AERIAL SURVEYS FOR LESSER PRAIRIE-CHICKEN LEKS:
DETECTABILITY AND DISTURBANCE RESPONSE

by

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ABSTRACT

The lesser prairie-chicken (*Tympanuchus pallidicinctus* [LPC]) is a prairie grouse species that attends leks (areas where male LPCs assemble and compete for breeding opportunities) during the spring reproductive season. Lesser prairie-chickens inhabit Texas, New Mexico, Colorado, Oklahoma, and Kansas and are a species of conservation concern. The LPC is also a candidate species for listing as threatened or endangered under the Endangered Species Act because of substantial reductions in population size and occupied range. Historically, LPC populations have been monitored by ground-based lek surveys and counts of birds attending leks, but these methods are labor intensive, limited by access, often restricted to roads, and may be a poor index of abundance. These drawbacks created the need to test and apply innovative conservation ideas crucial to the survival and management of LPC populations. We believe aerial surveys may alleviate the drawbacks of traditional monitoring methods. Our study objectives were to evaluate aerial survey techniques, estimate lek detectability, assess LPC response to aircraft disturbance, and create predictive models to explain lek detectability and disturbance response.

We flew aerial surveys using 3 aircraft platforms: a Cessna 172 fixed-wing aircraft, a Robinson R-22 Beta II helicopter, and a Robinson R-44 Raven II helicopter (hereon C172, R-22, and R-44, respectively). We conducted surveys in Texas and New Mexico. Ground observers and remote cameras were stationed on known leks during aerial surveys to assess lek activity and potential behavioral disturbance to LPCs, thus
enabling us to model lek detectability and LPC flush response to aerial surveys. We created \textit{a priori} models and used logistic regression to develop predictive models of lek detectability and LPC disturbance response. We used Akaike’s Information Criterion corrected for small sample size (AIC$_c$) to rank the models within the model sets.

We conducted a total of 58 flights during spring 2007–2008. From remote camera data, we determined that 305 active leks were available for detection. We found that detectability was 89.8\% (82.0–95.0\%; 95\% CI) from the R-44, 72.3\% (64.5–79.1\%) from the R-22, and 32.7\% (20.3–47.1\%) from the C172. Variables that influenced lek detection were aircraft type, distance to the lek, lek type (man-made or natural lek), and survey date. Model weights suggested that aircraft platform, distance to the lek, and lek type were important predictors of detectability.

We collected 49 ground observations of the response of LPCs on leks to aerial surveys during spring 2007–2009. We did not observe LPCs flushing in response to the C172. We found no difference in flush response between helicopters ($P = 0.33$; Fisher’s exact test) and observed a flush response of 43.2\% (28.4–59.0\%) from helicopters. When LPCs flushed from a lek, the mean return time was $7.0 \pm 2.6$ min (mean $\pm$ 95\% CI).

Modeling of disturbance response was limited to the helicopter platforms and we found that distance to the lek had the greatest impact on flush response, with a decreased flush response as distance to the lek increased. We concluded that aircraft disturbance did not adversely affect the lekking behavior of LPCs.

Aerial surveys can provide an efficient and effective technique for monitoring and detecting LPC leks. Lek density is an important population parameter and it is possible
to estimate lek density through aerial surveys. Furthermore, aerial surveys alleviate the
drawbacks associated with ground-based lek surveys by providing rapid survey coverage
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CHAPTER 1

INTRODUCTION

The lesser prairie-chicken (*Tympanuchus pallidicinctus* [LPC]) is a species of prairie grouse that originally inhabited large expanses of the plains of Texas, New Mexico, Colorado, Oklahoma, and Kansas (Hagen 2005). The species was traditionally a gamebird throughout its 5-state range, but Kansas is the only state that currently allows harvest. During the spring breeding season, male LPCs gather on leks to compete for breeding opportunities. Booming vocalizations, displaying rituals, and fighting among males are characteristic lekking behaviors (Hagen 2005). A myriad of pressures has resulted in LPCs having one of the smallest and most restricted populations of North American prairie grouse species (Figure 1.1) (Giesen 1998, Davis et al. 2008). It is estimated that total population size has declined by 97% (Crawford 1980) and distribution has declined by 92% since the 1800s (Taylor and Guthery 1980). The decline of LPC populations has been attributed to mis-managed grazing of rangelands, the conversion of native prairie to cropland, and habitat fragmentation (Lee 1950, Jackson and DeArment 1963, Crawford and Bolen 1976, Braun et al. 1994, Giesen 1998). Reoccurring drought conditions have also negatively affected LPCs by reducing plant biomass needed for forage and cover (Riley et al. 1993).

In the Texas Panhandle, between 1963–1980, a 78% reduction in distribution was detected (Sullivan et al. 2000). The lesser prairie-chicken population in Texas could be at an all time low. Recent estimates of the Texas population are 5,000–10,000 individuals
(Davis et al. 2008). In 1979, the population was estimated at 11,000–18,000 (Crawford 1980) and historic estimates placed total population size at 2 million (Litton 1978).

In 1995, the U.S. Fish and Wildlife Service (USFWS) was petitioned to list the LPC as threatened or endangered under the Endangered Species Act and, in 1998, the species was deemed, “warranted but precluded” from listing (USFWS 1998). The species remains a candidate species (North American Bird Conservation Initiative 2009) with its status reviewed annually. In December 2008, the LPC was elevated from a listing priority 8 to a listing priority 2 (USFWS 2008), bringing conservation efforts to a crucial stage.

Traditionally, LPC monitoring has consisted of road-based surveys and counts of males attending leks. However, drawbacks exist with these methods. Applegate (2000) described the troubles of restricting lek surveys to roads and Martin and Knopf (1982) identified the number of man-hours required to survey large tracts of habitat. Applegate et al. (2004) highlighted the need to “think outside the box” and initiate novel management efforts for prairie grouse species. We believe aerial lek survey research is the type of science identified as a need by Applegate et al. (2004). Although aerial surveys to locate prairie grouse leks have been conducted in the past (Eng 1955, Lehmann and Mauermann 1963, Martin and Knopf 1981, Schroeder et al. 1992), our project scale and flight frequency were much greater than previously attempted. Instead of focusing on cumulative lek detectability or determining specific lek locations on a study area from a single aircraft type, our research was designed to quantify lek detectability and disturbance response among aircraft platforms, and develop predictive
models to explain lek detectability and disturbance response. Broadly defined, our
objectives for this study were to determine the applicability of 3 aircraft platforms to
detect LPC leks and to assess the disturbance from aerial surveys to LPCs on leks. This
research was conducted at 4 sites in the Southern High Plains (Figure 1.2) during the

This work demonstrates my ability to think critically and interpret research
results. The following chapters are co-authored by Jon T. McRoberts, Matthew J. Butler,
Warren B. Ballard, Heather A. Whitlaw, David A. Haukos, and Mark C. Wallace and
written in a format and style intended for submission to the Journal of Wildlife
Management. Chapter II compares detectability of LPC leks from 3 aircraft platforms.
Chapter III examines the response of LPCs on leks to aerial survey disturbance. It is our
hope that these 2 chapters can be used jointly to advance LPC conservation efforts.
Literature Cited


in A. Poole and F. Gills, editors. The birds of North America. The Academy of

Natural Sciences, Philadelphia, Pennsylvania, USA and The American

Ornithologist’s Union, Washington, D.C., USA.

Hagen, C. A. 2005. Lesser prairie-chicken (Tympanuchus pallidicinctus). Birds of

North America online.


Jackson, A. S., and R. DeArment. 1963. The lesser prairie chicken in the Texas


7000-25, Texas Parks and Wildlife Department. Austin, USA.


North American Bird Conservation Initiative, U.S. Committee. 2009. The state of birds,

United States of America. U.S. Department of the Interior, Washington, D.C.,

USA.


U.S. Fish and Wildlife Service. 2008. Review of native species that are candidate for listing as endangered or threatened; annual notice of finding on resubmitted petitions; annual description of progress on listing actions; proposed rule. Federal Register 73:75175–75244.
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CHAPTER II
DETECTABILITY OF LESSER PRAIRIE-CHICKEN LEKS:
A COMPARISON OF SURVEYS FROM AIRCRAFT

Abstract

The lesser prairie-chicken (*Tympanuchus pallidicinctus* [LPC]) is a species of conservation concern traditionally monitored by spring road-based lek surveys and counts of males attending leks. Several drawbacks exist with traditional ground-based lek monitoring methodology such as the bias of restricting surveys to roads (Applegate 2000) and the number of man-hours required to survey large tracts of habitat (Martin and Knopf 1982). We evaluated aerial survey methodology to locate LPC leks using 3 aircraft platforms during spring 2007–2008 and created predictive models to explain lek detectability. We conducted lek surveys in Texas and New Mexico using a Cessna 172 airplane, R-22 Beta II helicopter, and R-44 Raven II helicopter (hereon C172, R-22, and R-44, respectively). We determined lek activity during our survey period with remote cameras placed on leks by cross-referencing the time on the photo frame to the time on our global positioning system (GPS) flight log. From remote cameras we found that 305 leks were available for detection during survey flights. We determined lek detectability was 32.7% (20.3–47.1%; 95% CI) in the C172, 72.3% (64.50–79.14%) in the R-22, and 89.8% (82.0–95.0%) in the R-44. We created 16 *a priori* logistic regression models incorporating aircraft platform, distance, platform × distance interaction, lek size, and lek type to predict LPC lek detection from aerial surveys. Our top ranked model included
platform, distance, and lek type ($\omega_i = 0.288$). We had 4 competitive models and used model averaging to draw inferences. Model averaging showed that detectability was generally greatest with the R-44, followed by the R-22, and lowest with the C172, with a slight deviation from this ranking at increased distances. Model averaging also suggested, within our transect width, that detectability decreased as distance from the transect to the lek increased during helicopter surveys, and detectability increased as distance from the transect to the lek increased during C172 surveys. Furthermore, model averaging revealed that man-made leks were more likely to be detected than natural leks, and that large leks were more likely to be detected than medium or small leks. We believe aerial surveys are an effective method to locate new leks and monitor lek density, and that aerial surveys alleviate several of the drawbacks associated with ground-based monitoring. We recommend using the R-44 to conduct lek surveys while flying at an altitude of 15 m at a speed of 60 km/hr on sunny mornings.

**Introduction**

Prairie grouse (*Centrocercus* and *Tympanuchus* spp.) populations have declined through the past 3 decades and the need exists to clarify the conservation status of prairie grouse species (Silvy and Hagen 2004). Of particular concern is the lesser prairie-chicken (*T. pallidicinctus [LPC]*), a species known to be vulnerable to anthropogenic impacts (Hammerstrom and Hammerstrom 1961). Lesser prairie-chicken populations are estimated to have declined by 97% (Crawford 1980) with a 92% reduction in occupied range since the 1800s (Taylor and Guthery 1980). The decline of LPC
populations has been attributed to drought, mis-managed grazing of rangelands, the conversion of native prairie to cropland, and habitat fragmentation (Lee 1950, Jackson and DeArment 1963, Crawford and Bolen 1976, Braun et al. 1994, Giesen 1998). In 1995, the U.S. Fish and Wildlife Service (USFWS) was petitioned to list the LPC as threatened or endangered under the Endangered Species Act and, in 1998, the species was deemed, “warranted but precluded” for listing (USFWS 1998). The species remains a candidate species (North American Bird Conservation Initiative 2009) with its status reviewed annually. In December 2008, the LPC was elevated from a listing priority 8 to a listing priority 2 (USFWS 2008), increasing the priority of conservation efforts for the species.

Managers have traditionally monitored prairie grouse with 2 types of spring lek surveys: leks counts (Schwartz 1945, Jackson and DeArment 1963, Bibby et al. 2000, Davis et al. 2008) and road-based lek surveys (Best et al. 2003, Davis et al. 2008, Ripper et al. 2008). Lek counts provide an index of the number of LPCs attending a known lek during the spring breeding season. Road-based transect surveys are used to locate leks by driving a route in suspected prairie grouse habitat and stopping at intervals to look and listen for leks. Both methods are accepted as standards for monitoring prairie grouse population trends. However, drawbacks exist with traditional lek monitoring methods (Robel 1980, Cannon and Knopf 1981, Applegate 2000, Walsh et al. 2004). Drawbacks of lek attendance counts include missing counts on unknown lek locations that are inherently needed to calculate an index (Cannon and Knopf 1981). Drawbacks of road-based lek surveys include accessibility to survey areas, man-hours required to completely
survey an area (Martin and Knopf 1982, Grensten 1987), and restricting surveys to roads (Applegate 2000, Anderson 2001). Also of concern is the possibility of LPCs not calling during the listening period, the unknown probability of hearing a lek as distance from the road increases, and differing environmental variables (e.g., topography, wind, background noise) confounding audibility. Neither method is designed to estimate lek density in large tracts of contiguous habitat void of road networks. Applegate et al. (2004:104) indentified the, “crucial need for a willingness to devise, test, and apply innovative ideas that are not normally considered in the management of grouse species, especially applying management to large areas within ecosystems.” Furthermore, Crawford (1980) indentified the study of survey techniques as an important research need for LPC management.

Aerial surveys for prairie grouse leks is not a new concept. Eng (1955) flew surveys in a fixed-wing aircraft to successfully locate greater sage-grouse (*C. urophsianus*) leks in Montana. Lehmann and Mauermann (1963) surveyed for Attwater’s prairie-chicken (*T. cupido pinnatus*) leks with both fixed-wing aircraft and helicopters. Martin and Knopf (1981) conducted surveys from fixed-wing aircraft for greater prairie chicken (*T. cupido [GPC]*) leks and Schroeder et al. (1992) used helicopter surveys to estimate the number of GPC and LPC leks in eastern Colorado. The objectives and scope of past prairie grouse aerial surveys were different, but a common conclusion among each study was that leks could be detected from aircraft. Our objectives were to 1) evaluate and develop line transect aerial survey methodology for a fixed-wing aircraft and helicopters to detect leks, 2) quantify lek detectability from 3 aircraft platforms, and 3)
create predictive models to explain lek detectability from aerial surveys. These objectives are justified by the need to estimate lek density for population monitoring efforts, a valuable population parameter identified by Haukos and Smith (1999). Furthermore, determining lek locations from aerial surveys will be useful to initiate other management activities and determine LPC occupied range.

**Study Area**

We conducted aerial surveys at 2 sites in Texas and 2 sites in eastern New Mexico. Study areas consisted of federal, state, and privately owned lands. Lek densities ranged from 0.1–0.6 lek/km². The Texas study sites were located in Hemphill and Yoakum counties. The Hemphill County site (5,007 ha) was dominated by Tivoli fine sand and Springer loamy fine sand soils (Natural Resources Conservation Service [NRCS] 2009). Average annual rainfall ranged from 38–64 cm and elevation in this region ranged from 670–1465 m (Vodehnal and Haufler 2008). The site was a short-mixed grass prairie ecosystem dominated by little bluestem (*Schizachyrium scoparium*) and sand sagebrush (*Artemisia filifolia*). The Yoakum County site (2,905 ha) was dominated by Brownfield fine sand and Brownfield-Circleback fine sand soils (NRCS 2009). The site was a xeric, sand dune ecosystem dominated by little bluestem (*Schizachyrium scoparium*) and shinnery oak (*Quercus havardii*). The New Mexico study sites were located in Chaves (3,961 ha) and Roosevelt (3,444 ha) counties. Both sites shared vegetative characteristics of the Yoakum County site and were dominated by Brownfield fine sand and Tivoli fine sand soil types (NRCS 2009). For the Yoakum,
Chaves, and Roosevelt counties region, Vodehnal and Haufler (2008) reported average annual rainfall of 33–56 cm and elevation of 795–1585 m. All 4 sites received light to moderate grazing and either had active oil or gas wells, or remnants of former wells.

**Methods**

**Aerial Surveys**

We conducted aerial surveys from 3 aircraft platforms: Cessna 172 fixed-wing aircraft (Cessna Aircraft Co., Wichita, KS; hereon C172), R-22 Beta II helicopter, and R-44 Raven II helicopter (Robinson Helicopter Co., Torrance, CA; hereon R-22 and R-44). The C172 held 3 observers (the pilot seated in the front left seat, an observer positioned in the front right seat, and another observer in the back left seat), the R-22 held 2 observers, and the R-44 held 4 observers, with the pilot serving as an observer in each platform. On average it cost US$135/hr to rent the C172, US$305/hr to rent the R-22, and US$520/hr to rent the R-44. We conducted flights between mid-March and mid-May 2007–2008. We based our flight methodology on previous surveys for prairie grouse leks (Eng 1955, Lehmann and Mauermann 1963, Martin and Knopf 1981, Schroeder et al. 1992) and ptarmigan (*Lagopus* spp.) (Pelletier and Krebs 1998). We surveyed at an altitude of 15 m for helicopters and 50 m for the fixed-wing aircraft. Our target flight speeds were 60 km/hr for the helicopters and 140 km/hr for the fixed-wing aircraft. Occasionally, we adjusted flight speed to maintain safe flying conditions during high winds (Pelletier and Krebs 1998). We did not fly during precipitation events or when forward visibility was less than 8 km. We began our initial test-flight survey at 0.5 hr
before sunrise, but we adjusted subsequent flights to begin at sunrise. We completed survey blocks no later than 2.5 hr post-sunrise. We conducted surveys in a north-south orientation in helicopters and in an east-west orientation in the C172. We started on the east side of survey blocks to minimize time facing the sun during helicopter surveys.

We developed flight paths in ArcGIS® 9.2 (Environmental Systems Research Institute, Inc., Redlands, CA). We separated transects by 400 m and the starting point of transect 1 was randomly generated. New transects were generated for each flight. We assigned waypoints used for navigation to both ends of transect lines. We loaded the consecutively numbered end-waypoints into a Garmin Model 60CSx global positioning system (GPS) unit and programmed a route into the GPS unit from which the pilot navigated. We programmed the GPS unit to record a track of our flight path (position recorded in 1-sec interval).

We alternated aerial observers \((n = 23)\) and pilots \((n = 5)\) to minimize detection bias associated with familiarity of lek locations within a study area. All aerial observers worked in the wildlife management field and received pre-flight instructions on LPC and lek search image. Aerial observers focused their attention within a 200 m search distance on the side of the aircraft in which they were seated. When a lek was located, the verbal command of “mark” was given and the observer in the front of the aircraft marked the way-point GPS coordinates. We used a single GPS unit to mark leks to avoid double-counts. The observer seated next to the pilot was responsible for recording leks spotted by the pilot (Appendix D).
Remote Cameras

We placed 1 or 2 programmable cameras (RECONYX Model RM30, RECONYX, Inc., Holmen, WI) on known lek locations within our survey block. Remote cameras have been documented as an effective, non-intrusive method to monitor avian species (Cutler and Swan 1999) and have been used to monitor prairie grouse (Holloran and Anderson 2003, Behney 2009). We programmed the cameras to take photographs during aerial surveys to determine LPC presence on leks during the survey period. This allowed us to determine which leks were available for detection when we flew in proximity of the lek (Figure 2.1). We could not assume that a lek was active and available for detection during our survey period simply because LPCs typically attended the lek. We attached the cameras to a T-post 30 cm above ground. We used natural vegetation to camouflage the cameras and make them inconspicuous to aerial observers. We set the cameras to take a photograph at 1-min intervals during our survey period (a 1-min interval was the shortest interval possible for the RECONYX Model RM30). We referenced the time on the photograph with our GPS flight track to determine if the lek was active and available for detection during our survey.

Data Analysis

We created 16 a priori logistic regression models (Hosmer and Lemeshow 2000) to evaluate variables influencing detectability (Table 2.1). We included aircraft platform in each model to meet our study objective and because of the management applicability. Beyond platform, we had a balanced model set including distance from the transect to the lek, survey date, lek type, lek size, and the platform × distance interaction as covariables.
The platform × distance interaction was necessary because a strip approximately 100 m wide was not viewable directly below the fixed-wing aircraft (Butler et al. 2007) causing a suspected difference in the slope of detection functions between the fixed-wing aircraft and the helicopters. We used SPSS® 16.0 (SPSS Inc., Chicago, IL) to analyze the data and Akaike’s Information Criterion corrected for small sample size (AICc) to evaluate the model set. The response variable was lek detection with a binary classification of 1 for lek detected and 0 for missed lek detection. We only included leks confirmed as active and available for detection in our models. We evaluated fit of our global model (Burnham and Anderson 2002) using the Hosmer-Lemeshow test (Hosmer and Lemeshow 2000) and used AICc weights to assess evidence for each model. To account for model selection uncertainty among competing models within our a priori set, we found it necessary to model average (Burnham and Anderson 2002, Anderson 2008).

We included lek size and type as categorical variables in our model set. We determined lek size by averaging the past 3 yr of mid-April lek counts collected by site managers. We classified a lek as “small” if the average count was ≤10 birds, “medium” if the count was 11-20 birds, and “large” if the average count was >20 birds (P. McDaniel, The Nature Conservancy, personal communication). We adopted dummy coding for the lek size categories. Lek type was also a categorical variable in our model set with a classification as either a “natural” or “man-made” lek (Taylor 1979). Examples of man-made leks at our sites included abandoned oil pads, oil pipeline scars, and clearings around stocktanks. We adopted a binary classification for the lek type variable, assigning 1 for man-made leks and 0 for natural leks.
We included distance and date as continuous variables in our model set. We calculated precise perpendicular distance from the aircraft to the lek using the ArcGIS minimum-distance function. This was possible in our study because we surveyed areas with known coordinates at the center of each lek. In an applied setting, it would be necessary to use laser range-finders from helicopters or streamers on struts from fixed-wing aircraft to obtain distance to lek (Guenzel 1997, Butler et al. 2007, Butler et al. 2008). We generated a standardized survey date value by assigning the day of our earliest survey date, 8 March, as standardized date value 0 and consecutively numbered until our latest survey date, 17 May, which received a value of 70. The standardized date allowed us to include a comparable date value for surveys conducted in 2007 and 2008. Because lek attendance has a peak (Schroeder and Braun 1992, Johnsgard 2002), we included standardized date as a quadratic variable in our model set.

Results

We conducted 58 survey flights during 8 March–17 May 2007 (Appendix B) and 12 March–10 May 2008 (Appendix C); 11 surveys in the C172, 28 in the R-22, and 19 in the R-44. Our target survey speeds were 140 km/hr in the C172 and 60 km/hr in both helicopters, yet our actual speeds were $135.5 \pm 7.0$ km/hr (mean $\pm$ 95% CI) in the C172, $60.5 \pm 3.0$ km/hr in the R-22, and $58.1 \pm 4.4$ km/hr in the R-44. At these speeds we were able to survey $4060.0 \pm 99.2$ ha/hr in the C172, $2211.9 \pm 127.3$ ha/hr in the R-22, and $2028.6 \pm 184.7$ ha/hr in the R-44. From the camera data, we determined that a total of 305 leks were active and available for detection during aerial surveys with 52 leks
available during C172 surveys, 155 leks during R-22 surveys, and 98 during R-44 surveys. Lek detectability was 32.7% (20.3–47.1%; 95% CI) in the C172, 72.3% (64.5–79.1%) in the R-22, and 89.8% (82.0–95.0%) in the R-44. We pooled detections from the 3 aircraft platforms and found small leks had 59.4% (46.4–71.5%) detectability, medium leks had 70.3% (61.6–78.1%) detectability, and large leks had 78.8% (70.0–85.9%) detectability. We pooled detections from the 3 platforms and found man-made leks had 76.7% (69.8–82.6%) detectability and natural leks had 63.2% (54.1–71.7%) detectability.

We used logistic regression and AIC to evaluate 16 candidate models to evaluate variables influencing detectability (Table 2.1). The global model fit the data ($\chi^2 = 4.188, df = 8, P = 0.840$). Our model with the greatest weight ($\omega_i = 0.288$) included aircraft platform, distance, platform × distance interaction, and lek type (Table 2.1). The interaction between platform and distance suggested the relationship between detectability and platform varied with distance (Figure 2.2). At 0 m we found that lek detectability was 33.70 times greater from the R-22 ($W = 23.071, df = 1, P \leq 0.001$) and 192.31 times greater from the R-44 ($W = 22.675, df = 1, P \leq 0.001$) than the C172, and lek detectability was 5.71 times greater from the R-44 ($W = 3.101, df = 1, P = 0.078$) when compared to the R-22. As distance increased the odds ratio between the C172 and both helicopters decreased, yet the odds ratio between the R-22 and R-44 increased (Figure 2.2). Lek detectability slightly increased with distance (odds ratio = 1.01; $W = 2.419, df = 1, P = 0.120$) during C172 flights, but decreased as distance increased in the R-22 (odds ratio = 0.98; $W = 8.852, df = 2, P = 0.003$) and R-44 (odds ratio = 0.98; $W =$
6.638, \( P = 0.010 \)). Additionally, we found that man-made leks were more likely to be detected (odds ratio = 1.92; \( W = 4.838, \text{df} = 1, P = 0.028 \)) than natural leks.

We had 4 competitive models and model averaged to draw inference across the model set (Table 2.2) (Burnham and Anderson 2002, Anderson 2008). Our model averaging suggested that lek detection increased by using the R-22 (odds ratio = 33.54, SE = 0.746) or R-44 (odds ratio = 191.79, SE = 1.111) instead of the C172 at distance 0 m, but the odds ratios among platforms varied as distance increased in the same manner as our top ranked model (Table 2.2). We found a slight increase in lek detectability as distance increased when the C172 was used (odds ratio = 1.01, SE = 0.005), but a decrease in lek detectability as distance increased in the R-22 (odds ratio = 0.98, SE = 0.006) and the R-44 (odds ratio = 0.98, SE = 0.009). We found that man-made leks were more likely to be detected (odds ratio = 1.85, SE = 0.302) than natural leks and medium-sized leks (odds ratio = 1.47, SE = 0.385) and large-sized leks (odds ratio = 2.20, SE = 0.404) were more likely to be detected than small leks. Additionally, we found that detectability increased as the lekking season progressed (odds ratio = 1.03, SE = 0.039); however, the survey date variable was not averaged because it only appeared in 1 of our competing models.

**Discussion**

Our study was the first to examine prairie grouse lek detectability from aerial surveys on a large scale. All previous studies of aerial surveys for prairie grouse had fewer survey flights. We feel that aerial surveying for LPC leks meets the challenge set
forth by Crawford (1980) and Applegate et al. (2004). Aerial surveys also resolve many of the drawbacks of traditional ground-based LPC lek monitoring such as not restricting surveys to roads, lessening the number of man-hours need to conduct ground-based surveys, and accessibility to remote habitat.

We estimated detectability to be 72.3% in the R-22. Schroeder et al. (1992) conducted 2 surveys for LPCs and 3 surveys for GPCs from a Bell 47 Soloy 2-observer helicopter, with individual flight lek detectability reported at 86.7% and 46.7% for LPCs and 60.0%, 25.0%, and 20.0% for GPCs. They flew LPC surveys during peak female attendance and again 2 weeks later, and GPC surveys at peak female attendance and 2 and 3 weeks later. Our estimate of detectability was within the range of Schroder et al. (1992) for LPC surveys, yet the reported GPC lek detectability was below our estimate. This could be a result of a difference in species or in differences in vegetation types among the sites. Additionally, Schroeder et al. (1992) did not mention the pilot serving as an observer during survey flights which may explain the lower detectability estimate.

Martin and Knopf (1981) conducted survey flights for GPCs with transects separated by 400 m in a C172 and reported maximum lek detection from a single survey flight of 52% in 1978 and 72% in 1979. Their detectability estimate was greater than the 32.7% we report and could be a result of pre-survey ground-based lek identification. Prior to surveys, Martin and Knopf (1981) conducted ground-based lek surveys to identify lek locations on 8 study areas of 4,144 ha. The lek locations they detected from the ground were the same leks that would be surveyed from the C172. It appears aerial observers had prior knowledge of all lek locations which could possibly result in a boost
Another possibility is that large, conspicuous leks were more likely to be detected from the ground-based surveys. We found that large leks were also more likely to be detected from aerial surveys. If the known leks located from ground searches were biased towards larger leks, then aerial detectability could be biased high because the leks used to estimate detectability were more easily detected than small or medium sized leks. A third possibility to explain the difference in detectability is Martin and Knopf (1981) flew at an altitude of 25–50 m, while we flew our surveys at 50 m. Flying at a lower altitude within the 25–50 m range may cause an increase in detectability by searching more efficiently close to the transect, although we do feel significant safety concerns exist in flying at this low altitude. We found no detectability estimates to compare our results from R-44 surveys.

Our *a priori* model set contained 4 competitive models and we found it necessary to use model averaging to account for model selection uncertainty and provide inference about predictive variables. Choice of aircraft platform had the most influence on lek detectability. We believe differences in lek detectability between the C172 and both helicopter platforms were results of the inability to survey directly below the C172 and increased speed necessary to safely fly the C172. We feel the difference in lek detectability between the R-22 and R-44 was a result of 2 additional observers present in the R-44. The interaction of platform and distance to the lek played an important role in lek detections. This interaction was caused by the inability to view beneath the C172 and caused the detection function for the C172 to have a positive slope, while lek detection functions for both helicopters had negative slopes. The C172 detection probability would
likely peak at some distance beyond the 200 m search width and then decline. We found that lek detectability decreased as distance increased with both helicopter platforms. A possibility that warrants further investigation is surveying at an altitude higher than 15 m to determine if detectability could increase with higher altitude.

Our results indicated that lek detectability was greater for man-made leks than natural leks. The greater detectability of man-made leks was likely due to the capability of targeting potential man-made lek sites on the landscape. Windmills, abandoned oil pads, and livestock watering tanks were all used as lek sites by LPCs and the absence of vegetation at these sites made LPCs easily detectable. We also found that lek detectability also increased with lek size. Butler et al. (2007) reached a similar conclusion, reporting that flock size of Rio Grande wild turkeys (*Meleagris gallopavo intermedia*) played an important role in aerial survey detectability.

Survey date appeared in 1 of our competitive models and played a surprisingly small role in detectability. We restricted our surveys to mid-March through mid-May, with the center of our survey period at peak lek attendance (Crawford and Bolen 1975). Had we surveyed through the January–June period of male LPC attendance on leks (Jones 1964), survey date would likely have had a greater impact on detectability by increasing the probability of detection closer to peak lek attendance. The infrequency of survey date in our competitive model set did demonstrate that observers were not “learning” specific lek locations. We flew 4 sites, and although we alternated among sites with 23 observers, we had initial concerns that an observer would remember lek locations and detectability would increase during subsequent flights. Had this concern
been valid, survey date would likely have played a greater role in our model set. The slight increase in lek detectability was likely a product of observer experience and the formulation of a search image for LPC leks.

We were frequently challenged by inclement weather in this study and were repeatedly grounded due to rain, fog, or high winds. If possible, surveys should be restricted to clear, sunny mornings. Martin and Knopf (1981) also stated that lek attendance drops during inclement weather. We also suggest restricting surveys to clear, sunny mornings because the white tail feathers of LPCs (that are visible during display behavior) reflected the sun and were visible at great distances. Contrary to previous studies on aerial surveys for leks, we recommend starting surveys for LPCs at sunrise, not 0.5 hr before sunrise as done by Schroeder et al. (1992) and Martin and Knopf (1981). We felt the amount of light at 0.5 hr before sunrise was not adequate, especially at distances approaching the 200 m search distance, to detect leks in LPC habitats.

Aerial surveys for wildlife have inherent dangers (Jones et al. 2006). We offer 2 cautions to wildlife managers who may implement our methodology. We suggest C172 implement a “key-hole” turn at the end of transects in which the pilot steers the aircraft first away from the next transect and then makes a wide loop back to the transect. The steep bank needed to reach the next transect (400 m distance) stretches the capabilities of the C172 and increases the likelihood of a stall. Much of the prairie grouse habitat across the Great Plains has been indentified as a potential site for wind energy development, including LPC range (McRoberts et al. 2009, Pruett et al. 2009). An initial step to wind energy development is the installation of meteorological (met) towers to assess wind
resources. These structures are often not marked with lights, paint, or other indicators (J. McRoberts, personal observation, Texas Tech University), not registered with the FAA, and stand at heights at which a collision is possible (e.g., 30–60 m). We suggest contacting local airports or wind energy developers to determine if met towers are located in survey areas.

Lek density is important in estimating population trends. We feel aerial lek surveys are a more effective method to estimate lek density than traditional ground-based road surveys because of the ability to survey all potential habitat. Our study areas have been actively monitored for lek locations for decades, yet we detected 4 new leks during our study period. Additionally, we conducted a survey in the R-44 on a test area with 5 documented lek locations, although the locations were unknown to aerial observers. We detected each known lek and found 5 new leks that were not detected by ground-based methods.

Lek counts have management applications, but it is important to attempt to account for all leks within a study area. If managers simply count males on stable, historic leks a delay in indentifying a population change is possible because attendance on stable, traditional leks would be the last to reflect the change (Haukos and Smith 1999). Satellite leks could remain undetected from ground survey because of remote locations or tendency to appear and disappear among seasons. In a 6-year study researching lek stability of GPCs, it was found that an estimated 23% of leks disappeared between consecutive years (Schroeder and Braun 1992). Satellite leks are critical to population assessment because it is suspected that young birds typically form these leks.
(Schroeder and Braun 1992). A logistically practical method is needed to survey all habitat and we believe aerial survey is the most pragmatic way to detect satellite leks.

Lek counts and road-based surveys have been a population assessment tool for decades and have been diligently used to define management objectives. However, the status of prairie grouse populations still remains unclear (Silvy and Hagen 2004). Advancing technology has made it possible to evaluate the potential of aerial survey to locate leks. While we cannot recommend counting the number of LPCs on a lek from aerial surveys (Appendix A), aerial surveys can be used to locate leks, and estimate lek density, which is superior to ground-based surveys. Additionally, managers will be able to conduct a more complete lek count index once the lek locations within a study area are located. If managers are unaware of all lek locations then density estimates and indices have little value and trends are speculative at best.

**Management Implications**

The conservation status of the LPC may also require a rapid population survey only possible from aircraft. Aerial surveys allow for complete coverage of an area to estimate lek density and find new lek locations. We recommend conducting surveys in the R-44 because of the greater detectability than the R-22 or C172. We do not recommend conducting lek surveys in the C172 because of safety concerns. However, other fixed-wing aircraft may have potential, and future research would be needed to address their applicability. We also suggest conducting surveys on clear mornings during peak lek activity because of the highly observable white tail feathers visible during
display. Additionally, future studies should quantifiably test the traditional road-based lek survey methodology so comparability between the 2 methods is possible. At first glance, aerial surveys are expensive, but when compared to the man-hour costs required by traditional ground-based methods aerial surveys become cost effective. We applied hourly aircraft rental rates and calculated that the R-22 would cost 2.4 times the price of the C172, increasing lek detectability by 39.6%; the R-44 would cost 4.0 times the price of the C172, increasing lek detectability by 57.1%; and the R-44 would cost 1.7 times the price of the R-22, increasing lek detectability by 17.5%. If aerial lek surveys are implemented as a management practice we suggest ground-truthing newly detected leks so the leks may be used for other management activities such as trapping for radio-telemetry or genetic studies.

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and insight, and we thank pilot A. Wheatly for technical guidance. We are grateful to the private landowners of Texas and New Mexico for allowing us to survey and monitor leks on their property. We thank all pilots for providing safe flight conditions and thank aerial observers for volunteering their time. We appreciate R. Herbert, A. Haskell, and J. Wallace for reviewing remote camera data. We are grateful to the Houston Safari Club for their financial support. We also thank Texas Tech University Department of Natural Resources Management graduate and undergraduate students for assistance with project field work.
Literature Cited


Guenzel, R. J. 1997. Estimating pronghorn abundance using aerial line transect sampling. Wyoming Game and Fish Department, Cheyenne, USA.


U.S. Fish and Wildlife Service. 2008. Review of native species that are candidate for listing as endangered or threatened; annual notice of finding on resubmitted petitions; annual description of progress on listing actions; proposed rule. Federal Register 73:75175–75244.

Table 2.1. Ranking of candidate logistic regression models predicting detectability of lesser prairie-chicken leks from aerial surveys in Texas and New Mexico, USA, during spring 2007–2008. For each logistic regression model, we give $-2\times$log-likelihood ($-2$LL), number of parameters ($K$), second-order Akaike’s Information Criterion ($\text{AIC}_c$), difference in $\text{AIC}_c$ compared to lowest $\text{AIC}_c$ of the model set ($\Delta_i$), $\text{AIC}_c$ weight ($\omega_i$), and percent accuracy ($n = 305$).

<table>
<thead>
<tr>
<th>Model</th>
<th>$-2$LL</th>
<th>$K$</th>
<th>$\text{AIC}_c$</th>
<th>$\Delta\text{AIC}_c$</th>
<th>$\omega_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLAT + DIST + PLAT × DIST + TYPE</td>
<td>288.240</td>
<td>7</td>
<td>302.617</td>
<td>0.000</td>
<td>0.287</td>
</tr>
<tr>
<td>PLAT + DIST + PLAT × DIST + SIZE + TYPE</td>
<td>284.727</td>
<td>9</td>
<td>303.337</td>
<td>0.720</td>
<td>0.201</td>
</tr>
<tr>
<td>PLAT + DIST + PLAT × DIST + DATE + TYPE</td>
<td>285.301</td>
<td>9</td>
<td>303.911</td>
<td>1.294</td>
<td>0.151</td>
</tr>
<tr>
<td>PLAT + DIST + PLAT × DIST + SIZE</td>
<td>288.080</td>
<td>8</td>
<td>304.567</td>
<td>1.949</td>
<td>0.108</td>
</tr>
<tr>
<td>PLAT + DIST + PLAT × DIST + DATE + SIZE + TYPE</td>
<td>282.380</td>
<td>11</td>
<td>305.281</td>
<td>2.664</td>
<td>0.076</td>
</tr>
<tr>
<td>PLAT + DIST + PLAT × DIST</td>
<td>293.108</td>
<td>6</td>
<td>305.390</td>
<td>2.772</td>
<td>0.072</td>
</tr>
<tr>
<td>PLAT + DIST + PLAT × DIST + DATE</td>
<td>289.540</td>
<td>8</td>
<td>306.026</td>
<td>3.409</td>
<td>0.052</td>
</tr>
<tr>
<td>PLAT + DIST + PLAT × DIST + DATE + SIZE</td>
<td>285.387</td>
<td>10</td>
<td>306.136</td>
<td>3.519</td>
<td>0.049</td>
</tr>
<tr>
<td>PLAT + SIZE + TYPE</td>
<td>300.615</td>
<td>6</td>
<td>312.897</td>
<td>10.279</td>
<td>0.002</td>
</tr>
</tbody>
</table>
Table 2.1. Continued

<table>
<thead>
<tr>
<th>Model&lt;sup&gt;a&lt;/sup&gt;</th>
<th>-2LL</th>
<th>K</th>
<th>( AIC_c )</th>
<th>( \Delta AIC_c )</th>
<th>( \omega_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLAT+TYPE</td>
<td>306.565</td>
<td>4</td>
<td>314.699</td>
<td>12.081</td>
<td>0.001</td>
</tr>
<tr>
<td>PLAT+SIZE</td>
<td>305.240</td>
<td>5</td>
<td>315.441</td>
<td>12.823</td>
<td>0.000</td>
</tr>
<tr>
<td>PLAT+DATE+SIZE+TYPE</td>
<td>300.040</td>
<td>8</td>
<td>316.526</td>
<td>13.909</td>
<td>0.000</td>
</tr>
<tr>
<td>PLAT+DATE+TYPE</td>
<td>305.862</td>
<td>6</td>
<td>318.144</td>
<td>15.527</td>
<td>0.000</td>
</tr>
<tr>
<td>PLAT+DATE+SIZE</td>
<td>304.445</td>
<td>7</td>
<td>318.822</td>
<td>16.205</td>
<td>0.000</td>
</tr>
<tr>
<td>PLAT</td>
<td>313.371</td>
<td>3</td>
<td>319.451</td>
<td>16.834</td>
<td>0.000</td>
</tr>
<tr>
<td>PLAT+DATE</td>
<td>312.338</td>
<td>5</td>
<td>322.538</td>
<td>19.921</td>
<td>0.000</td>
</tr>
</tbody>
</table>

<sup>a</sup> PLAT = aircraft platform, DIST = distance to lek, PLAT*DIST = platform \( \times \) distance interaction, TYPE = lek type (man-made or natural), SIZE = lek size, DATE = survey date + survey date squared.
Table 2.2. Coefficients for top 4 logistic regression models and model averaged coefficients for detectability of lesser prairie-chicken leks in Texas and New Mexico, USA, during spring 2007–2008.

<table>
<thead>
<tr>
<th>Model</th>
<th>Model 1&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Model 2&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Model 3&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Model 4&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Model Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\beta$</td>
<td>SE</td>
<td>$\beta$</td>
<td>SE</td>
<td>$\beta$</td>
</tr>
<tr>
<td>Platform 1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.5176</td>
<td>0.7323</td>
<td>3.3969</td>
<td>0.7344</td>
<td>3.7264</td>
</tr>
<tr>
<td>Platform 2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.2591</td>
<td>1.1044</td>
<td>5.2169</td>
<td>1.1081</td>
<td>5.4443</td>
</tr>
<tr>
<td>Distance</td>
<td>0.0080</td>
<td>0.0052</td>
<td>0.0072</td>
<td>0.0052</td>
<td>0.0073</td>
</tr>
<tr>
<td>Platform 1 x Distance</td>
<td>-0.0179</td>
<td>0.0060</td>
<td>-0.0165</td>
<td>0.0061</td>
<td>-0.0186</td>
</tr>
<tr>
<td>Platform 2 x Distance</td>
<td>-0.0179</td>
<td>0.0084</td>
<td>-0.0211</td>
<td>0.0084</td>
<td>-0.0223</td>
</tr>
<tr>
<td>Lek Type</td>
<td>0.6535</td>
<td>0.2971</td>
<td>0.5548</td>
<td>0.3031</td>
<td>0.6130</td>
</tr>
<tr>
<td>Size 1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.3589</td>
<td>0.3847</td>
<td>0.4244</td>
<td>0.3806</td>
<td>0.4244</td>
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<tr>
<td>Size 2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.7444</td>
<td>0.4027</td>
<td>0.8711</td>
<td>0.3947</td>
<td>0.7889</td>
</tr>
<tr>
<td>Date</td>
<td></td>
<td></td>
<td>0.0286</td>
<td>0.0392</td>
<td></td>
</tr>
<tr>
<td>Date&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td>-0.0002</td>
<td>0.0005</td>
<td></td>
</tr>
</tbody>
</table>
Model 1 = Platform + Distance + Platform × Distance + Lek Type; Model 2 = Platform + Distance + Platform × Distance + Lek Size + Lek Type; Model 3 = Platform + Distance + Platform × Distance + Survey Date + Lek Type; Model 4 = Platform + Distance + Platform × Distance + Lek Size

We used dummy variable coding where C172 was reference category. Platform 1 = R-22 referenced against C172, Platform 2 = R-44 referenced against C172.

We used dummy variable coding where small lek size was the reference category. Size 1 = medium lek referenced against small lek, Size 2 = large lek referenced against small lek.
Figure 2.1. Remote camera photo taken to determine lesser prairie-chicken lek activity during aerial lek survey in Yoakum County, Texas, USA, 21 April 2007.
Figure 2.2. The estimated probability of lesser prairie-chicken lek detection from aerial survey data collected in Texas and New Mexico, USA, during spring 2007–2008. Predictions based on logistic regression model of platform, distance, platform × distance interaction, and lek type.
CHAPTER III

BEHAVIORAL RESPONSE OF LESSER PRAIRIE-CHICKENS ON LEKS

TO AERIAL SURVEYS

Abstract

The lesser prairie-chicken (*Tympanuchus pallidicinctus* [LPC]) is a species of conservation concern. Aerial surveys can be used to detect and monitor LPC leks, but the need exists to understand the response of LPCs to survey aircraft. We conducted LPC lek surveys in Texas and New Mexico using a Cessna 172 airplane, R-22 Beta II helicopter, and R-44 Raven II helicopter. From the ground, we observed the behavior of LPCs at 49 leks during survey flights. We saw no flush response from the Cessna 172 during ground observations, yet observed flush responses of 38.5% (20.2–59.4%; 95% CI) and 50.0% (26.0–74.0%) from the R-22 and R-44, respectively. We found no difference in flush response between helicopter types (*P* = 0.326). We used logistic regression models to predict LPC flush response to aerial surveys. We found that distance from the transect was the most important flush response predictor during helicopter surveys. When flushed, LPCs returned to the lek and resumed pre-disturbance behavior in 7.0 ± 2.6 min (mean ± 95% CI). We believe aerial surveys can be conducted without harm to the LPC lek dynamic.
Introduction

The lesser prairie-chicken (*Tympanuchus pallidicinctus* [LPC]) is a species of prairie grouse that inhabits the High Plains of the Southern Great Plains of Texas, New Mexico, Oklahoma, Colorado, and Kansas (Hagen 2005). Historic populations numbers are reported to have been reduced by 97% since the 1800s (Crawford 1980) with the species’ distribution reduced substantially since pre-settlement (Crawford and Bolen 1976, Taylor and Guthery 1980, Giesen 1998, Hagen et al. 2004). Reductions in population size and occupied habitat are attributed to increased cultivation of grasslands for agriculture, mismanaged grazing regimes, and fragmented habitat (Braun et al. 1994). In 1998, the U.S. Fish and Wildlife Service (USFWS) was petitioned to list the LPC under the Endangered Species Act (USFWS 1998). The LPC was deemed “warranted, but precluded” for listing and is currently a candidate species with a listing priority of 2 (USFWS 2008). To successfully manage the declining species, a need to “think outside the box” with novel management approaches was identified for prairie grouse conservation efforts (Applegate et al. 2004). Lesser prairie-chickens have been, and are currently, monitored across their 5-state range with road-based surveys (Davis et al. 2008). This method is labor intensive, costly, and limited by access (Martin and Knopf 1981, Grensten 1987). Furthermore, road-based lek surveys may not be an efficient method to locate new or satellite leks to allow managers to estimate lek density. Lek density is critical for indicating LPC population trends and identifying temporary satellite leks is necessary to estimate population trends (Haukos and Smith 1999). We investigated the possibility of using aerial surveys to locate LPC leks (Chapter II). This
method would alleviate many of the disadvantages with road-based leks surveys; however, it is necessary to consider the impacts of potential disturbances from aircraft on LPCs.

Wildlife species are frequently counted, monitored, and captured from aircraft (Caughley 1977). Although the technique is expensive, it enables managers to cover large amounts of area or areas that are inaccessible by other means (Quang and Lanctot 1991). Efficiency of aerial surveys is often a question of detectability, bias, or flight parameters (Caughley 1974, Shupe et al. 1987, Green et al. 2006, Butler et al. 2007, Pearse et al. 2007). Efroymson (2001:251) identified the need, “to provide guidance for the assessment of ecological risks from low-altitude aircraft overflights.” Such guidance must be based on well designed wildlife studies.

Rarely has rigorous attention been given to impacts from aircraft on target avian species, and when impacts from aerial surveys have been reported, it was often anecdotal (Delaney et al. 1999). Delaney et al. (1999) noted that predictive models explaining the relationship between aerial disturbance and quantifiable effects on wildlife were scarce in the scientific literature. Aerial disturbance studies have been conducted in response to military flights (Anderson et al. 1989, Grubb and Bowerman 1997, Stalmaster and Kaiser 1997, Goudie and Jones 2004), yet military disturbances are often substantially different (i.e., sonic booms, low altitude, high sound intensity) than disturbances from aerial surveys for avian species. Aerial disturbance studies have been conducted on raptors (Anderson et al. 1989, Grubb and Bowerman 1997, Stalmaster and Kaiser 1997); waterfowl (Conomy et al. 1998, Ward et al. 1999, Goudie and Jones 2004); and seabirds
(Brown 1990, Harris 2005) with disturbance impacts varying among species and flight parameters.

Aerial surveys have been conducted on a large number of other avian species with no study of impact to the target species (e.g., Thorstrom et al. 2002, Butler et al. 2008). One particular group of birds that have been surveyed by aircraft with no subsequent response investigation are prairie grouse. Aerial surveys have been conducted on greater prairie-chickens (Tympanuchus cupido [GPC]) (Lehmann and Mauermann 1963, Martin and Knopf 1981), LPCs (Schroeder et al. 1992), and sage grouse (Centrocercus urophasianus) (Eng 1954). However, to our knowledge no report exists on the response of prairie grouse species to aerial surveys. Additionally, aerial surveys for prairie grouse typically occur during the critical spring lekking period. Therefore, it is essential to understand impacts of survey flights on LPCs and other prairie grouse species if aerial surveys are to be used responsibly for management activities. Therefore, our study objectives were to 1) assess aircraft disturbance to LPCs on leks, 2) identify variables that influence flush response, and 3) compare flush response among aircraft platforms.

**Study Area**

We collected aerial response data at 2 sites in Texas and 2 sites in eastern New Mexico. Study areas consisted of Federal, State, and privately owned lands. Lek densities ranged from 0.1–0.6 lek/km². The Texas study sites were located in Hemphill and Yoakum counties. The Hemphill County site (5,007 ha) was dominated by Tivoli fine sand and Springer loamy fine sand soils (Natural Resources Conservation Service
Texas Tech University, Jon T. McRoberts, August 2009

[NRCS] 2009). Average annual rainfall ranged from 38–64 cm and elevation in this region ranged from 670–1465 m (Vodehnal and Haufler 2008). The site was a short-mixed grass prairie ecosystem dominated by little bluestem (*Schizachyrium scoparium*) and sand sagebrush (*Artemisia filifolia*). The Yoakum County site (2,905 ha) was dominated by Brownfield fine sand and Brownfield-Circleback fine sand soils (NRCS 2009). The site was a xeric, sand dune ecosystem dominated by little bluestem (*Schizachyrium scoparium*) and shinnery oak (*Quercus havardii*). The New Mexico study sites were located in Chaves (3,961 ha) and Roosevelt (3,444 ha) counties. Both sites shared vegetative characteristics of the Yoakum County site and were dominated by Brownfield fine sand and Tivoli fine sand soil types (NRCS 2009). For the Yoakum, Chaves, and Roosevelt counties region, Vodehnal and Haufler (2008) reported average annual rainfall of 33–56 cm and elevation of 795–1585 m. All sites received light to moderate grazing and either had active oil or gas wells, or remnants of wells.

**Methods**

**Aerial Surveys**

We conducted aerial transect surveys for LPC leks during the spring of 2007–2009. During 2007, we conducted surveys in 3 aircraft: a Cessna 172 fixed-wing airplane (Cessna Aircraft Company, Wichita, KS; hereon C172), R-22 Beta II helicopter, and R-44 Raven II helicopter (Robinson Helicopter Company, Torrance, CA; hereon R-22 and R-44). We varied surveys among aircraft to prevent a seasonal response bias toward any of the platforms. During 2008 and 2009 we did not use the C172. Transects were
separated by 400 m giving a searchable distance of 200 m on either side of the transect. Surveys were flown at an altitude of 50 m for the C172 and 15 m for the R-22 and R-44. Target flight speeds were 140 km/hr for the C172 and 60 km/hr for the helicopters. Minor deviations in flight speed occurred as needed to maintain safe flying conditions. We began surveys at sunrise and concluded surveys no later than 2.5 hr post-sunrise.

Response Monitoring

We observed LPC response to aerial surveys by conducting ground-based lek observations concurrent with aerial surveys. We used flushing as our measure of LPC response to aerial surveys. We used a binary variable classification (i.e., lek flushed or did not flush) because single birds within a flock usually responded as a flock (Bélanger and Bédard 1989, Ward et al. 1994).

We positioned lek observers near known leks in either a blind or a vehicle. Observation points ranged from 35–200 m from the core area of the lek, depending on the characteristics and visibility of the lek. Observers arrived prior to sunrise and approached the observation point cautiously to prevent flushing LPCs when birds were already present on the lek. Observers recorded the number of male and female LPCs on the lek at 5-min intervals (Appendix D). During the 5-min interval, we scan-sampled the lek and recorded behavior such as strutting/displaying, face-offs, fighting, stationary-loafing, stationary-alert, feeding, and copulations (Appendix D). By noting the behavior prior to aircraft presence we determined the time span from disruption to resumption of normal lekking behavior if a flush response occurred. As aircraft approached, observers switched to continuous monitoring and noted LPC behavior during the disturbance period.
(transect with greatest auditory and visual aircraft presence). If LPCs flushed from the lek as a result of the aerial survey we noted the time of the flush. Observers monitored the lek at least 1 hr after the disturbance to quantify the elapsed time until LPCs returned to the lek and resumed normal lekking behavior, or to determine if LPCs did not return during the 1 hr monitoring period.

**Data Analysis**

We monitored known lek locations and calculated perpendicular distance from the center of the lek to the aerial transect line. We calculated this distance using the minimum-distance function in ArcGIS® 9.2 (Environmental Systems Research Institute, Inc., Redlands, CA). We generated a standardized survey date value by assigning the day of our earliest survey date, 8 March, as standardized date value 0 and consecutively numbered until our latest survey date, 17 May, which received a value of 70. The standardized date allowed us to include a comparable date value for surveys conducted in different years. We used Fisher’s exact test (Conover 1999) to compare flush responses among aircraft platforms.

We created predictive flush models using logistic regression (Hosmer and Lemeshow 2000) to model the probability of LPC lek flush due to disturbance from aerial surveys. We created and evaluated 7 *a priori* candidate models using aircraft platform, distance to lek, and survey date as covariables. We used the second order Akaike’s Information Criterion (AIC<sub>c</sub>) weights to determine the predictive accuracy of models (Burnham and Anderson 2002, Forster and Sober 2004, Anderson 2008). We evaluated the goodness-of-fit of the most parameterized model using the Hosmer-Lemeshow test.
Each individual lek response was considered a unique sample. We used SPSS® 16.0 (SPSS Inc., Chicago, IL) to analyze the data. We also classified observations in 1 of 4 categories in a manner similar to that used by Krausman and Hervert (1983) to classify the response of mountain sheep (*Ovis canadensis mexicana*) to aerial surveys, and Anderson et al. (1989) to classify red-tailed hawk (*Buteo jamaicensis*) response to helicopter overflights. We classified LPCs as “no response” to aerial surveys if LPCs did not flush. We classified LPCs that flushed with subsequent return as “flush with return” and the time for LPCs to return to the lek and resume pre-disturbance lekking activity was recorded. We classified LPCs that flushed and did not return within 1 hr as “flush with no return,” whereas LPCs that flushed and permanently abandoned the lek were classified as “lek abandoned” (though lek abandonment was never observed). We classified lek responses in this manner to draw inferences on rates of different disturbance responses among aircraft platforms and compare the average return time if LPCs flushed and returned to resume lekking.

**Results**

We recorded 49 ground-based lek observations during our survey periods of 8 March 2007–17 May 2007, 12 March 2008–10 May 2008, and 03 April 2009. Of the 49 ground observations, 26 were of the response to the R-22, 18 were of the response to the R-44, and 5 were of the response to the C172. Flight parameters were different between helicopters and fixed-wing aircraft and we treated them as 2 separate classes. We never observed LPCs running from a lek in response to approaching aircraft. If LPCs flushed,
they typically flushed as the aircraft approached, or when the aircraft was perpendicular to the lek. We observed LPCs flushing after the aircraft passed the lek on 1 occasion.

We observed flushing on 0 of 5 observations (0.0–45.07%; 95% CI) when surveys were conducted with the C172. We observed LPCs flushing on 10 of 26 observations (38.5% [20.2–59.4%]) when surveys were conducted with the R-22, and on 9 of 18 observations (50.0% [26.0–74.0%]) when surveys were conducted with the R-44. Flush response was similar between helicopters ($P = 0.326$; Fisher’s exact test). We observed that LPCs flushed and returned to the lek on 14 occasions with an average return time of $7.0 \pm 2.6$ min (mean $\pm$ 95% CI). We used a 2-sample $t$-test and found no difference (SE = 2.698, $t = 0.847$, df = 12, $P = 0.413$) between average return time when flushed by a R-22 (8.14 min, SE = 2.41) or a R-44 (5.86 min, SE = 1.20). We observed that LPCs flushed from the lek and did not return within the 1 hr post-flush monitoring window on 5 occasions (R-22, $n = 3$; R-44, $n = 2$). However, all of the leks with a flush and no return response remained active through the lekking season. We did not observe a single instance of LPCs permanently abandoning a lek as a result of aerial surveys.

We used helicopter platform, distance from the transect to the lek, and standardized survey date to create predictive models to explain flush response. The C172 was not incorporated into our models because of the small number of observations from that platform. We created 7 candidate a priori logistic regression models (Table 3.1). The most parameterized model fit the data ($\chi^2 = 1.480$, df = 8, $P = 0.993$). Our modeling exercise yielded 3 competitive models. Our model incorporating distance had the most predictive ability ($\omega_i = 0.326$). This model showed that with every 1 m increase in
distance from the transect line to the center of the lek there was a 1.0% decrease in probability of LPCs flushing (odds ratio = 0.99; $W = 3.661$, df = 1, $P = 0.056$). Our model including distance and survey date was a second competitive model. This model showed that with every 1 m increase in distance there was a 0.9% decrease in probability of LPCs flushing (odd ratio = 0.99; $W = 2.604$, df = 1, $P = 0.107$) and that as standard survey date increased by 1 day there was a 2.2% decrease in probability of LPCs flushing (odds ratio = 0.98; $W = 1.112$, df = 1, $P = 0.292$). Our third competitive model contained survey date and suggested that as standard survey date increased by 1 day there was a 3.0% decrease in probability of LPCs flushing (odds ratio = 0.97; $W = 2.258$, df = 1, $P = 0.133$). These models indicated that LPCs were less likely to flush as distance from the transect to the lek increased and as the spring lekking season progressed.

**Discussion**

This is the first study to quantifiably document the response of prairie grouse on leks to aerial surveys. We feel that flushing appeared to serve as an appropriate indicator of LPC response to aircraft, but cannot offer additional behavioral cues to indicate response to aircraft. We observed frequent lapses in displaying, calling, or other activities typical of lekking prairie grouse throughout our observational efforts, but pauses in lekking behavior would be difficult to attribute to aerial disturbance.

We concluded that aerial survey disturbance did not negatively impact LPCs. We did not observe a flush response in a majority (56.8% [41.0–71.7%; 95% CI]) of our observations. When LPCs did flush in response to aerial surveys, they generally (73.7%
(48.8–90.1%) returned to the lek and resumed pre-disturbance behavior within a 10-min interval. Through the course of our 3-year study we observed 5 occasions when LPCs flushed from the lek and did not return within our 1-hr post-disturbance monitoring window. These are the most troubling data because of possible missed reproductive opportunities. However, the 5 flushes without return observations represented a small percentage (10.2% [3.4–22.2%]) of our response data. Furthermore, 4 of these flushes occurred outside the timeframe of peak daily lek attendance of males (i.e., 105 min after sunrise; Crawford and Bolen 1975) and 4 occurred outside the period of peak female lek attendance (i.e., second and third weeks of April; Hagen 2005).

Distance from the lek to the transect was the most important predictor within our helicopter flush response models. We are unable to compare this conclusion to other species of prairie grouse, but Ward et al. (1999) reached the same conclusion when modeling the response of geese (Branta spp.). Furthermore, Delaney et al. (1999) found that as helicopter stimulus distance decreased, Mexican spotted owls (Strix occidentalis lucida) flush frequency increased. We designed our aerial surveys methodology in a manner so that the maximum distance from the aircraft to a lek was 200 m. As distance progressed toward the 200 m maximum, we observed a decrease in flushing frequency. If transect spacing was decreased we would expect to see a greater flush response among LPCs. Conversely, if transect spacing was increased we would expect to see a lower flush response.

We found no difference in flush response between the 2 helicopter platforms. This is likely explained by the similar flyover sound intensity of the R-44 and the R-22,
measured at 81.9 dB and 81.3 dB, respectively (personal communication, C. Sennett, Robinson Helicopter Co.). The length of the R-44 (11.7 m) is greater than the R-22 (8.8 m) (personal communication, C. Sennett, Robinson Helicopter Co.), but is seems unlikely the difference would be perceived by LPCs and affect flushing.

Our lek observation sample size was small ($n = 5$) for the C172, but some trends were apparent. No leks flushed in response to fixed-wing aircraft and we feel this could be a result of different flight methodology. A likely difference in flush response was due to altitude and speed of C172 surveys. To maintain safe flying conditions we conducted fixed-wing survey flights at an attitude $>3$ times and at a speed $>2$ times than that of the helicopter surveys. These differences in methodology resulted in a disturbance source that was further from the lek with a comparatively shorter duration. Had we flown the C172 at the same altitude and speed as the helicopters (though safety consideration make that impossible) we would likely have seen a greater flush response.

Martin and Knopf (1981) noted that GPCs flushed from C172 surveys flown at an altitude of 25–50 m. We conducted surveys at 50 m, potentially twice as high as surveys conducted by Martin and Knopf (1981) and the lower range of their survey altitude could explain their flush observations. Lehmann and Mauermann (1963) found that Attwater’s prairie-chickens ($T. c. pinnatus$) showed less response to helicopters than of an airplane, and also observed that lek courtship activity and feeding often continued uninterrupted when the helicopter was in close proximity. We are unaware of the flight parameters they implemented, but their conclusions support those of Martin and Knopf (1981) that prairie grouse do respond to fixed-wing aircraft, and support our conclusion that
helicopter surveys are not detrimental to the lekking system. Furthermore, had we monitored additional responses to C172 surveys it seems probable that we would have observed a flush response, and our reported 0.0% flush response is likely a misrepresentation based on a small sample size.

We found that flush response decreased as our study progressed each spring. Lek monitoring efforts began in early March and continued through mid-May. This time coincided with the peak of lek activity and female attendance. We concluded our flights in mid-May, when males were still regularly attending leks but we observed males on leks through early June. We offer 2 explanations for the decrease in flush response through our monitoring period. The first, and what we consider more likely, is that as female lek attendance peaks during mid-April (Crawford and Bolen 1975, Hagen 2005) the resulting increase in intensity of displaying activity among males (Hagen 2005) causes fewer flush responses. However, it is important to note that our surveys were completed toward the end of lekking season. If we continued to fly surveys and monitor LPC response into June we may find that flushing response increases as lekking intensity decreases at the end of the lekking season. Our conclusion that flush responses decrease with date should be taken in the context of our monitoring period of mid-March through mid-May. Martin and Knopf (1981) noticed a similar pattern of GPCs tending not to flush from aircraft as spring progressed.

The second hypothesis to explain the decreased flush response through our monitoring period was that LPCs habituate to aircraft disturbance. Avian species have been documented to habituate to aircraft over time (Anderson et al. 1989, Conomy et al.
We do not feel this was the underlying reason LPCs did not flush from leks. No lek was exposed to aerial surveys more than 8 times throughout a spring. Furthermore, we applied our methodology to 2 additional areas that had not been previously exposed to aircraft disturbance and timed these surveys to coincide with peak lekking activity. During these surveys we detected leks from the air, but ground observers did not see a flush response from the LPCs attending the leks. Pelletier and Krebs (1998) found that ptarmigan (*Lagopus* spp.) did not appear to habituate to aerial surveys. These observations support the hypothesis that flush response was more likely to be dependent on lekking activity than habituation.

**Management Implications**

We believe that helicopter surveys separated by 400 m and flown at an altitude of 15 m can be used during the spring lekking season to detect new leks and estimate lek density without adverse affects on LPCs. If managers want to minimize flush responses during aerial surveys, we suggest widening transects because we found distance from the transect to the lek was the greatest indicator of a flush response. We also suggest waiting until the weeks immediately following the peak of lekking activity to conduct surveys if managers hope to reduce flushing. We found that flushing decreased through the lekking season, a conclusion supported by other studies. We suggest investigators monitor flush response from fixed-wing aircraft due to our small sample size. Our recommendations are specific to the aircraft platforms used in this study. If other aircraft platforms are used to conduct surveys, investigators may also need to monitor LPC behavior in
response to other platforms not evaluated by our study. We recommend conducting lek observations during aerial surveys to determine if different responses exist among prairie grouse species.

**Acknowledgments**

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Literature Cited


(Meleagris gallopavo) detectability from helicopters and ramifications for 


Sons, New York, New York, USA.

Pages 1–7 in P. A. Vows and F. L. Knopf, editors. Proceedings of the Prairie 
Grouse Symposium. Oklahoma State University, Stillwater, Oklahoma, USA.


prairie-chicken conservation initiative. Lesser prairie chicken interstate working 


   Estimation and correction of visibility bias in aerial surveys of wintering ducks. 

Pelletier, L., and C. J. Krebs. 1998. Evaluation of aerial surveys of ptarmigan Lagopus 

   Biometrics 47:1089–1102.

   estimating numbers of greater and lesser prairie-chicken leks in eastern Colorado. 


Stalmaster, M. V., and J. L. Kaiser. 1997. Flushing responses of wintering bald eagles to 


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.


Table 3.1. Ranking of candidate logistic regression models predicting flush response from helicopter surveys for lesser prairie-chickens in Texas and New Mexico, USA, 2007–2009. For each logistic regression model, we give $-2\times\text{log-likelihood}$ ($-2\text{LL}$), number of parameters ($K$), second-order Akaike’s Information Criterion ($\text{AIC}_c$), difference in $\text{AIC}_c$ compared to lowest $\text{AIC}_c$ of the model set ($\Delta_i$), and $\text{AIC}_c$ weight ($\omega_i$) ($n = 44$).

<table>
<thead>
<tr>
<th>Model</th>
<th>$-2\text{LL}$</th>
<th>$K$</th>
<th>$\text{AIC}_c$</th>
<th>$\Delta_i$</th>
<th>$\omega_i$</th>
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</thead>
<tbody>
<tr>
<td>DIST</td>
<td>56.177</td>
<td>2</td>
<td>60.470</td>
<td>0.000</td>
<td>0.326</td>
</tr>
<tr>
<td>DIST + DATE</td>
<td>55.036</td>
<td>3</td>
<td>61.636</td>
<td>1.166</td>
<td>0.182</td>
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<tr>
<td>DATE</td>
<td>57.799</td>
<td>2</td>
<td>62.091</td>
<td>1.622</td>
<td>0.145</td>
</tr>
<tr>
<td>PLAT + DIST$^b$</td>
<td>55.595</td>
<td>3</td>
<td>62.195</td>
<td>1.725</td>
<td>0.138</td>
</tr>
<tr>
<td>PLAT + DATE + DIST</td>
<td>54.245</td>
<td>4</td>
<td>63.270</td>
<td>2.800</td>
<td>0.080</td>
</tr>
<tr>
<td>PLAT + DATE</td>
<td>56.931</td>
<td>3</td>
<td>63.531</td>
<td>3.061</td>
<td>0.071</td>
</tr>
<tr>
<td>PLAT</td>
<td>59.600</td>
<td>2</td>
<td>63.892</td>
<td>3.423</td>
<td>0.059</td>
</tr>
</tbody>
</table>

$^a$ DISTANCE = perpendicular distance from transect to lek, DATE = standardized survey date of aerial survey, PLAT = aircraft platform (R-44 = 1, R-22 = 0).

$^b$ The effect of PLAT is likely spurious because the $-2\text{LL}$ of the PLAT + DIST model changes <0.6 when compared to the DBH model.
CHAPTER IV
CONCLUSION

This study was suggested by Texas Parks and Wildlife Department field biologists responsible for ground-based lek counts and surveys for lesser prairie-chickens (*Tympanuchus pallidicinctus* [LPC]). These individuals saw the need to refine or replace the traditional lek monitoring methodology. They needed a technique to remove the bias of surveying from roads, rapidly survey large tracks of remote habitat, find new leks, and accurately determine LPC occupied range. We believe our aerial survey data show that lek surveys can be conducted in remote habitat away from roads. Furthermore, we located previously unknown leks during survey flights and we saw leks appear and disappear between spring 2007 and 2008. We refined aerial survey methodology, identified factors that influenced lek detectability from aircraft, and monitored leks to determine if aerial surveys are detrimental to the lekking system.

Lek detectability was greatest at 89.8% (82.0–95.0%; 95% CI) when using the R-44 Raven II helicopter. Lek detectability from the R-22 Beta II helicopter was 72.3% (64.5–79.1%). We found that small leks were less likely to be detected than large or medium leks. The small leks could likely be satellite leks. These leks are important for estimates of lek density and population trends. We recommend conducting lek surveys in the R-44, if management resources permit, to boost detectability and hopefully detect small leks. The price of the fixed-wing Cessna 172 (C172) airplane was considerably lower than either helicopter platform. However, we found that lek detectability was
lowest at 32.7% (20.3–47.1%) with the C172. We do not recommend lek surveys from the C172 because of the strip of habitat not viewable directly below the airplane and safety concerns.

Our data suggest that aerial surveys are an effective method to survey for leks. However, it was also necessary to determine if aerial surveys disrupted lekking, rendering the methodology unfit for LPC management. We monitored LPCs on leks as aircraft passed over or near the lek and observed that LPCs showed no response to aircraft on 56.8% (41.0–71.7%) of observations. When we did observer LPCs flushing in response to aerial surveys, the LPCs typically returned to the lek in a short amount of time (7.0 ± 2.6 min; mean ± 95% CI) and resumed pre-disturbance lekking behavior. Based on our observations we feel that aerial surveys do not disrupt the lekking dynamic.

We designed our aerial survey technique for repetition. We avoided expensive and specialized technology with the hope that wildlife managers could implement our methodology with equipment they currently possess. We believe the knowledge is in place to conduct surveys to locate leks and we believe a change in lek survey methodology would assist LPC management goals.
APPENDIX A

AERIAL ESTIMATION OF THE NUMBER OF LESSER PRAIRIE-CHICKENS
ATTENDING LEKS
We attempted to count the number of lesser prairie-chickens (*Tympanuchus pallidicinctus* [LPC]) attending a lek during 2007–2008 aerial surveys. We did not deviate from our transect or target flight speed to obtain counts because lek counts were not a study objective. Previous investigations documented the difficulty of making an accurate count of prairie grouse (*Centrocercus* and *Tympanuchus* spp.) on leks during aerial surveys (Eng 1955, Lehmann and Mauermann 1963, Martin and Knopf 1981, Schroeder et al. 1992). However, no metric has been published to support this claim. Our objective was to quantify the difference in counts made from aerial observers to counts made from ground observers to determine if aerial lek counts are possible. We collected 50 paired lek counts taken from the ground and the air during spring 2007 and 2008. We observed 27 counts from the R-22 Beta II helicopter, 17 from the R-44 Raven II helicopter (Robinson Helicopter Co., Torrance, CA), and 6 from the Cessna 172 fixed-wing aircraft (Cessna Aircraft Co., Wichita, KS). We counted an average of 13.1 LPCs (SE = 1.216) during lek ground counts, yet counted an average of 5.5 LPCs (SE = 0.801) on the same leks from the air when aircraft observations were pooled. We used a paired $t$-test and found an average difference of 7.6 LPCs (SE = 0.929, $t = 8.182$, df = 49, $P = \leq 0.001$) between aerial and ground counts. Additionally, we found the magnitude of difference between aerial and ground counts was similar among platforms ($F = 2.219$, df = 2, 47, $P = 0.120$). We believe that more observations are needed to obtain a correction factor to account for LPCs not counted from the air. While it may be tempting to try to extrapolate total population estimates from these data, that is not possible at this time and should not be attempted.
Literature Cited

Eng, R. L. 1954. Use of aerial coverage in sage grouse strutting ground counts.

Proceedings of the Annual Conference of the Western Association of State Game
and Fish Commissioners 34:231–233.


estimating numbers of greater and lesser prairie-chicken leks in eastern Colorado.

APPENDIX B

2007 AERIAL LEK SURVEY SUMMARY

<table>
<thead>
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a Test flight not included in analysis.
Figure B.1. Lesser prairie-chicken aerial survey, Chaves County New Mexico, USA, 8 March 2007.
Figure B.2. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 16 March 2007.
Figure B.3. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 18 March 2007.
Figure B.4. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 25 March 2007.
Figure B.5. Lesser prairie-chicken aerial survey, Lea County, New Mexico, 26 March 2007.
Figure B.6. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 27 March 2007.
Figure B.7. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 29 March 2007.
Figure B.8. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 31 March 2007.
Figure B.9. Lesser prairie-chicken aerial survey, Hemphill County, Texas, USA, 3 April 2007.
Figure B.10. Lesser prairie-chicken aerial survey, Hemphill County, Texas, USA 4 April 2007.
Figure B.11. Lesser prairie-chicken aerial survey, Hemphill County, Texas, USA, 5 April 2007.
Figure B.12. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 10 April 2007.
Figure B.13. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 11 April 2007.
Figure B.14. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 13 April 2007.
Figure B.15. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 15 April 2007.
Figure B.16. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 16 April 2007.
Figure B.17. Lesser prairie-chicken aerial survey, Hemphill County, Texas, USA, 18 April 2007.
Figure B.18. Lesser prairie-chicken aerial survey, Hemphill County, Texas, USA, 19 April 2007.
Figure B.19. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 21 April 2007.
Figure B.20. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 22 April 2007.
Figure B.21. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 23 April 2007.
Figure B.22. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 24 April 2007.
Figure B.23. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 25 April 2007.
Figure B.24. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 26 April 2007.
Figure B.25. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 27 April 2007.
Figure B.26. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 29 April 2007.
Figure B.27. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 1 May 2007.
Figure B.28. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 3 May 2007.
Figure B.29. Lesser prairie-chicken aerial survey, Hemphill County, Texas, USA, 6 May 2007.
Figure B.30. Lesser prairie-chicken aerial survey, Hemphill County, Texas, USA, 7 May 2007.
Figure B.31. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 10 May 2007.
Figure B.32. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 11 May 2007.
Figure B.33. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 16 May 2007.
Figure B.34. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 17 May 2007.
APPENDIX C

2008 AERIAL LEK SURVEY SUMMARY
Table C.1. Summary of Lesser prairie-chicken aerial survey data in Texas and New Mexico, USA, 12 March–13 May 2008.

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Figure C.1. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 12 March 2008.
Figure C.2. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 13 March 2008.
Figure C.3. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 13 March 2008.
Figure C.4. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 20 March 2008.
Figure C.5. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 21 March 2008.
Figure C.6. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 26 March 2008.
Figure C.7. Lesser prairie-chicken aerial survey, Yoakum County, Texas, USA, 27 March 2008.
Figure C.8. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 2 April 2008.
Figure C.9. Lesser prairie-chicken aerial survey, Hemphill County, Texas, USA, 4 April 2008.
Figure C.10. Lesser prairie-chicken aerial survey, Hemphill County, Texas, USA, 5 April 2008.
Figure C.11. Lesser prairie-chicken aerial survey, Hemphill County, Texas, USA, 6 April 2008.
Figure C.12. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 11 April 2008.
Figure C.13. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 12 April 2008.
Figure C.14. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 13 April 2008.
Figure C.15. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 18 April 2008.
Figure C.16. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 19 April 2008.
Figure C.17. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 20 April 2008.
Figure C.18. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 28 April 2008.
Figure C.19. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 29 April 2008.
Figure C.20. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 30 April 2008.
Figure C.21. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 5 May 2008.
Figure C.22. Lesser prairie-chicken aerial survey, Roosevelt County, New Mexico, USA, 6 May 2008.
Figure C.23. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 8 May 2008.
Figure C.24. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 9 May 2008.
Figure C.25. Lesser prairie-chicken aerial survey, Chaves County, New Mexico, USA, 10 May 2008.
APPENDIX D

LESSER PRAIRIE-CHICKEN AERIAL SURVEY

DATA SHEETS
### Lesser Prairie Chicken Aerial Survey Data Form

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<th>Height (m)</th>
<th>Sighted by</th>
<th># of Birds</th>
<th>Flushed Y/N (how many)</th>
<th>Man-made or Nat. Lek</th>
<th>Veg. Type</th>
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**Figure D.1.** Lesser prairie-chicken aerial survey data form.
### Figure D.2. Lesser prairie-chicken disturbance response data form.

<table>
<thead>
<tr>
<th>Time</th>
<th># Males</th>
<th># Females</th>
<th>Lek Total</th>
<th>Notes</th>
<th>Behavior (note: face-offs, booming/display, fighting, copulation attempts, etc.)</th>
<th>Cloud (%)</th>
<th>Precip.</th>
<th>Wind Speed/Temp.</th>
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_______________________________  _______________________
Jon T. McRoberts                                2 July 2009
Student Signature                                Date

Disagree  (Permission is not granted.)

_______________________________  _______________________
Student Signature                                Date