMPANUCHUS PALLIDICINCTUS*)

Lesser prairie-chickens (*Tympanuchus pallidicinctus*) are endemic to mixed-grass and short-grass prairies of North America (Patten et al. 2005) which are dominated by shinnery oak (*Quercus havardii*) and sand sagebrush (*Artemisia filifolia*; Giesen 1998). The historic lesser prairie-chicken range included portions of southwestern Kansas, southeastern Colorado, western Oklahoma, eastern New Mexico, and the Texas Panhandle (Sullivan et al. 2000).

Lesser prairie-chicken populations have declined across the historic range (Hagen and Giesen 2005), with declines as great at 92% in range and 97% in population having been estimated (Taylor and Guthery 1980). The cause of the decline in lesser prairie-chicken populations is thought to be due to changes in land-use practices (Aldrich 1963, Jackson and DeArment 1963, Sullivan et al. 2000, Woodward et al. 2001) and exacerbated by droughts (Jackson and DeArment 1963, Hagen et al. 2004).

The U. S. Fish and Wildlife Service was petitioned to list lesser prairie-chicken as threatened under the ESA in 1995 (U. S. Fish and Wildlife Service 1998). The U. S. Fish and Wildlife Service determined that listing was warranted, but precluded due to higher priority species (U. S. Fish and Wildlife Service 1998). The U. S. Fish and Wildlife Service uses a listing priority matrix to assign listing priorities to species to be considered for protection under the ESA (U. S. Fish and Wildlife Service 1983). After reviewing the petition, lesser prairie-chickens were assigned a listing priority of 8 (U. S. Fish and Wildlife Service 1998). Recently, the listing priority for lesser prairie-chickens was increased to 2 (U. S. Fish and Wildlife Service 2008), which indicates that listing for this species is likely imminent. As such, standardized and reliable monitoring protocols are needed to assess population trends.

Lesser prairie-chickens exhibit a clumped polygynous mating system (Bergerud 1988), where males gather at communal display grounds termed leks. Leks are arenas where males congregate for the purpose of breeding (Hoglund and Alatalo 1995). Females visit leks only to breed and have the opportunity to select from the males present for the purposes of breeding. Males offer no parental care (Hoglund and Alatalo 1995). In lesser prairie-chickens, leks are typically found at the same location annually and males exhibit a high degree of lek-site fidelity (Fuhlendorf et al. 2002, Hagen et al. 2005).

Assessment of lesser prairie-chicken population trends have primarily been derived from road-based lek surveys (Applegate 2000, Best et al. 2003, Wildlife Management Institute 2005, Ripper et al. 2008). A main assumption of road-based lek surveys is that displaying male lesser prairie-chickens within 1.6 km of the survey point are detectable by surveyors (Clifton and Krementz 2006). However, several environmental factors (e.g., topography, wind speed, wind direction) may influence detection of active leks (McRoberts et al. 2011). State agencies have recognized this and attempt to minimize probable biases associated with sound attenuation due to increased wind speeds. For example, road-based lek surveys are suspended when wind speed is ≥

32 km/hr in Texas and ≥ 19.2 km/hr in Kansas (Wildlife Management Institute 2005, Davis et al. 2008). However, factors influencing the detectability of active leks during road-based surveys, and the magnitude of those influences, have not been quantitatively assessed.

In light of the increased listing priority of lesser prairie-chickens, accurate estimates of population trends are needed to assess population status and efficacy of future management activities. Hagen et al. (2004) indicated there is a need for standardization of survey methodologies. The objective of this study was to assess environmental factors that might influence detectability of active lesser prairie-chicken leks during road-based surveys. I present probabilities of detection of active leks in 2 ecoregions in Texas.

## STUDY AREA

This study was conducted on private lands in Cochran, Gray, and Yoakum counties and private and public lands in Hemphill County. All study sites were located within the current lesser prairie-chicken range and currently have known lesser prairie-chicken leks in the vicinity or historically supported leks.

Sites in Cochran, Gray and Yoakum counties were in the High Plains Ecoregion (Gould 1962, Bender et al. 2005). Sites in Hemphill County were in the Rolling Plains Ecoregion (Bender et al. 2005). The Gray County site was at the eastern edge of the Caprock Escarpment. Mean annual precipitation and temperatures were similar between the Gray County and Hemphill County sites with mean annual precipitation of 52 cm; mean low temperature was -5° C occurring in January, and mean high temperature was

35° C occurring in July. Sites in Cochran and Yoakum counties were similar with mean annual precipitation of 46 cm; mean low temperature was 2° C occurring in January, and mean high temperature was 25° C occurring in July (Grisham 2012).

Land cover and land uses were similar for all study sites. Land cover in the study areas was a mixed-grass prairie ecosystem dominated by little bluestem (*Schizachyrium scoparium*), sand sagebrush (*Artemisia filifolia*), and shinnery oak (*Quercus havardii*; Gould 1962, Haukos and Smith 1999). Primary land uses were cattle ranching interspersed with oil and gas development and some Conservation Reserve Program lands, center-pivot agriculture, and dry-land agriculture (McRoberts et al. 2011).

## METHODS

I made digital recordings of male vocalizations, termed booming, on active leks and transferred the recordings to digital playback units. I calibrated each digital playback unit to equal the sound intensity of an active live male displaying on a lek (Butler et al. 2010).

I established 61 trial leks (14 in Cochran and Yoakum counties combined, 12 in Gray County, and 25 in Hemphill County). A trial lek consisted of 2 calibrated digital playback units positioned 10 m part with one call oriented north-south and the other oriented east-west at a height of 15 cm (Figure 5.1). Each digital playback unit had a speaker on either end of the unit and both speakers were used. Transects ≤ 3,200 m in each cardinal direction intersected at each trial lek (Figure 5.1). Transect length varied for trial leks based on location of the trial lek in relation to permission to access surrounding properties (Table 5.1). Observations were made during the spring lekking period during the same time that state agencies make road-based lek surveys.

Two observers walked along transects starting at the farthest point from the trial lek and stopped every 100 m and listened for booming for 3 min at each listening post and recorded if booming was heard during that 3 min period and the direction of booming if heard. After the 3 min listening period, observers used handheld weather meters to record wind speed (mean km/hr for 1 min) and a compass to record wind direction (azimuth from which the wind was coming at the observer). Observers staggered their start time along transects to insure independence of observations (i.e., only 1 observer was at a listening post during an observation period). Surveys began 30 min before sunrise and were discontinued at noon. Observers were trained to recognize booming lesser prairie-chickens by observing live leks (active leks with male lesser prairie-chickens in attendance) for at least 10 days prior to conducting any trial lek surveys.

Surveys of trial leks were suspended if wind speeds were ≥ 32 km/hr for 20 minutes prior to the scheduled start of the survey or during 3 consecutive measurements during the survey. If surveys were suspended after the start, they were resumed on the next day that weather permitted at the first listening post where wind speed was measured ≥ 32 km/hr.

I standardized wind direction relative to each transect and categorically classified wind direction as head wind, cross wind, or tail wind. Head winds were blowing towards the observer in an arc between 316° and 44°; cross winds were blowing across transect in arcs between 45° and 135° or 225° and 315°; tail winds were blowing from behind the observer in an arc between 136° and 224°.

I developed logistic regression equations (Zar 2010) to describe detectability of trial leks. Regression models included every possible combination of additive and interactive effect of ecoregion (High Plains and Rolling Plains), wind speed, wind direction, and distance from trial lek. I used multimodel inference (Anderson 2008) to select the best model based on Akaike's Information Criterion (AIC; Akaike 1973, Burnham and Anderson 1998). I predicted detection probability under varying environmental conditions based on the regression equation that best described detection probability (Zar 2010).

## RESULTS

I conducted observations at 5,732 listening posts (Table 5.1). Each observation was an independent trial and no observer surveyed the same point more than once. Observations ranged from 80 at 100 m to 48 at 3,200 m from trial leks in the High Plains ecoregion and 114 at 100 m to 86 at 3,200 m from trial leks in the Rolling Plains (Table 5.1).

I developed 23 models to describe probability of detection of a trial lek (Table 5.2). The top model was the fully interactive model. However, the β-parameter estimates for the interactive term in the top model was < 0.0001. As such, the interactive term provided no information with respect to predicting the probability of detecting a trial lek. The second best model was the fully additive model (Table 5.1). When I removed the fully interactive model from the model set, the fully additive model received > 99%

of the Akaike weight. Therefore, I used the fully additive model. The resulting predictive β-parameter estimate was:

> *Logit probability of detecting trial lek* = 2.49 - ($0.03^{-1}$) (*distance from trial lek*) - (0.12) (*wind speed*) + (1.29) (*head wind*) - (1.04) (*tail wind*) + (0.25) (*Rolling Plains ecoregion*)

I used the predictive β-parameter estimate to predict the probability of detecting a trial lek at distances from the trial lek between 100 and 3,200 m for each ecoregion for each wind direction (Figures 5.2 through 5.7). Distance from the trial lek had a major influence on the probability of detection regardless of ecoregion. Additionally, the probability of detecting a trial lek was greater with a head wind than a cross wind and greater in a cross wind than a tail wind, independent of ecoregion. However, location did have an influence on detectability; the probability of detecting a trial lek was greater in the Rolling Plains than the High Plains of Texas.

In a head wind in the High Plains of Texas, the probability of detecting a trial lek was < 0.5 between 800 and 900 m when wind speed was 10 km/hr, between 400 and 500 m when wind speed was 20 km/hr, and at any distance measured when wind speed was > 30 km/hr (Figure 5.2). In a cross wind in the High Plains of Texas the probability of detecting a trial lek was < 0.5 between 400 and 500 m when wind speed was 10 km/hr and at any distance measured when wind speed was > 20 km/hr (Figure 5.3). In a tail wind in the High Plains of Texas the probability of detecting a trial lek was < 0.5 at any distance measured when wind speed was > 10 km/hr (Figure 5.4).

In a head wind in the Rolling Plains of Texas the probability of detecting a trial lek was < 0.5 between 900 and 1,000 m when wind speed was 10 km/hr, between 500 and 600 m when wind speed was 20 km/hr, between 100 and 200 m when wind speed was 30 km/hr, and at any distance measured when wind speed was 40 km/hr (Figure 5.5). In a cross wind in the Rolling Plains of Texas the probability of detecting a trial lek was < 0.5 between 400 and 500 m when wind speed was 10 km/hr and at any distance measured when wind speed was > 20 km/hr (Figure 5.6). In a tail wind in the Rolling Plains of Texas the probability of detecting a trial lek was < 0.5 between 100 and 200 m when wind speed was 10 km/hr and at any distance measured when wind speed was > 20 km/hr (Figure 5.7).

## DISCUSSION

Road-based lek survey protocols typically assume that all leks within 1,600 m of the survey point are detected (Clifton and Krementz 2006). Possible attenuation of sound from a lek due to wind speed is taken into account, albeit at different magnitudes for different state agencies (Wildlife Management Institute 2005, Davis et al. 2008). I have shown that other factors (e.g., wind direction and ecoregion) also need to be taken into account. The influence of ecoregion on detectability of an active lek is probably due to sound propagation as a function of topography.

I have also demonstrated that a major assumption of road-based lek surveys, that being detectability of lesser prairie-chickens to 1,600 m, is probably never met. As such, it is possible that the predictions of lesser prairie-chicken populations derived from surveys are underestimated because all active leks within the designated survey area are not detected due to distance from the survey point. Additionally, because wind direction has a major influence on detectability, leks located downwind from an observer have less chance to be detected. Based on my results, as few as 25% or less of the active leks in areas thought to be surveyed during road-based lek surveys may actually be detected.

Lesser prairie-chickens have become a species of substantive conservation concern and are currently undergoing review for federal protection. Given the possibility of protective listing under the Endangered Species Act, it is crucial do have accurate population assessment and monitoring protocols in place. This study reinforces the need for standardized survey protocols for lesser prairie-chickens (Hagen et al. 2004). Furthermore, this study identifies factors, and the magnitude of influence by those factors, that can lead to the violation of assumptions in existing road-based lek survey protocols. Knowing the factors that influence active lek detectability will allow managers to develop protocols that will result in more accurate population assessments.

## MANAGEMENT IMPLICATIONS

Alternate survey methodologies such as aerial surveys (McRoberts et al. 2011) and mark-resight surveys (Clifton and Krementz 2006) have been suggested to improve assessments of lesser prairie-chicken occurrence and population trends. However, these survey methods may be labor- or cost-prohibitive. In contrast, state agencies commonly use road-based lek surveys due to logistical and financial feasibility. One or a few biologists or managers can cover a large area during the lekking season. Although road-based lek surveys do have utility, the assumptions associated with such surveys as currently conducted may be too broad, and the violation of these assumptions can have a significant impact on the results. This study provides tools for improving road-based lek surveys in the future by illustrating the area surrounding a survey point that should be considered actually surveyed under given environmental conditions.

## LITERATURE CITED

Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Page 267-281 *in* B. N. Petran and F. Csaki, editors. International Symposium on Information Theory. Second Edition. Akademiai Kiado, Budapest, Hungary.

Aldrich, J.W. 1963. Geographic orientation of American Tetraonidae. Journal of Wildlife Management. 27:528-545.

Anderson, D. R. 2008. Model based inference in the life sciences: a primer on evidence. Springer. New York, USA.

Applegate, R. D. 2000. Use and misuse of prairie chicken lek surveys. Wildlife Society Bulletin 28:457-463.

Bender, S., S. Shelton, K. C. Bender, and A. Kalmbach, editors. 2005. Texas comprehensive wildlife conservation strategy 2005-2010. Texas Parks and Wildlife Department, Austin, TX, USA.

Bergerud, A. T. 1988. Mating systems in grouse. Pages 439-472 *in* A. T. Bergerud and M. W. Gratson, editors. Adaptive Strategies and Population Ecology of Northern Grouse, Volume II: Theory and Synthesis. University of Minnesota Press, Minneapolis, USA.

Best, T. L., K. Geluso, J. L. Hunt, and L. A. McWilliams. 2003. The lesser prairie-chicken (*Tympanuchus pallidicinctus*) in southeastern New Mexico: a population survey. Texas Journal of Science 55:225-234.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach.

Butler, M. J., W. B. Ballard, R. D. Holt, and H. A. Whitlaw. 2010. Sound intensity of booming in lesser prairie-chickens. Journal of Wildlife Management 74:1160-1162.

Clifton, A. M., and D. G. Krementz. 2006. Estimating numbers of greater prairie-chickens using mark-resight techniques. Journal of Wildlife Management 70:479-484.

Davis, D. M., R. E. Horton, E. A. Odell, R. D. Rogers, and H. A. Whitlaw. 2008. Lesser prairie-chicken conservation initiative. Lesser Prairie-chicken Interstate Working Group, Colorado Division of Wildlife, Fort Collins, USA.

Fuhlendorf, S. D., A. J. W. Woodward, D. M. Leslie, Jr., and J. S. Shackford. 2002. Multi-scale effects of habitat loss and fragmentation on lesser prairie-chicken populations of the US Southern Great Plains. Landscape Ecology 17:617-628.

Giesen, K. M. 1998. Lesser prairie-chicken (*Tympanuchus pallidicinctus*), No. 364. *in* A. Poole and F. Gill, editors. The Birds of North America. The Birds of North America, Inc. Philadelphia, Pennsylvania, USA.

Gould, F. W. 1962. Texas plants - a checklist and ecological summary. The Agricultural and Mechanical College of Texas, Texas Agricultural Experiment Station, College Station, USA.

Grisham, B. A. 2012. The ecology of lesser prairie-chickens in shinnery oak-grassland communities in New Mexico and Texas with implications toward habitat management and future climate change. Ph.D. Dissertation, Texas Tech University, Lubbock, USA.

Hagen, C. A., and K. M. Giesen. 2005. Lesser prairie-chicken (*Tympanuchus pallidicinctus*). The Birds of North America Online. A. Poole, editor. Ithaca: Cornell Lab of Ornithology. Retrieved from the Birds of North America Online: *http://bna.birds.cornell.edu/bna/species/364*

Hagen, C.A., B.E. Jamison, K.M. Griesen, and T.Z. Riley. 2004. Guidelines for managing lesser prairie-chicken populations and their habitats. Wildlife Society Bulletin. 32:69-82.

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. The Condor 107:78-86.

Haukos, D. A., and L. M. Smith. 1999. Effects of lek age on age structure and attendance of lesser prairie-chickens (Tympanuchus pallidicinctus). American Midland Naturalist 142:415–420.

Hoglund, J, and R. V. Alatalo. 1995. Leks. Princeton University Press, New Jersey, USA.

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

McRoberts, J. T., M. J. Butler, W. B. Ballard, H. A. Whitlaw, D. A. Haukos, and M. C. Wallace. 2011. Detectability of lesser prairie-chicken leks: a comparison of surveys from aircraft. Journal of Wildlife Management 75:771-778.

Patten, M. A., D. H. Wolfe, E. Shochat, and S. K. Sherrod. 2005. Habitat fragementation, rapid eveloution and population persistence. Evolutionary Ecology Research 7:235-249.

Ripper, D., M. McLachlan, T. Toombs, and T. VerCauteren. 2008. Assessment of Conservation Reserve Program fields within the current distribution of lesser prairie-chicken. Great Plains Research 18:205-218.

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. The Prairie Naturalist 32:177-188.

Taylor, M.A., and F.S. Guthery. 1980. Status, ecology, and management of the lesser prairie-chicken. U.S. Department of Agriculture Forest Service Technical Report RM-77. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado, USA.

U. S. Fish and Wildlife Service. 1983. Endangered and threatened species listing and recovery guidelines. Federal Register. 48:43098-43105.

U. S. Fish and Wildlife Service. 1998. Endangered 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.

U. S. Fish and Wildlife Service. 2008. Endangered and threatened wildlife and plants; review of native species that are candidates for listing as endangered or threatened; annual notice of findings on resubmitted petitions; annual description of progress on listing actions. Federal Register. 73:75176-75244.

Wildlife Management Institute. 2005. A comprehensive review of science-based methods and processes of the Wildlife and Parks Division of the Texas Parks and Wildlife Department. A Report to the Executive Director of Texas Parks and Wildlife Department, Wildlife Management Institute, Washington, D. C., USA.

Woodward, A.J.W., S.D. Fuhlendorf, D.M. Leslie, Jr., and J. Shackford. 2001. Influence of landscape composition and change on lesser prairie-chicken (*Tympanicus pallidicinctus*) populations. American Midland Naturalist. 145:261-274.

Zar, J. H. 2010. Biostatistical Analysis. Fifth edition. Prentice Hall, Upper Saddle River, New Jersey, USA.

Table 5.1. Number of observations at given distance from trial leks in the High Plains and Rolling Plains ecorgeions of Texas, USA, used to collect data to examine the influence of environmental factors on probability of detection of active lesser prairie-chicken leks.

| Distance from Trial Lek | High Plains | Rolling Plains | Total |
|---|---|---|---|
| 100 | 80 | 114 | 194 |
| 200 | 80 | 114 | 194 |
| 300 | 80 | 114 | 194 |
| 400 | 80 | 114 | 194 |
| 500 | 80 | 114 | 194 |
| 600 | 80 | 114 | 194 |
| 700 | 80 | 114 | 194 |
| 800 | 80 | 114 | 194 |
| 900 | 80 | 114 | 194 |
| 1000 | 80 | 114 | 194 |
| 1100 | 80 | 114 | 194 |
| 1200 | 80 | 114 | 194 |
| 1300 | 80 | 114 | 194 |
| 1400 | 80 | 114 | 194 |
| 1500 | 78 | 114 | 192 |
| 1600 | 76 | 112 | 188 |
| 1700 | 74 | 110 | 184 |
| 1800 | 74 | 108 | 182 |
| 1900 | 72 | 104 | 176 |
| 2000 | 72 | 102 | 174 |
| 2100 | 72 | 102 | 174 |
| 2200 | 72 | 102 | 174 |
| 2300 | 72 | 102 | 174 |
| 2400 | 72 | 100 | 172 |
| 2500 | 66 | 100 | 166 |
| 2600 | 66 | 98 | 164 |
| 2700 | 64 | 96 | 160 |
| 2800 | 62 | 94 | 156 |
| 2900 | 60 | 94 | 154 |
| 3000 | 60 | 92 | 152 |
| 3100 | 50 | 90 | 140 |
| 3200 | 48 | 86 | 134 |
| Total | 2330 | 3402 | 5732 |

Table 5.2. Logistic regression models describing probability of detection of trial leks in the High Plains and Rolling Plains ecorgeions of Texas, USA.

| Model | AIC | ΔAIC | $\omega^a$ | $K^b$ | Deviance |
|---|---|---|---|---|---|
| Distance x Wind Speed x Wind Direction x Ecoregion | 2443.64 | 0.00 | 0.96 | 8 | 2427.64 |
| Distance + Wind Speed + Wind Direction + Ecoregion | 2450.00 | 6.36 | 0.04 | 6 | 2438.00 |
| Distance x Wind Speed x Wind Direction | 2461.05 | 17.41 | 0.00 | 7 | 2447.05 |
| Distance + Wind Speed + Wind Direction | 2471.42 | 27.78 | 0.00 | 5 | 2461.42 |
| Distance x Wind Direction | 2598.96 | 155.32 | 0.00 | 6 | 2586.96 |
| Distance + Wind Direction | 2599.24 | 155.60 | 0.00 | 4 | 2591.24 |
| Distance x Wind Speed | 2698.72 | 255.08 | 0.00 | 4 | 2690.72 |
| Distance x Wind Speed x Ecoregion | 2729.33 | 285.69 | 0.00 | 5 | 2719.33 |
| Distance + Wind Speed + Ecoregion | 2743.75 | 300.11 | 0.00 | 4 | 2735.75 |
| Distance + Wind Speed | 2770.61 | 326.97 | 0.00 | 3 | 2764.61 |
| Distance x Ecoregion | 2782.92 | 339.28 | 0.00 | 4 | 2774.92 |
| Distance + Ecoregion | 2844.40 | 400.76 | 0.00 | 3 | 2838.40 |
| Distance | 2878.88 | 435.24 | 0.00 | 2 | 2874.88 |
| Wind Speed x Wind Direction | 4159.72 | 1716.08 | 0.00 | 6 | 4147.72 |
| Wind Speed + Wind Direction | 4160.06 | 1716.42 | 0.00 | 4 | 4152.06 |
| Wind Direction + Ecoregion | 4187.76 | 1744.12 | 0.00 | 4 | 4179.76 |
| Wind Direction x Ecoregion | 4190.64 | 1747.00 | 0.00 | 6 | 4178.64 |
| Wind Direction | 4194.31 | 1750.67 | 0.00 | 3 | 4188.31 |
| Wind Speed + Ecoregion | 4301.20 | 1857.56 | 0.00 | 3 | 4295.20 |
| Wind Speed x Ecoregion | 4303.20 | 1859.56 | 0.00 | 4 | 4295.20 |
| Wind Speed | 4312.21 | 1868.57 | 0.00 | 2 | 4308.21 |
| Ecoregion | 4332.46 | 1888.82 | 0.00 | 2 | 4328.46 |
| Intercept Only | 4346.35 | 1902.71 | 0.00 | 1 | 4344.35 |

[a] Akaike weight

[b] No. of parameters in each model

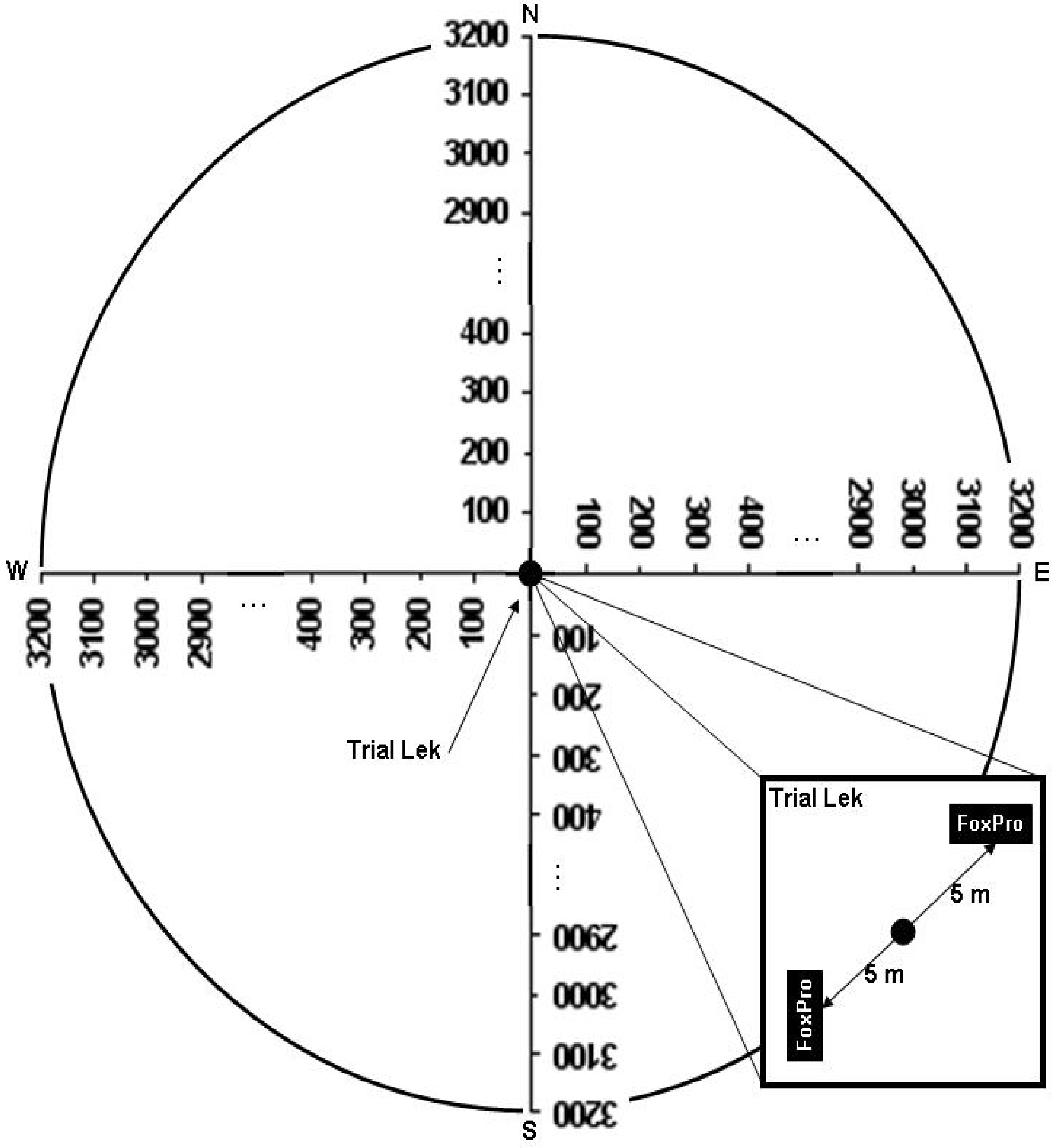


Figure 5.1. A trial lek used to assess factors influencing detectability of active lesser prairie-chicken leks in Cochran, Gray, Hemphill, and Yoakum counties, Texas, USA.

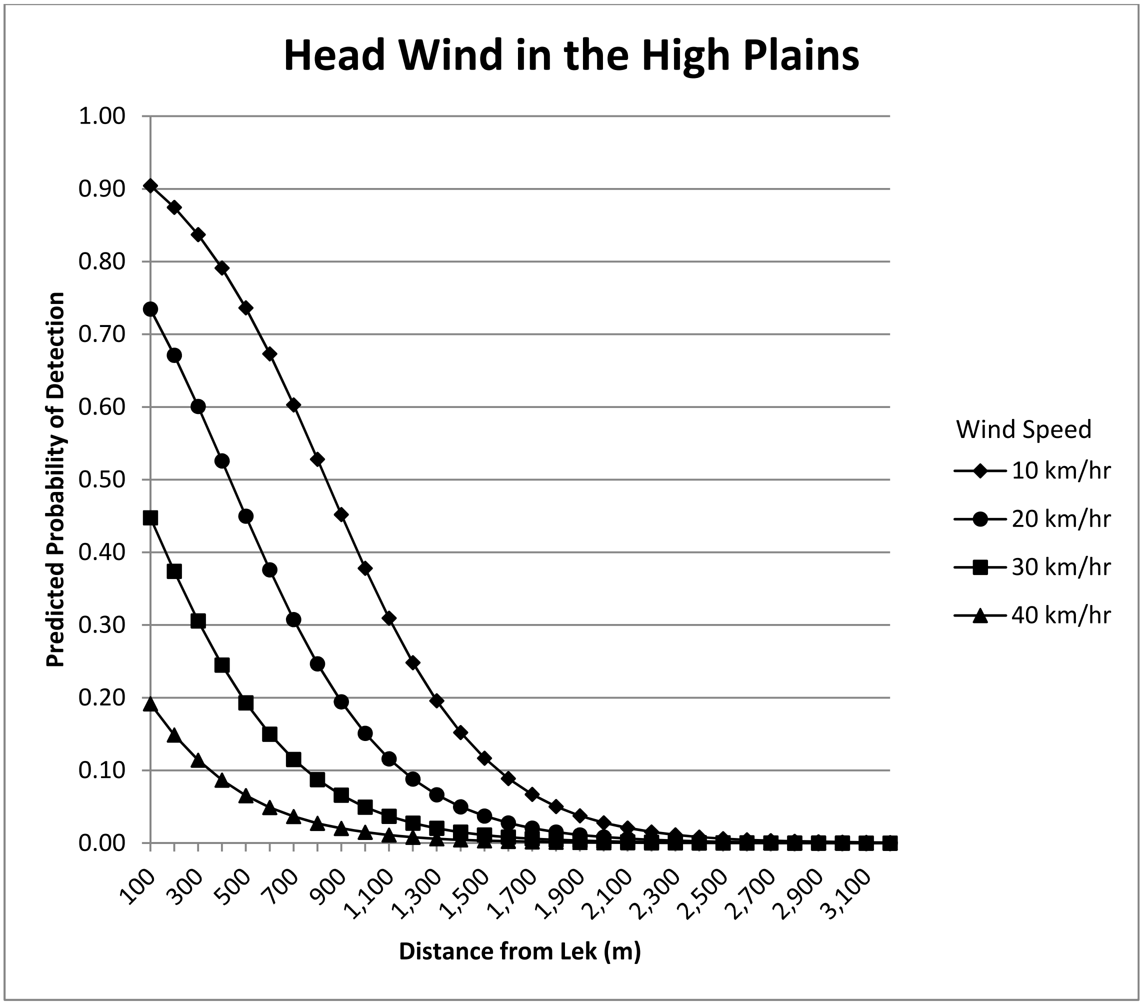


Figure 5.2. Probability of detecting a trial lek in a head wind in the High Plains ecoregion of Texas, USA.

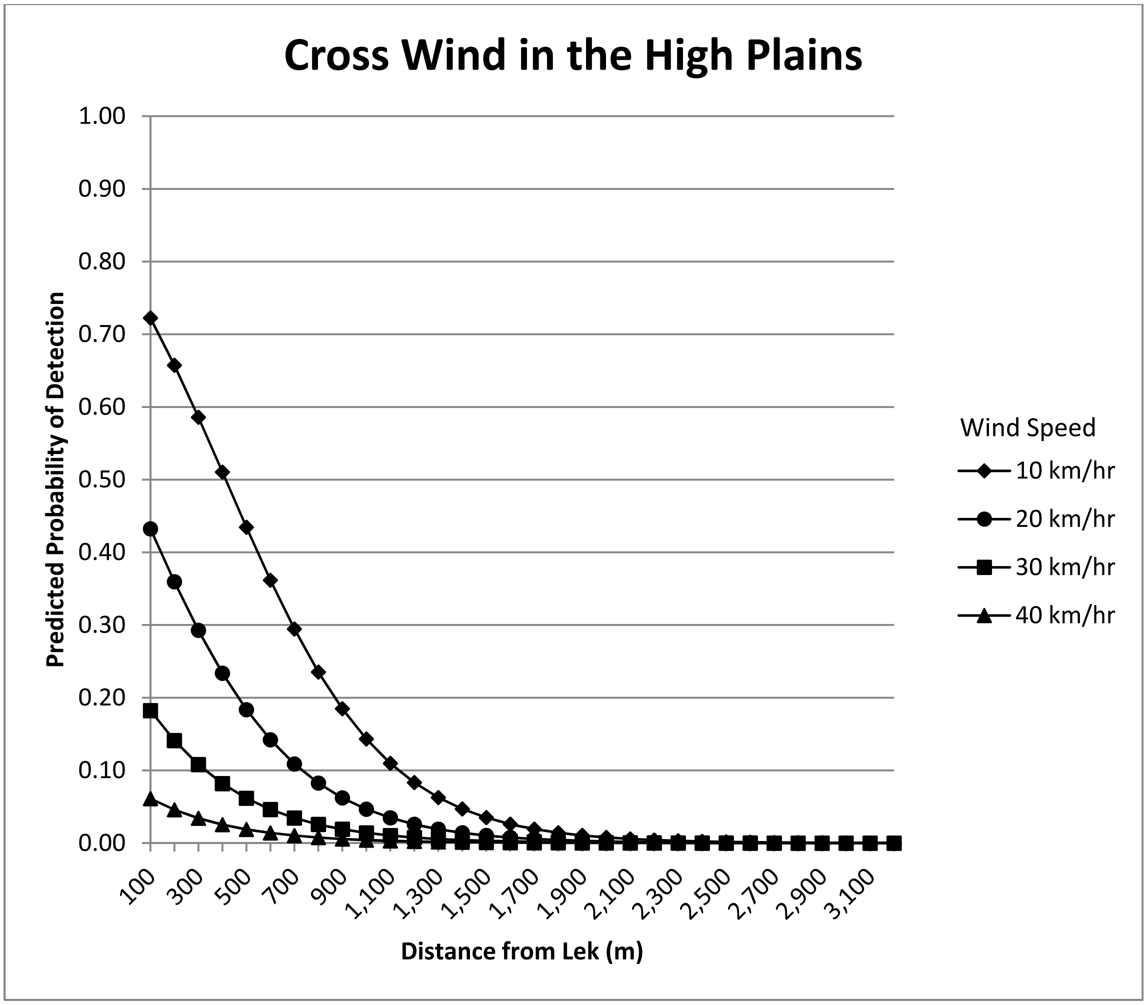


Figure 5.3. Probability of detecting a trial lek in a cross wind in the High Plains ecoregion of Texas, USA.

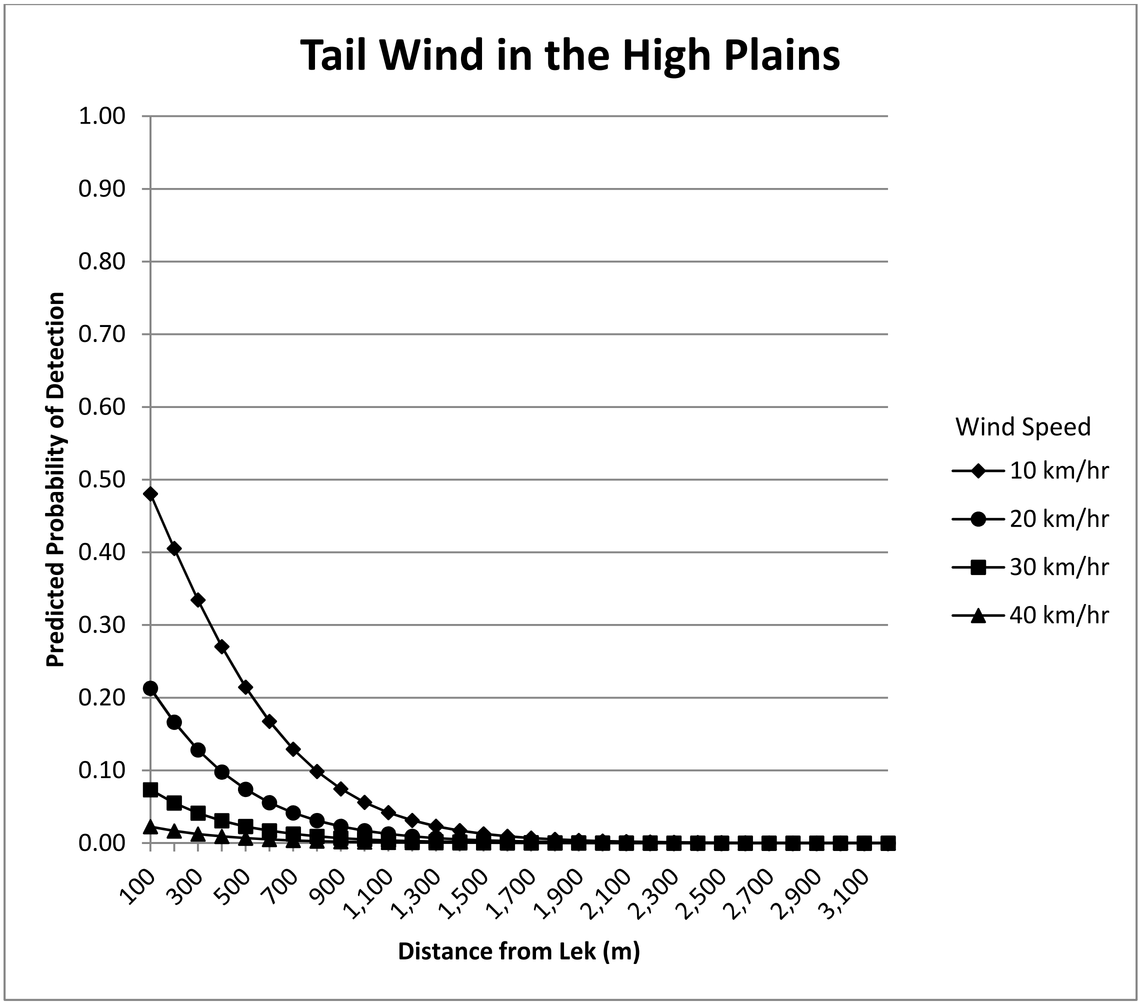


Figure 5.4. Probability of detecting a trial lek in a tail wind in the High Plains ecoregion of Texas, USA.

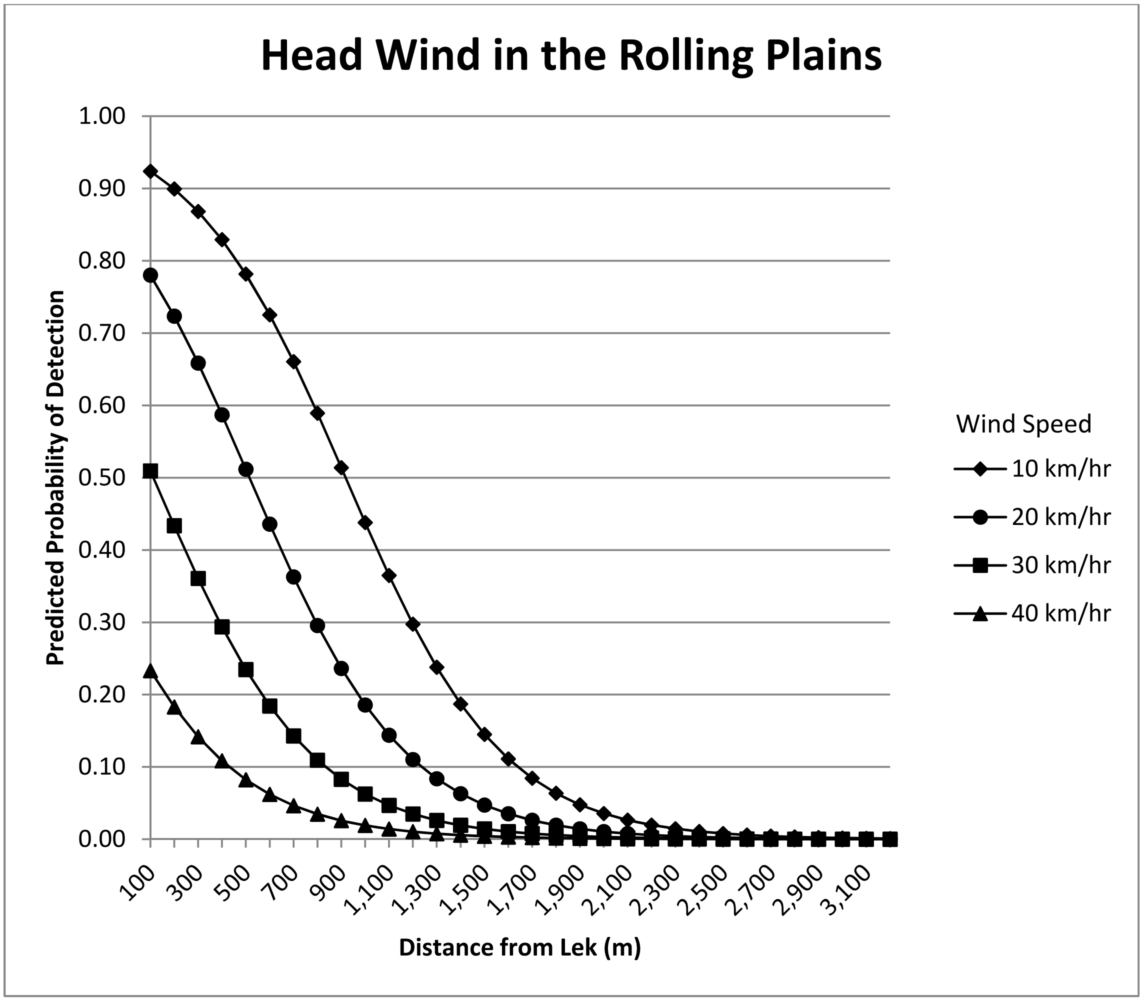


Figure 5.5. Probability of detecting a trial lek in a head wind in the Rolling Plains ecoregion of Texas, USA.

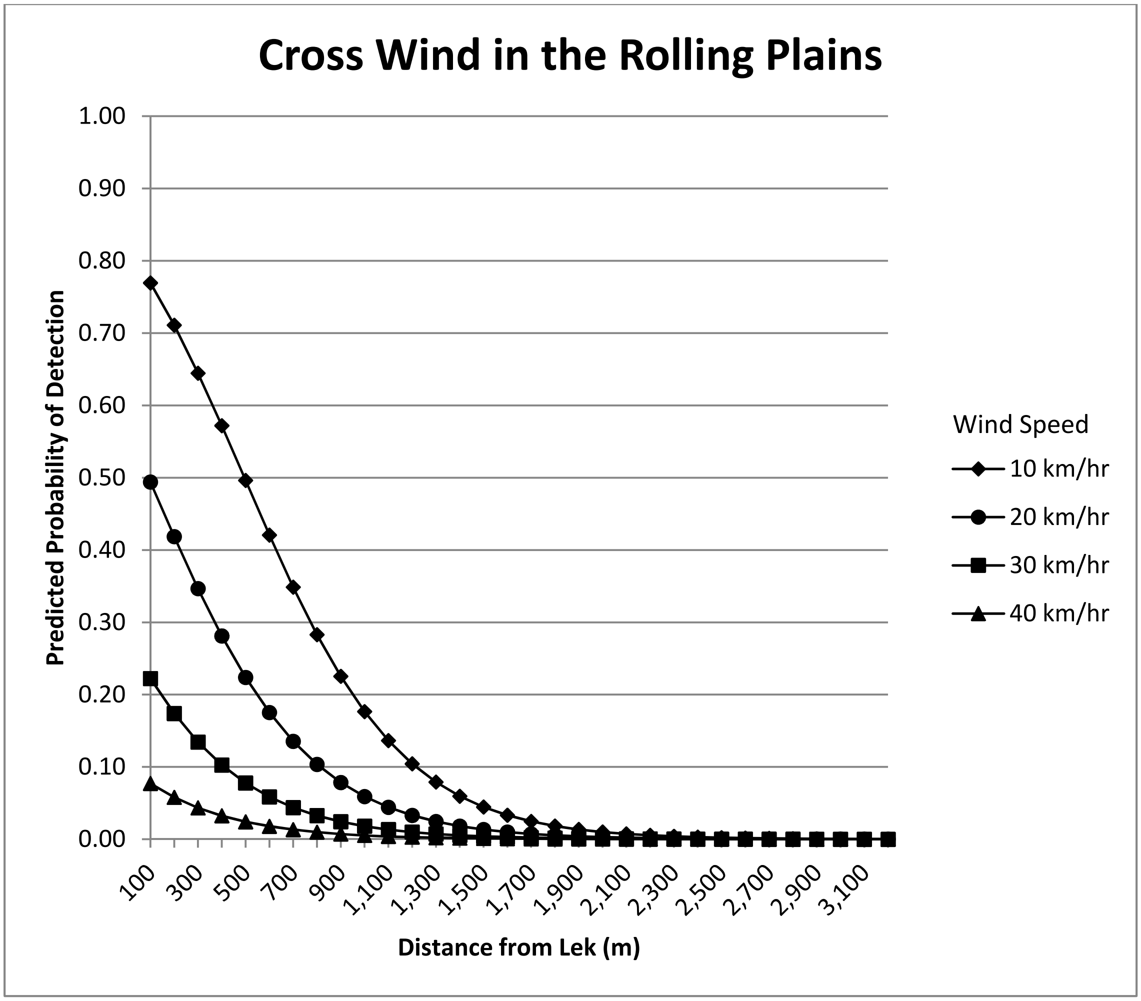


Figure 5.6. Probability of detecting a trial lek in a cross wind in the Rolling Plains ecoregion of Texas, USA.

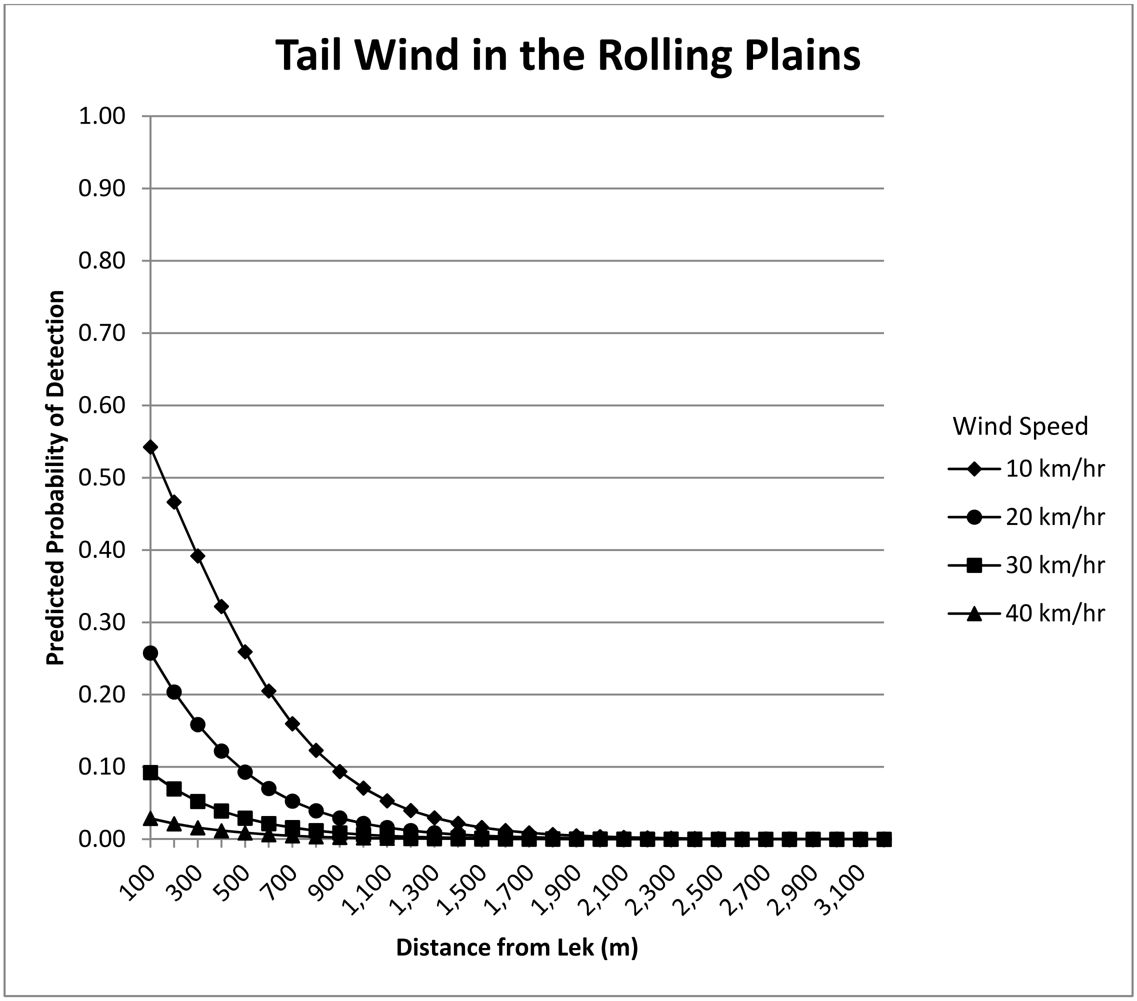


Figure 5.7. Probability of detecting a trial lek in a tail wind in the Rolling Plains ecoregion of Texas, USA.