HABITAT USE AND GROWTH AND DEVELOPMENT

OF JUVENILE LESSER PRAIRIE CHICKENS

IN SOUTHEAST NEW MEXICO

By

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PREFACE

This study evaluated habitat and microclimate use and the growth and development of lesser prairie-chicken broods in southeast New Mexico. Lesser prairie-chickens have a tendency to remain within 4.8 km of a lek. Within 4.8 km of each lek trapped for hens, hens with broods had the potential to select sites of sand shinnery oak that were treated with herbicides and sites not treated with herbicides. Specific objectives were (1) to determine if broods were selecting locations that are different in terms of the thermal microclimate than random locations for different times of the day, (2) to identify brood habitat differences among multiple spatial scales, times of day and random locations from three different land management practices, (3) determine the effects of herbicide applications, commonly used as surrogates for historical fire regimes, and other land management practices on brood rearing habitat and to (4) compare juvenile growth rates to Kansas juvenile lesser prairie-chickens.

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TABLE OF CONTENTS

Chapter Page

I. INTRODUCTION……..…...1

II. HABITAT USE OF LESSER PRAIRIE-CHICKEN BROODS IN SOUTHEASTERN NEW MEXICO…….....3

Abstract……..4

Introduction…….……...4

Methods…….……7

Results…..……...…….……14

Discussion……...…….……19

Literature Cited…….……...27

III. GROWTH AND DEVELOPMENT OF LESSER PRAIRIE-CHICKEN BROODS IN SOUTHEAST NEW MEXICO…….....41

Abstract……42

Introduction…….……42

Methods…….……...43

Results / Discussion…….……46

Literature Cited…….……...50

LIST OF TABLES

CHAPTER II

Table: Page

1. Dominant plant species in each plant category found at brood and random locations. The superscript "a" denotes plants included in "Other" stem density and "b" denotes plants included in "Other" canopy and basal cover contacts……..……32

2. Comparison of all variables sampled at brood locations and each land management practice. Capital letters indicate variables significantly different from brood locations (e.g. H = "higher than brood" and L = "lower than brood") in the same row. Areas that were grazed with no herbicides were most similar to brood locations and ungrazed herbicide sites were least similar to brood locations. Broods could be found on all sites, but only on areas similar to their selected variables. For example, on ungrazed herbicide sites sand dunes were left untreated and provided the structural habitat characteristics selected by broods. On all 3 land management types, temperature did not differ from brood locations during "cool" time periods. However, during "warm" time periods temperatures on the 3 land management types were significantly hotter than brood locations…….……...…….33

3. Comparison of all variables sampled at brood and random locations within each land management practice. Capital letters indicate variables significantly different from brood locations (e.g. H = "higher than brood" and L = "lower than brood") in the same row. Brood and random locations within areas that were grazed without herbicide use were most similar for and land management practice. Sites ungrazed and treated with herbicide contained the greatest difference for all variables measured at brood and random locations within these sites. On all 3 land management types, temperature did not differ between brood and random locations within each site during "cool" time periods. However, during "warm" time periods temperatures on grazed sites without herbicide use were significantly hotter than brood locations.....34

CHAPTER III

Table: Page

1. Parameter estimates and 95% bootstrap bias-corrected accelerated confidence intervals (CI_L, CI_U) for equations describing growth of Lesser Prairie-Chickens in southeast New Mexico. Growth rate (*K*) and inflection point (*I*) were estimated through modeling using the logistic equation for mass and Gompertz equation for wing chord. Time (*t*) needed to grow from 10 to 90% of the asymptote is presented

for mass and 50 to 90% of the asymptote wing chord.

All asymptotes (*A*) were fixed in our modeling efforts. We estimated asymptotes by randomly selecting an equal number of male and female juvenile birds from the following spring seasons of each sampled summer. We then pooled these values across genders and years to calculate a mean, standard error, and sample size for each measure; the values for body mass and wing chord are as follows: (713 ± 7 g, $n = 32$) and (210 ± 1 g, $n = 32$) for juvenile lesser prairie-chickens captured in spring seasons of 2003 and 2004 for southeast New Mexico……..54

2. Measurements (mean ± SE) of body mass, bill length, head width, and wing chord length for juvenile lesser prairie-chickens from 0 to 115 days post-hatching in southeastern New Mexico. Time intervals of 5 days were used to summarize the data.

   No data were collected from chicks between 16-20, 46-60, 66-100, and 106-110 days post-hatching……...55

LIST OF FIGURES

CHAPTER II

Figure: Page

1. Demonstrates the selection of temperatures by broods that are counter in terms of what temperature is available at random locations. Temperature at brood locations with corresponding random average temperature according to time of day (a) and temperature difference according to random average temperature (b) for brood locations in southeastern New Mexico, summers of 2002 – 2003. Graph b was used to separate brood locations into 2 categories of temperature selection as indicated by the vertical line that separates the graph into "cool" and "warm" time periods……36

2. Differences of habitat use at multiple spatial scales and temperature categories by lesser prairie-chicken broods. Broods selected higher rod contacts (i.e. tallest rod contacts), more rod contacts 10-50 cm and > 50 cm during "warm" time periods at the point scale. The importance of sand shinnery oak is demonstrated by looking at its stem density; broods always selected higher stem densities of sand shinnery oak regardless of spatial scale or temperature. Vertical lines represent 1 SE.....38

3. Brood habitat selection within ungrazed herbicide area using Ivlev's Electivity Index for habitat preference-avoidance analysis on lesser prairie-chicken broods in New Mexico. Ivlev's index varies from -1.0 to +1.0, with positive values indicating preference, negative values avoidance, and 0 indicating random use. Broods (n = 6) located on ungrazed herbicide area selected sand dunes that were not treated with herbicide. Only 17% of brood locations (n = 81) found on ungrazed herbicide sites used areas treated with herbicide and these locations were during cool times of the day……40

CHAPTER III

Figure: Page

1. Growth curves and relationships between morphological attributes of juvenile lesser prairie-chickens as described by the logistic (mass) (n = 46) and Gompertz growth equations (wing chord) (n = 43)…….53

CHAPTER I

INTRODUCTION

This Thesis is composed of 2 manuscripts that are formatted for submission to scientific journals. Chapter 2 is formatted for submission to Conservation Biology, a publication of the Society for Conservation Biology, whereas chapter 3 is formatted for The Prairie Naturalist, a publication of Great Plains Natural Science Society.

CHAPTER II

HABITAT USE OF JUVENILE LESSER PRAIRIE CHICKENS IN SOUTHEAST NEW MEXICO

Abstract – The structural attributes of shrubland plant communities may provide thermal refugia and protective cover necessary for wild animals to survive. We evaluated the wide spread effects of herbicide use on sand shinnery oak plant communities to determine what impact herbicides might have on the thermal environment for lesser prairie-chicken broods in southeast New Mexico during the summers of 2002 and 2003. Based on data from 257 brood locations and 53 random locations, lesser prairie-chicken broods selected locations on sand shinnery oak dominance with taller plant heights and more over head cover when temperatures exceeded 26.4 °C than what was available at random. Temperatures did not differ between random sites in presence or absence of herbicide applications. Habitat selection was more dependent on the structural attributes contained within areas not treated with herbicide and these sites were often selected at a fine spatial scale. Habitat management that seeks to conserve native shrublands may increase the abundance or help to sustain populations of lesser prairie-chickens in semi-arid environments.

Introduction

Grasslands and shrublands of the Great Plains are some of the most imperiled ecosystems in the world (Samson and Knopf 1994). In the past 100 years more than 500,000 ha of sand shinnery oak (*Quercus havardii*) plant communities have been converted to cropland or grassland in the Southern Great Plains (Peterson and Boyd 1998). Some of these sand shinnery oak conversions were conducted as habitat improvement and conservation efforts to benefit wildlife (Doerr and Guthery 1983, Olawsky and Smith 1991); however, decline in sand shinnery oak plant communities has also led to the decline or displacement of other organisms within this region (Degenhardt

and Jones 1972, Willig et al. 1993, Johnson et al. 2004). Specifically, lesser prairie-chicken (*Tympanuchus pallidicinctus*) populations occupy only 18% of their historic range as of 1963 with an additional loss of 78% from 1963 to 1980 (Crawford 1980, Taylor and Guthery 1980). Population declines are largely correlated with declining native shrubland plant communities, including sand shinnery oak (Peterson and Boyd 1998, Bailey and Williams 2000, Sullivan et al. 2000). Hence, it is important to examine the relationship of native shrubland plant communities to lesser prairie-chickens and determine the importance of shrubs to populations of this declining species that has become an indicator of many ecosystems in the southern Great Plains.

Oddly enough, some researchers indicate that removing sand shinnery oak might benefit lesser prairie-chickens (Doerr and Guthery 1983, Olawsky and Smith 1991), but permanently removing sand shinnery oak with herbicides seems illogical because (1) sand shinnery oak is a slow reproducing rhizomatous shrub that does not invade previously unoccupied areas (Wiedeman 1960, Dhillion et al. 1994); (2) sand shinnery oak is part of a rapid decline of plant communities associated with North America's diminishing Great Plains (Samson and Knopf 1994, Peterson and Boyd 1998); (3) lesser prairie-chickens have been repeatedly documented as dependent on shrublands across their range (Copelin 1963, Olawsky and Smith 1991, Boyd and Bidwell 2001, Fuhlendorf et al. 2002, Patten et al. 2005) and (4) sand shinnery oak removal paradigms are often based on the false premise that this shrub is a woody invasive species and has increased in stature since settlement because of removal of fire (York and Dick-Peddie 1969). Some lesser prairie-chicken researchers have justified using herbicides to reduce the dominance of sand shinnery oak in an attempt to restore these systems to the pre-

settlement vegetation that was dependent on frequent fires for maintaining the vegetation at a lower stature (Doerr and Guthery 1983, Olawsky and Smith 1991). Several researchers have suggested that herbicides can be used as a surrogate for historical fire regimes (Doerr and Guthery 1983, Olawsky and Smith 1991, Patten et al. 2005), although clearly these practices are different (Jones and Pettit 1984). Typically tebuthiuron, an herbicide that inhibits woody plant's photosynthetic ability, has been used to treat sand shinnery oak (Pettit 1979); and application of tebuthiuron can permanently eradicate sand shinnery oak as well as other species from shrubland ecosystems (Jones and Pettit 1984). Prescribed fire, on the other hand, only kills the above-ground portion of sand shinnery oak and the fire-tolerant plants recover in 2-3 years (Harrell et al. 2001, Boyd and Bidwell 2001). Since sand shinnery oak and other native shrubs are important to lesser prairie-chickens across their range (Copelin 1963, Olawsky and Smith 1991, Boyd and Bidwell 2001, Fuhlendorf et al. 2002, Patten et al. 2005) conservationists should closely examine those land management strategies that can eradicate species like sand shinnery oak or create permanent vegetation structural change to these unique shrubland ecosystems.

We hypothesized that native shrubs are important to lesser prairie-chicken brood habitat selection at multiple scales and that at least some of this selection is based on local microclimate characteristics. Our objectives were (1) to determine if hens with broods were selecting locations that are different in thermal microclimate from random locations for different times of the day, (2) to identify brood habitat differences from random locations at multiple spatial scales and during hot and cool portions of the day, and (3) determine the effects of herbicide applications, commonly used as surrogates for

historical fire regimes, and other land management practices on brood rearing habitat. Selection of brood rearing sites that have different vegetation and microclimate from random sites would suggest that temperature and the loss of valuable brood rearing habitat due to shrub removal could be one contributing mechanism causing observed declines of lesser prairie-chickens (Taylor and Guthery 1980, Woodward et al. 2001, Fuhlendorf et al. 2002). The effects of the wide spread application of herbicides were evaluated for differences in the thermal environment as well as vegetation structure suggesting that the effects of treatments can be related to lesser prairie chicken brood rearing habitat.

Methods

Study Area

Our study was conducted on 3 sites within a 24,484 ha matrix of land management practices in southern Roosevelt County, New Mexico (33° 40'N, 103°06'W) during the summers of 2002 and 2003. Sand shinnery oak plant communities dominated the landscape but were fragmented by cultivation and areas treated with herbicide to remove sand shinnery oak. The area is primarily used for cattle grazing and 86% of the land is privately owned. One of the 3 sites includes 3,296 ha of prairie-chicken management areas owned by New Mexico Game Commission that were ungrazed sand shinnery oak plant communities containing 617 ha of previously cultivated land, which we labeled as ungrazed no herbicide sites. Ungrazed sites without herbicide use contained the highest percentage of intact sand shinnery plant community within a site on our study area compared to other sites and were surrounded on all sides by other land management practices. Ungrazed sites with herbicide use comprised 3,441 ha of our

study area and > 70% of sand shinnery oak plant communities had been removed with the herbicide tebuthiuron (0.60 lbs active ingredient acre^{-1} [0.40 kg ha^{-1}]) between 2000 and 2003. Sand dunes on ungrazed sites with herbicide use were not treated with herbicide in the spraying process, leaving ~ 443 ha of interspersed remnant sand shinnery oak plant communities on sand dunes within the herbicide treated area. Grazed sites without herbicide use were grazed with cattle and dominated by sand shinnery oak plant communities; these sites comprised > 38% of our study area and were fragmented by previous and current cultivation efforts. Grazed sites without herbicide use encompass the privately owned ungrazed no herbicide and ungrazed herbicide sites. The remaining land was 137 ha of conservation reserve program (CRP) and 8,816 ha of previously and currently cultivated land which we labeled as "other".

Climate is semi-arid continental with an average frost-free growing period of 200 days extending from mid April to late October (Wright 2003). Average annual precipitation is 41 cm with 85% falling as rain from April through October (Wright 2003). Average annual temperatures are 14°C to 16°C with lows of –34°C and highs > 40°C (Wright 2003). Soil textures vary from sand to sandy clay loam (Wright 2003). Topography is level to undulating with slopes ranging from 0 to 5%, but usually less than 3% (Wright 2003). Elevation ranges from 1,080 m to 1,300 m (Wright 2003). Sand shinnery oak plant communities dominate the region (Peterson and Boyd 1998). Other common shrubs and sub shrubs include sand sagebrush (*Artemisia filifolia*), honey mesquite (*Prosopis glandulosa*), cholla (*Opuntia imbricata*), broom snakeweed (*Gutierrezia sarothrae*), and yucca (*Yucca glauca*). Common grasses consist of sand bluestem (*Andropogon hallii*), little bluestem (*Schizachyrium scoparium*), silver bluestem

(*Bothriochola laguroides*), blue grama (*Bouteloua gracilis*), black grama (*Bouteloua eriopoda*), sideoats grama (*Bouteloua curtipendula*), sand dropseed (*Sporobolus cryptandrus*), and purple three-awn (*Aristida purpurea*). Common forbs are western ragweed (*Ambrosia psilostachya*), annual wild buckwheat (*Polygonum convolvulus*), and camphorweed (*Heterotheca latifolia*). Peterson and Boyd (1998) provide a comprehensive list of other plants associated with sand shinnery oak communities relevant to the study area.

Hen and Brood Monitoring

During fall of 1999 and 2001 and spring of 1999-2003, the George Miksch Sutton Avian Research Center (GMSARC) trapped adult lesser prairie-chickens on their breeding grounds (leks) using walk-in funnel traps (25 traps lek^{-1}) connected by 8 m lengths of drift fence in large "W" arrays (Haukos et al. 1990). Captured birds were weighed, measured, and fitted with a 15-g (≤ 2% of the bird's weight) bib-mounted radiotransmitter with a loop antenna (Telemetry Solutions, Inc., and Wildlife Materials, Inc.). In 2002 and 2003, we tracked 19 radiocollared prairie-chicken hens with broods from GMSARC's ongoing lesser prairie-chicken study to locate brood rearing habitat. By happenstance we encountered an additional 5 hens with broods without transmitters to total 24 hens with broods in all. Out of the 24,484 ha, trapping efforts focused on 7 active leks within 4.8 km of the tebuthiuron treated area. Previous studies on telemetered lesser prairie-chickens indicate a strong tendency to remain within this distance of a lek (Taylor and Guthery 1980, Giesen 1994, Riley et al. 1994). By focusing within this given distance of the leks, hens with broods had equal opportunity to select any of the 3

sites and potentially use areas with reduced or intact sand shinnery oak plant communities.

Microclimate and Habitat Sampling

Nests were located by encircling suspect hens, using their radio signals, to determine nesting status. Once nest sites were confirmed, a scent free "marker" radio transmitter was placed 1 m north of each nest to be used as a point of reference for future nest monitoring. Nests were monitored every other day by listening to hen and marker radio signals from a specified landmark ~60 m away from each nest to determine a hen's proximity to the marker radio. If hen and marker radio signals were not coming from the same direction we assumed that a hen was off its nest. Vacant nests were approached to verify nesting status. After hatching confirmations were made we followed each brood (during the hours of 600 – 2400 and 3-4 times a week) to gather vegetation structure, exposure, and microclimate (i.e. ambient temperature) information. After visual confirmation of the brood's location, using the hen's radio signal, the location was marked for sampling the following day, so that there would be minimal disturbance of hens with broods. Date, time, observer, land management practice (i.e. describing grazing or herbicides practices) and Global Positioning System (GPS) coordinates were recorded on the tracking date. On the day of brood tracking a handheld weather device (Kestrel™ 3000, Kestrel Meters Co., Minneapolis, MN) was used to get a 30-second average temperature at chick height (10 cm above ground) exactly where a chick was found. Temperature and vegetation structure information collected at brood locations could then be compared to the same information collected at random locations.

Random and brood habitat information was collected by passing a thin metal rod, measuring 6.4 mm in diameter x 1.2 m long, through the vegetation to record various plant structural attributes (Heady et al. 1959, Wiens 1974) along a 10 m line transect with the midpoint of a line transect centered on an exact location of a brood. The rod was held plumb to collect various plant attributes. We recorded canopy cover contacts (highest plant part touching the rod ≥ 20 cm above ground), basal cover contacts and plant category at each meter interval along the 10 m line. Basal cover contacts were recorded when the tip of the metal rod touched a plant's basal area. For canopy and basal cover contacts we combined species data into plant categories: tallgrass, other grass, sand shinnery oak, sand sagebrush, mesquite and other (Table 1). For each 5 m interval, we recorded stem density in a circular 0.5 m radius plot and its associated plant category where the rod touched the ground, 1 m radius maximum plant height (highest plant part within a 1 m radius of rod), and tallest rod contact (highest plant part touching the rod). All plant parts touching the rod were also recorded as a measure number of plant contacts within each strata (<10 cm, 10-50 cm, and >50 cm, Wiens 1974) at each 5 m interval. In addition to the above mentioned habitat measures at each 5 m interval, we recorded angle of obstruction (only for 2003) in each cardinal direction (Kopp et al. 1998) instead of 8 radii (Harrell and Fuhlendorf 2002). We recorded each angle of obstruction measurement by leaning a wooden board measuring 8 cm in width x 1.5 cm in height x 120 cm long that was equipped with a digital level (SMARTTOOL™, Gulf Instrument Inc., Metairie, LA) in each direction until a plant part touched the board between 0.15 m and 1 m heights. Brood sampling transects went 5 m each direction from the brood's location to the northeast and southwest to avoid running parallel to manmade features

such as roads and fence lines whereas random sampling transects were random in direction but the randomness of their locality was limited within GPS coordinate boundaries of the 3 land management practices. By selecting random points within each land management practice, we could compare random temperatures to similar date and time temperatures that were recorded at brood locations.

In order to compare brood habitat and microclimate to random locations, we located random transects at 53 randomly generated GPS points across the study area. Random points fell in areas that were managed as follows: (1) Grazed no herbicide (n = 15) (2) Ungrazed no herbicide (n = 28) and (3) Ungrazed herbicide (n = 10). Sites with cattle were owned by private landowners and grazed continuously at an estimated 0.81 – 2.63 hectares per animal unit month (ha/AUM) (Wright 2003). To gather microclimate information from each land management practice, we placed HOBO® dataloggers (dataloggers, Onset Computer Corp., Bourne, MA) one meter apart in three 10 m random transects (n = 11 points), so that each land management practice would be sampled simultaneously. These dataloggers recorded temperature and relative humidity at 15 minute intervals for 1 week and were mounted approximately 10 cm (chick height) on top of wooden stakes and covered with white plastic guttering material to protect them from mud and debris. Once the 7-day sampling period was complete, data was downloaded from each datalogger and moved to a new random location within the same land management practice. Random transects with dataloggers recorded temperature continuously for the entirety of both summers. We used the microclimate information from the random transects to evaluate temperature differences between brood and random locations for similar dates and times.

Data Analyses

Temperature and habitat variables were analyzed at 2 spatial scales and 2 temperature categories. The entire 10 m transect was considered to be the "line" scale observation, and midpoint of the 10 m transect (the 5 m interval or exact brood location) was considered to be the "point" scale observation. Temperature categories were created based on meaningful temperature differences between brood and random locations. In order to get corresponding temperatures from random locations to compare to brood locations, we averaged all 11 temperature samples in each random transect and then averaged temperatures across all 3 random transects to get one random average temperature for each brood tracking event's date and time. We subtracted temperatures from each brood tracking event to corresponding random average temperatures to calculate a difference. All points (n = 180) with a negative difference were classified as "cool" and all points (n = 77) with a positive difference were classified as "warm", because of the selection of cooler or warmer habitats than random.

To analyze our first objective, we calculated the difference between brood and random average temperatures, for similar date and time events. Regression analysis was used to determine whether there was a relationship between temperatures at brood locations and random average temperatures according to time of day (PROC GLM, SAS Institute 2003) and we compared temperature difference to random average temperature (PROC REG, SAS Institute 2003).

To analyze our second objective, we separated all brood locations into composite groups of spatial scale and temperature category. For this objective we pooled all random transect locations regardless of land management to compare to brood locations.

Using the spatial scale and temperature category composite groups, we analyzed brood habitat selection with analysis of variance (PROC MIXED, SAS Institute 2003) to examine vegetation attributes among spatial and temperature categories. Satterthwaite's approximation was used to correct for unbalanced design and we used least squares means to conduct pairwise comparisons among these composite groups.

To analyze the third objective, we compared all 23 vegetation and habitat structural variables collected at brood locations to each of the 3 land management practices and we compared the same information for brood and random locations within each of land management practice using analysis of variance (PROC MIXED, SAS Institute 2003). Additionally, we compared temperatures for each land management practice during "cool" and "warm" time periods. Unlike the second objective, where random average temperatures could potentially represent numerous combinations of land management types, we only used temperatures that were represented each of the 3 land management types and brood locations for the same dates and times. "Cool" and "warm" time periods, brood locations, and land management practice combinations were analyzed using analysis of variance (PROC MIXED, SAS Institute 2003). Again Satterthwaite's approximation was used to correct for unbalanced design and we used least squares means to conduct pairwise comparisons among all combinations of land management practices, brood locations, and temperature categories. By comparing all habitat variables and temperature categories collected at brood locations to each land management practice we could infer which practice was most similar and most dissimilar from brood locations.

Results

Between 1999 and 2003 the GMSARC completed 324 trap-mornings to capture birds for their study and to be used in our study. For our study in 2002 to 2003 we actively tracked (located within 2 weeks of last tracking date) 72 hens, producing 61 nests and 19 broods. There were 24 broods encountered in all for 2002 and 2003, but 5 broods were from unmarked (did not have radio transmitters) hens encountered serendipitously. We followed all hens with broods until none of the chicks remained, in order to obtain 257 visual confirmations on the 24 broods. Broods used all land management practices, but selected distinct vegetation and habitat structures within each land management practice. The number of brood locations as a percentage of habitat used that were found on each land management practice are as follows: 47% Grazed no herbicide, 21% Ungrazed no herbicide, 33% Ungrazed herbicide (n = 257, brood locations).

Objective 1 - Temperature Selection

We found that temperature was highly variable even within a 10 m sampling line. Using temperature data collected by dataloggers from random locations, we determined that the greatest standard deviation in temperature among all 11 dataloggers within transects was ± 13°C. Hens with broods selected habitat with ambient temperatures different from random locations and the direction of differences was dependent on time of day and the diurnal variation of temperature (Fig. 1) (F = 1688.8, df = 255, $p < 0.0001$; Fig. 1a). The difference between brood and random temperatures was negatively correlated with the temperature of random transects (r = -0.71, $p < 0.0001$; Fig. 1b) indicating broods select habitats that are warmer than random during cool times and

cooler than random during warm times. This suggests that hens and broods are selecting habitats, at least partially, because of the need to moderate temperature extremes.

Objective 2 - Habitat Selection Differences Among Spatial Scale and Temperature Selection Categories for Brood Locations

In examining habitat selection at multiple spatial scales, we found the stem density of sand shinnery oak, tallest rod contacts, rod contacts 10 – 50 and > 50 cm were significantly different at brood locations when compared to random locations. Of these 4 variables only the stem density of sand shinnery oak was significant among temperature selection and random categories at the line scale and it was greater at brood locations than at random locations. Line scale habitat selection for stem density of sand shinnery oak, at both cool and warm time periods, was significantly higher (x ± SE, 14.75 ± 0.91 cool, 13.90 ± 0.56 warm) than random locations (10.40 ± 1.05; $F = 5.53$, df = 2, 307, $p = 0.004$, $t = 3.12$, df = 307, $p = 0.002$, $t = 2.94$, df = 307, $p = 0.004$, respectively) indicating that selection of sand shinnery oak was preferred over what was available at random. We did not detect a significant difference in stem density of sand shinnery oak between cool and warm time periods ($t = 0.79$, df = 307, $p = 0.43$) for the line scale (Fig. 2), suggesting that a thermal selection preference for sand shinnery oak stem density was not observed at the line scale.

However, all 4 variables varied significantly ($p \leq 0.05$) across temperature and random categories for the point scale observations. Point scale observations of cool and warm time periods were significantly higher in stem density of sand shinnery oak (14.01 ± 1.00 cool, 14.30 ± 0.61 warm) than random locations (10.40 ± 1.15; overall $F = 4.66$, df = 2, 307, $p = 0.01$, $t = 2.38$, df = 307, $p = 0.02$, $t = 3.01$, df = 307, $p = 0.003$,

respectively), without differences between warm and cool point time periods (t = -0.25, df = 307, p = 0.80) indicating that broods select higher stem densities of sand shinnery oak regardless of spatial scale or temperature. During warm time periods, at the point scale, broods selected significantly higher rod contacts, as measured by tallest rod contact (29.37 ± 1.48 cm) than cool time periods (20.06 ± 2.41 cm; t = -3.29, df = 307, p = 0.001), and higher than random locations (15.57 ± 2.78 cm; t = 4.39, df = 307, p < 0.0001) demonstrating that tallest rod contact selection is limited to fine scales and temperature dependencies. Broods selected significantly more rod contacts (2.11 ± 0.14 rod contacts) 10 – 50 cm at the point scale during warm time periods than random locations (1.35 ± 0.27 rod contacts; t = 2.50, df = 307, p = 0.01) suggesting that broods select more over head canopy cover from rod contacts during warmer times of the day, and these differences in the number of rod contacts did not differ significantly from that of point scale observations during cool time periods (1.59 ± 0.24 rod contacts; t = -1.91, df = 307, p = 0.06) also suggesting that selection for rod contacts 10 – 50 cm is limited to broader scales and during the heat of the day. At the point scale, during warm time periods broods selected significantly more (0.33 ± 0.05 rod contacts) rod contacts > 50 cm than cool time periods and random locations (0.09 ± 0.09 rod contacts; t = -2.30, df = 307, p = 0.02, 0.05; t = 2.38, df = 307, p = 0.02, respectively) suggesting that selection of more rod contacts > 50 cm is observable at fine scales and occurs during the heat of the day.

Objective 3 – Land management practices compared to Brood Locations

Vegetation attributes varied greatly among the 3 land management practices (Table 2). Total grass canopy cover increased with the herbicide treatment and decreased

with the presence of grazing; 27.27% ± 6.78 (n = 10 transects) for ungrazed sites treated with herbicide, 16.56% ± 3.03 (n = 28) on sites ungrazed without herbicide, and 2.42% ± 1.07 (n = 15) on grazed sites without herbicide use. Sand shinnery oak canopy cover was lowest for ungrazed sites with herbicide application 3.64% ± 2.78 (n = 10), highest for ungrazed sites without herbicide use 14.61% ± 2.40 (n = 28) and on grazed sites without herbicide 13.33% ± 2.64 (n = 15). Sand shinnery oak stem density (number of stems within 0.5 m radius) was highest with the presence of grazing and lowest under the herbicide treatment; the densities are as follows: 2.87 ± 1.50 (n = 10) on ungrazed sites with herbicide use, 11.10 ± 1.72 (n = 28) on ungrazed sites without herbicide use and 14.11 ± 1.98 (n = 15) on grazed sites without herbicide applied.

Habitat structure varied among land management practices (Table 2 and Table 3). The greatest difference between a land management practice and sites where broods were located or the difference between brood and random locations within a site occurred on the ungrazed sites with herbicide use where 14 of 23 (Table 2) and 10 of 23 (Table 3) measured habitat variables were significantly different from brood locations ($p \leq 0.05$). In particular, percent canopy cover of sand shinnery oak was significantly lower (t = 3.03, df = 306, p = 0.003) by 78% than brood locations and 70% lower (t = 1.98, df = 304, p = 0.05) on random versus brood locations within ungrazed sites with herbicide use. Mean percent of total grass canopy cover was 62% higher on ungrazed sites with herbicide use than compared to brood locations (t = -3.60, df = 306, p = 0.0004). Eight of 23 habitat variables measured on ungrazed sites without herbicide use were significantly different from brood locations ($p \leq 0.05$), and brood and random locations within these sites had 5 of 23 habitat variable that were different. However ungrazed sites without

herbicide use did not differ in the mean percent of sand shinnery oak canopy cover from brood locations among land management practices or within these sites nor did they differ in tallgrass canopy cover. The grazed sites without herbicide use were most similar for all brood locations and 1 variable out of the 23 habitat variables measured was significantly different from brood locations ($p \leq 0.05$). Similarly, brood and random locations within grazed sites without herbicide use were most similar with 3 of 23 habitat variable being different than random. The tallest rod contact was significantly lower on grazed sites without herbicide use than compared to brood locations ($t = 2.20$, df = 306, $p = 0.03$) and same was true for brood and random locations within these sites ($t = 2.04$, df = 304, $p = 0.04$).

There was no difference for temperatures during the same date and time periods at brood and random locations for "cool" ($F = 0.04$, df = 4, 150, $p = 0.99$) or "warm" ($F = 0.51$, df = 4, 525, $p = 0.73$) time periods among the land management types, indicating that some other measure of habitat structure was responsible for moderating the thermal environment. However "warm" random locations were hotter than brood locations within grazed sites without herbicide use ($t = -3.04$, df = 344, $p = 0.003$), indicating wider temperature range on these sites.

Discussion

Since European settlement, much of North America's native prairies and shrublands on the Great Plains were lost to cultivation and shrub removal programs without regard to ecosystem function (Samson and Knopf 1994, Dhillion et al. 1994). In this loss, almost 25% of the 2 million ha of land dominated by sand shinnery oak plant communities were converted to grass using herbicides and other shrub removal

techniques for various agricultural demands (Peterson and Boyd 1998). Many organisms are dependent on shrubland plant communities like sand shinnery oak, for food, shade, and escape cover from predators (Copelin 1963, Sharpe and Van Horne 1999, Boyd and Bidwell 2001). One such organism is the lesser prairie-chicken. This gallinaceous bird is commonly associated with shrubland plant communities across its range (Baker 1953, Copelin 1963, Aldrich 1963, Taylor and Guthery 1980, Giesen 1994). Past and present lesser prairie-chicken research have described both sand sagebrush and sand shinnery oak shrublands as important habitat for thermal cover (Copelin 1963) and sustainability at multiple spatial scales (Woodward et al. 2001, Fuhlendorf et al 2002, Patten et al. 2005). In spite of this relationship it has been a common practice to control sand shinnery oak under the guise of lesser prairie-chicken conservation (Doerr and Guthery 1983, Olawsky and Smith 1991). Our study found direct evidence supporting thermal selection and the dependency of lesser prairie-chicken broods on sand shinnery oak dominance in their shrubland habitats. Some of the observed habitat selection could be associated with avoidance of more extreme air temperatures but selection for greater amounts of shinnery was independent of temperature, suggesting that sand shinnery oak is preferred habitat for a number of reasons.

Thermal and Habitat Selection

Broods had access to a variety of habitat types that ranged from dense shrublands that were not grazed to lands treated with herbicides to remove or reduce shrubs and sites that had heavy grazing intensities. Temperatures recorded at these sites through random placement of sampling points were different from sites selected by broods and the differences were dependent upon the air temperatures and time of day. During cool time

periods (< 26.4 °C) broods selected warmer sites that were dominated by sand shinnery oak. During warm time periods (≥ 26.4 °C) broods selected cooler sites that were also dominated by sand shinnery oak, but had taller rod contacts (i.e. tallest rod contact) and more rod contacts (i.e. rod contacts 10 – 50 cm and > 50 cm) and than cool time periods or random locations. These differences indicate that lesser prairie-chickens may be selecting for moderation of temperature extremes. However, since sand shinnery oak is included in both cool and warm selection sites, it is difficult to separate sand shinnery oak selection from thermal selection. The significance of sand shinnery oak to brood habitat selection remains obscure; it may reflect thermal advantages (broods selecting for varying structural attributes within sand shinnery oak), but at this time our temperature data from each land management practice did not reveal any thermal differences (Table 2).

Broods selected locations within all 3 land management practices, and these locations were isolated to areas of living sand shinnery oak. For instance, 33% of the 257 brood locations were found on ungrazed sites treated with herbicide, but 83% of these locations were isolated to sand dunes that were not treated with herbicide and the remaining 17% of these locations were found on treated areas during cool times of the day. Using Ivlev's Electivity Index (I = % habitat used - % habitat available / % habitat used + % habitat available; Ivlev 1961), our data further suggests that on ungrazed sites treated herbicide broods avoided areas treated with tebuthiuron and preferred the untreated sand dunes (Figure 3). Broods may select sand dunes because of their topography for protection from the sun throughout different times of the day, but nonetheless broods selected areas of sand shinnery on each site than compared to random.

Habitat Structure and Scale

Our data suggests that sand shinnery oak plant communities can provide the structural attributes necessary for creating thermal refugia and other life requirements. For instance, plant structure measured from rod contacts > 50 cm and tallest rod contacts were more abundant and taller at brood locations when temperatures, 10 cm above ground level, exceeded 26.4 °C than compared to random or habitat selected during cool times of the day. However, broods did not select different amounts of sand shinnery oak stem densities during different times of the day, but they did select sites where sand shinnery oak was more abundant than compared to random. This continuous selection of shrubs does not negate the importance of woody plants in creating thermal refugia, because selection of shrubs is consistent with anecdotal observations of a lesser prairie-chicken study in the shrublands of western Oklahoma where birds were documented using the shade of sand shinnery oak mottes (Donaldson 1969). However, our study suggests that they may be selecting shinnery cover for additional reasons aside from thermal refugia.

Our results indicate that habitat selection was also dependent upon spatial scale. We detected differences in habitat structure use at the point scale where broods selected taller rod contacts (i.e. tallest rod contact) and more rod contacts > 50 cm and 10-50 cm than compared to line scale and random observations. Within the point scale observations broods also selected taller rod contacts (i.e. tallest rod contact) and more rod contacts > 50 cm during warm time periods; therefore, demonstrating an inter-dependence of spatial scale and time of day habitat selection. It was not surprising that heat avoidance behavior occurred within a small spatial scale, since the landscape and

sites broods used were dominated by sand shinnery oak and any habitat selection based on temperature might be within a few meters. For example, since temperatures can differ by as much as 13°C within a 10 m line, it only further suggests that habitat selection would be at such a fine scale. Broods had numerous shrubs to choose from sites varying in land management practices and they chose sites at a point scale with plant structures indicative of providing temperatures (e.g. canopy cover from 2 different strata of rod contacts and tallest rod contacts).

The Effects of Tebuthiuron on Sand shinnery oak

The overall picture that arises from our study is that tebuthiuron reduces both the floristic and plant structure characteristics that lesser prairie-chicken broods utilize. For example, of the 23 habitat measures collected on tebuthiuron treated sites, 61% were different than brood locations. Tebuthiuron highly modified sand shinnery oak sites by increasing basal and canopy cover contacts for grasses and decreasing canopy cover and stem density for sand shinnery oak. The application rate at which tebuthiuron was applied in this study rate should permanently remove sand shinnery oak (Jones and Pettit 1984) and our initial results 3 years post-treatment do not indicate a sand shinnery oak's recovery. Given that tebuthiuron has the potential to permanently remove sand shinnery oak, the modification sand shinnery oak plant communities to benefit lesser prairie-chickens is not warranted. Moreover, since we observed that sand shinnery oak was consistently more abundant at brood locations, and broods were rarely seen on treated sites, only further suggests that sand shinnery oak can provide important plant structure for the brood rearing stage of lesser prairie-chickens.

Due to an improper invasive shrub classification placed on sand shinnery oak (York and Dick-Peddie 1969), Texas and New Mexico, the two states with the highest historical estimates of sand shinnery oak, have converted 500,000 ha of shrubland to cropland or grazing lands (Deering and Pettit 1972). Texas alone has converted over 405,000 ha and now has the lowest amount of lesser prairie-chicken occupation proportional to their historical range of any other state (Peterson and Boyd 1998, Sullivan et al. 2000). Sand shinnery oak is not an invasive shrub, and in fact, it is rhizomatous and slow to reproduce (Wiedeman and Penfound 1960). This shrub has germinated successfully in a lab (Peterson and Boyd 1998), but there is little documentation as to germination successes in the wild (Wiedeman 1960, Dhillion et al. 1994). Even more disturbing is the use of root killing herbicides like tebuthiuron, which permanently removed this shrub on many sites within lesser prairie-chicken's range (Peterson and Boyd 1998). We are not suggesting that conversions of sand shinnery oak communities are the only limiting factors for lesser prairie-chicken recovery, but we are suggesting that native shrubs are critical components to lesser prairie-chicken sustainability.

Conservation Implications

The recent conversion of large amounts of sand shinnery oak and sand sagebrush shrublands will reduce the amount of summer protective cover necessary for lesser prairie-chickens to prosper. Given the data from our study and the abundance of leks, nests, and brood rearing areas on or associated with shrubland communities (Copelin 1963, Olawsky and Smith 1991, Boyd and Bidwell 2001, Fuhlendorf et al. 2002, Patten et al. 2005), we suggest that any long-term shrubland conversions will have a negative impact on lesser prairie-chicken populations. Because large tracts of shrubland

communities are decreasing and native shrubs drive reproductive output for ground nesting birds (Guthery et al. 2001), it is likely lesser prairie-chickens will go extinct if permanent losses of shrubland communities continue. To avoid this situation, shrubland plant communities should be conserved at a scale consistent with lesser prairie-chicken sustainability (Fuhlendorf et al. 2002).

In a broader context, there is now a variety of evidence that shrubland plant communities are important for moderating the microclimate used by sedentary animals (Goldstein 1984, Wolf et al. 1996, Forrester et al. 1998, Sharpe and Van Horne 1999). Albeit the results of our study are limited to a particular region and its population of lesser prairie-chickens, our conclusions are more generally applicable. Shrubland-using animals are associated with shrubs because of the plant's structural properties that create a usable thermal environment or preferred cover. To maintain populations of such organisms, shrubland managers will need to consider habitat use of all organisms at a landscape level approach.

Habitat Management Alternatives

Since our results and others demonstrate the significance of sand shinnery oak in providing the preferred habitat structure selected by lesser prairie-chickens (Copelin 1963, Olawsky and Smith 1991, Boyd and Bidwell 2001, Fuhlendorf et al. 2002, Patten et al. 2005), alternatives to herbicides should be considered when managing sand shinnery oak. For example, techniques like prescribed fire (Boyd and Bidwell 2001) or prescriptive goat browsing (Villena and Pfister 1990) could be less damaging in the long term to sand shinnery oak, and yet benefit multi-purpose demands. A study conducted on the influence of prescribed fire on sand shinnery oak in western Oklahoma found that

sand shinnery oak was temporarily reduced for 2 to 3 years post fire before returning to a similar composition and structure as preferred by lesser prairie-chickens for nesting and brood rearing (Boyd and Bidwell 2001). Although western Oklahoma receives more precipitation than southeastern New Mexico, areas like our study site may require different temporal burning frequencies. Most importantly, prescribed fire, unlike most herbicides, does not permanently remove sand shinnery oak (Boyd and Bidwell 2001). Sand shinnery oak is important to the most critical life stage for lesser prairie-chickens in southeastern New Mexico. Management efforts not focused on conserving sand shinnery oak may be detrimental to lesser prairie-chicken recovery.

Literature Cited

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

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

Baker, M. F. 1953. Prairie chickens of Kansas. Publication No. 5. University of Kansas Museum of Natural History, Lawrence, Kansas, USA.

Boyd, C. S., and T. G. Bidwell. 2001. Influence of prescribed fire on lesser prairie-chicken habitat in shinnery oak communities in western Oklahoma. Wildlife Society Bulletin **29**:938-947.

Copelin, F. F. 1963. The lesser prairie-chicken in Oklahoma. Technical Bulletin No. 6. Oklahoma Department of Wildlife Conservation, Oklahoma City, Oklahoma, USA.

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

Deering, D. W., and R. D. Pettit. 1972. Sand shinnery oak acreage survey. Research Highlights Noxious Brush and Weed Control; Range, Wildlife, & Fisheries Management 2:14. Lubbock: Texas Tech University, College of Agricultural Sciences and Natural Resources.

Degenhardt, W. G., and K. L. Jones. 1972. A new sagebrush lizard, *Sceloporus graciosus*, from New Mexico and Texas. Herpetologica **28**:212-217.

Dhillion, S. S., M. A. McGinley, C. F. Friese, and J. C. Zak. 1994. Construction of sand

shinnery oak communities of the Llano Estacado: animal disturbances, plant community structure, and restoration. Restoration Ecology **2**:51-60.

Doerr, T. B., and F. S. Guthery. 1983. Effects of tebuthiuron on lesser prairie-chicken habitat and foods. Journal of Wildlife Management **47**:1138-1142.

Donaldson, D. D. 1969. Effect on lesser prairie chickens of brush control in western Oklahoma. Ph.D. dissertation. Oklahoma State University, Stillwater.

Forrester, N. D., F. Guthery, S. D. Kopp, and W. E. Cohen. 1998. Operative temperature reduces habitat space for northern bobwhites. Journal of Wildlife Management **62**:1506-1511.

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. 1994. Movements and nesting habitat of lesser prairie-chicken hens in Colorado. Southwestern Naturalist **39**:96-98.

Goldstein, D. L. 1984. The thermal environment and its constraint on activity of desert quail in summer. Auk **101**:542-550.

Guthery, F. S., C. L. Land, and B. W. Hall. 2001. Heat loads on reproducing bobwhites in the semiarid subtropics. Journal of Wildlife Management **65**:111-117.

Harrell, W. C., and S. D. Fuhlendorf. 2002. Evaluation of habitat structural measures in a shrubland community. Journal of Range Management **55**:488-493.

Harrell, W. C., S. D. Fuhlendorf, and T. G. Bidwell. 2001. Effects of prescribed fire on sand shinnery oak communities. Journal of Range Management **54**:685-690.

Haukos, D. A., L. M. Smith, and G. S. Broda. 1990. Spring trapping of lesser prairie-

chickens. Journal of Field Ornithology **61**:20-25.

Heady, H. F., R. P. Gibbens, and R. W. Powell. 1959. A comparison of the charting, line intercept, and line point methods of sampling shrub types of vegetation. Journal of Range Management **12**:180-188.

Ivlev, V.S. 1961. Experimental ecology of the feeding of fishes. Yale University Press, New Haven, Conn.

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. Southwestern Naturalist **49**:334-343.

Jones, V. E., and R. D. Pettit. 1984. Low Rates of Tebuthiuron for Control of Sand Shinnery Oak. Journal of Range Management **37**:488-490.

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.

Olawsky, C. D., and L. M. Smith. 1991. Lesser prairie-chicken densities on tebuthiuron-treated and untreated sand shinnery oak rangelands. Journal of Range Management **44**:364-368.

Patten, M. A., D. H. Wolf, E. Shochat, and S. K. Sherrod. 2005. Effects of microhabitat and microclimate selection on adult survivorship of the lesser prairie-chicken. Journal of Wildlife Management. *in press*.

Peterson, R. S., and C. S. Boyd. 1998. Ecology and management of sand shinnery communities: a literature review. USDA Forest Service General Technical Report. Rocky Mountain Forest and Range Experiment Station, Fort Collins,

Colorado, USA.

Pettit, R. D. 1979. Effects of picloram and tebuthiuron pellets on sand shinnery oak communities. Journal of Range Management **32**:196-200.

Riley, T. Z., C. A. Davis, M. A. Candelaria, and H. R. Suminski. 1994. Lesser prairie-chicken movements and home ranges in New Mexico. Prairie Naturalist **26**:183-186.

Samson, F., and F. Knopf. 1994. Prairie Conservation in North-America. Bioscience **44**:418-421.

SAS Institute. 2003. SAS/STAT user's guide. Version 9.1 SAS Institute, Cary, North Carolina.

Sharpe, P. B., and B. Van Horne. 1999. Relationships between the thermal environment and activity of Piute ground squirrels (*Spermophilus mollis*). Journal of Thermal Biology **24**:265-278.

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

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

Villena, F., and J. A. Pfister. 1990. Sand shinnery oak as forage for angora and spanish goats. Journal of Range Management **43**:116-122.

Wiens, J. A. 1974. Habitat heterogeneity and avian community structure in North American grasslands. American Midland Naturalist **91**:195-213.

Wiedeman, V. E. 1960. Preliminary ecological study of the shinnery oak area of western Oklahoma. Page 46. University of Oklahoma, Norman.

Wiedeman, V. E., and W. T. Penfound. 1960. A preliminary study of the shinnery in Oklahoma. Southwestern Naturalist **5**:117-122.

Willig, M. R., R. L. Colbert, R. D. Pettit, and R. D. Stevens. 1993. Response of small mammals to conversion of a sand shinnery oak woodland into a mixed mid-grass prairie. Texas Journal of Science **45**:29-43.

Wolf, B. O., K. M. Wooden, and G. E. Walsberg. 1996. The use of thermal refugia by two small desert birds. Condor **98**:424-428.

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

Wright, E. 2003. Ecological site description. Pages 1-15. United States Department of Agriculture Natural Resources Conservation Service.

York, J. C., and W. A. Dick-Peddie 1969. Arid Lands in Perspective. University of Arizona Press, Tucson.

Table 1. Dominant plant species in each plant category found at brood and random locations. The superscript "a" denotes plants included in "Other" stem density and "b" denotes plants included in "Other" canopy and basal cover contacts.

Plant Cateogory	Genus	Species
Tallgrasses		
	Andropogon	hallii
	Schizachyrium	scoparium
	Bothriochola	laguroides
	Bouteloua	curtipendula
	Tripsacum	dactyloides
	Sporobolus	cryptandrus
Other Grasses		
	Bouteloua	gracilis
	Bouteloua	hirsuta
	Bouteloua	eriopoda
	Aristida	oligantha
	Aristida	purpurea
	Buchloe	dactyloides
Sand Shinnery Oak		
	Quercus	havardii
Mesquite		
	Prosopis	glandulosa
Sand Sagebrush		
	Artemisia	filifolia
Total Woody		
	Quercus	havardii
	Prosopis	glandulosa
	Artemisia	filifolia
Other		
	Polygonum	convolvulus[b]
	Ambrosia	psilostachya[b]
	Herterotheca	latifolia[b]
	Yucca	glauca[a,b]
	Opuntia	imbricata[a,b]
	Gutierrezia	sarothrae[a,b]

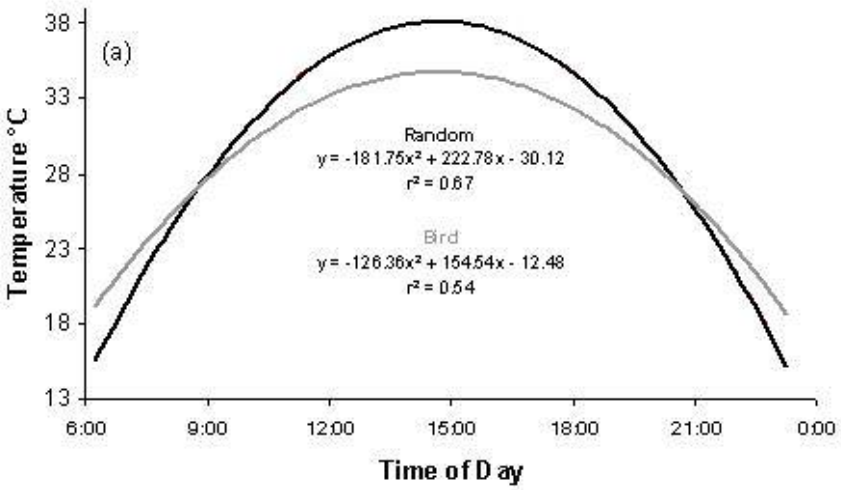
Table 2. Comparison of all variables sampled at brood locations and each land management practice. Capital letters indicate variables significantly different from brood locations (e.g. H = "higher than brood" and L = "lower than brood") in the same row. Areas that were grazed with no herbicides were most similar to brood locations and ungrazed herbicide sites were least similar to brood locations. Broods could be found on all sites, but only on areas similar to their selected variables. For example, on ungrazed herbicide sites sand dunes were left untreated and provided the structural habitat characteristics selected by broods. On all 3 land management types, temperature did not differ from brood locations during "cool" time periods. However, during "warm" time periods temperatures on the 3 land management types were significantly hotter than brood locations.

	Land Management Practices and Brood Information							
	Grazed No Herbicide		Ungrazed No Herbicide		Ungrazed Herbicide		Brood	
Habitat Variables	Mean (SE)	N	Mean (SE)	N	Mean (SE)	N	Mean (SE)	N
% CANOPY COVER CONTACTS ≥ 20 cm								
Tallgrasses	1.21 (0.83)	15	11.36 (2.59)	28	21.82 (5.94) H	10	7.36 (0.73)	257
Other Grasses	1.21 (0.83)	15	5.19 (2.45)	28	5.45 (3.09)	10	3.08 (0.55)	257
Total Grasses	2.42 (1.07)	15	16.56 (3.03)	28	27.27 (6.78) H	10	10.44 (1.01)	257
Sand Shinnery Oak	13.33 (2.64)	15	14.61 (2.40)	28	3.64 (2.78) L	10	16.63 (0.85)	257
Sand Sagebrush	0.61 (0.61)	15	1.30 (0.77)	28	0 (0.00)	10	0.74 (0.18)	257
Mesquite	0.61 (0.61)	15	0 (0.00)	28	2.73 (1.94) H	10	0.28 (0.19)	257
Total Woody	14.55 (2.48)	15	15.91 (2.41)	28	6.36 (3.05) L	10	17.65 (0.86)	257
Other	4.85 (2.15)	15	15.19 (1.58) H	28	2.73 (1.39)	10	2.23 (0.30)	257
% BASAL COVER CONTACTS								
Tallgrasses	0 (0.00)	15	4.55 (1.19) H	28	5.45 (3.09) H	10	1.56 (0.25)	257
Other Grasses	1.21 (0.83)	15	1.30 (0.77)	28	2.73 (1.39) H	10	0.67 (0.16)	257
Total Grasses	1.21 (0.83)	15	5.84 (1.34) H	28	8.18 (3.70) H	10	2.23 (0.29)	257
Other	0.61 (0.61)	15	0 (0.00)	28	0 (0.00)	10	0.18 (0.09)	257
CANOPY HEIGHTS (cm)								
Maximum Canopy Height	69.98 (3.57)	15	77.79 (2.71)	28	86.00 (5.06) H	10	72.08 (0.91)	257
STRATA CONTACTS								
< 10 cm	0.22 (0.11)	15	1.06 (0.15) H	28	1.63 (0.29) H	10	0.54 (0.05)	257
10-50 cm	0.78 (0.25)	15	1.74 (0.24) H	28	1.10 (0.35)	10	1.23 (0.07)	257
> 50 cm	0.11 (0.09)	15	0.01 (0.01)	28	0.07 (0.04)	10	0.12 (0.02)	257
Tallest Rod Contact (cm)	10.53 (2.32) L	15	18.56 (1.98)	28	14.73 (3.69)	10	16.76 (0.65)	257
STEM DENSITY								
Sand Shinnery Oak	14.11 (1.98)	15	11.1 (1.72) L	28	2.87 (1.50) L	10	14.13 (0.46)	257
Sand Sagebrush	0.09 (0.04)	15	0.15 (0.07)	28	0.07 (0.07)	10	0.08 (0.01)	257
Mesquite	0.02 (0.02)	15	0 (0.00)	28	0.10 (0.07) H	10	0.01 (0.01)	257
Other	0.31 (0.15)	15	0.71 (0.18) H	28	0.70 (0.30) H	10	0.23 (0.03)	257
Total Woody Stem	14.22 (1.96)	15	11.25 (1.72) L	28	3.03 (1.47) L	10	14.22 (0.46)	257
Angle of Obstruction	69.08 (3.44)	8	71.32 (1.55)	16	65.51 (3.17)	8	67.80 (0.64)	170
TEMPERATURE °C								
Cool Time Periods	23.93 (0.94)	31	24.09 (0.94)	31	24.37 (0.87)	31	25.10 (0.66)	31
Warm Time Periods	34.27 (0.59) H	108	35.24 (0.58) H	108	34.67 (0.57) H	108	32.15 (0.49)	108
Variables Different From Brood Locations	2 of 25		9 of 25		15 of 25			

Table 3. Comparison of all variables sampled at brood and random locations within each land management practice. Capital letters indicate variables significantly different from brood locations (e.g. H = "higher than brood" and L = "lower than brood") in the same row. Brood and random locations within areas that were grazed without herbicide use were most similar for and land management practice. Sites ungrazed and treated with herbicide contained the greatest difference for all variables measured at brood and random locations within these sites. On all 3 land management types, temperature did not differ between brood and random locations within each site during "cool" time periods. However, during "warm" time periods temperatures on grazed sites without herbicide use were significantly hotter than brood locations.

	Land Management Practices and Brood Information											
	Grazed No Herbicide				Ungrazed No Herbicide				Ungrazed Herbicide			
	Brood		Random		Brood		Random		Brood		Random	
Habitat Variables	**Mean (SE)**	**N**	**Mean (SE)**	**N**	**Mean (SE)**	**N**	**Mean (SE)**	**N**	**Mean (SE)**	**N**	**Mean (SE)**	**N**
% CANOPY COVER CONTACTS ≥ 20 cm												
Tallgrasses	2.37 (0.47)	123	1.21 (0.83)	15	8.58 (1.21)	53	11.36 (2.59)	28	14.03 (1.75)	81	21.82 (5.94) H	10
Other Grasses	2.73 (0.61)	123	1.21 (0.83)	15	1.03 (0.40)	53	5.19 (2.45) H	28	4.38 (1.1)	81	5.45 (3.09)	10
Total Grasses	5.10 (0.79)	123	2.42 (1.07)	15	9.61 (1.28)	53	16.56 (3.03) H	28	18.41 (2.24)	81	27.27 (6.78)	10
Sand Shinnery Oak	20.1 (1.33)	123	13.33 (2.64)	15	15.27 (1.51)	53	14.61 (2.40)	28	12.23 (1.34)	81	3.64 (2.78) L	10
Sand Sagebrush	0.89 (0.30)	123	0.61 (0.61)	15	1.20 (0.43)	53	1.30 (0.77)	28	0.22 (0.16)	81	0 (0.00)	10
Mesquite	0 (0.00)	123	0.61 (0.61)	15	1.20 (0.92)	53	0 (0.00)	28	0.11 (0.11)	81	2.73 (1.94) H	10
Total Woody	20.99 (1.32)	123	14.55 (2.48)	15	17.67 (1.63)	53	15.91 (2.41)	28	12.57 (1.32)	81	6.36 (3.05)	10
Other	1.03 (0.30)	123	4.85 (2.15) H	15	4.46 (0.87)	53	15.19 (1.58)	28	2.58 (0.56)	81	2.73 (1.39)	10
% BASAL COVER CONTACTS												
Tallgrasses	0.37 (0.16)	123	0 (0.00)	15	2.57 (0.67)	53	4.55 (1.19)	28	2.69 (0.56)	81	5.45 (3.09)	10
Other Grasses	0.67 (0.26)	123	1.21 (0.83)	15	0.51 (0.29)	53	1.30 (0.77)	28	0.79 (0.29)	81	2.73 (1.39) H	10
Total Grasses	1.03 (0.30)	123	1.21 (0.83)	15	3.09 (0.73)	53	5.84 (1.34) H	28	3.48 (0.61)	81	8.18 (3.70) H	10
Other	0.22 (0.16)	123	0.61 (0.61)	15	0.17 (0.17)	53	0 (0.00)	28	0.11 (0.11)	81	0 (0.00)	10
CANOPY HEIGHTS (cm)												
Maximum Canopy Height	65.77 (1.04)	123	69.98 (3.57)	15	78.7 (1.87)	53	77.79 (2.71)	28	77.33 (1.73)	81	86.00 (5.06)	10
STRATA CONTACTS												
< 10 cm	0.28 (0.04)	123	0.22 (0.11)	15	0.97 (0.14)	53	1.06 (0.15)	28	0.65 (0.09)	81	1.63 (0.29) H	10
10-50 cm	1.11 (0.08)	123	0.78 (0.25)	15	1.42 (0.16)	53	1.74 (0.24)	28	1.30 (0.16)	81	1.10 (0.35)	10
> 50 cm	0.12 (0.03)	123	0.11 (0.09)	15	0.16 (0.06)	53	0.01 (0.01) L	28	0.09 (0.03)	81	0.07 (0.04)	10
Tallest Rod Contact (cm)	16.36 (0.93)	123	10.53 (2.32) L	15	18.04 (1.58)	53	18.56 (1.98)	28	16.53 (1.1)	81	14.73 (3.69)	10
STEM DENSITY												
Sand Shinnery Oak	15.94 (0.55)	123	14.11 (1.98)	15	12.96 (1.03)	53	11.10 (1.72)	28	12.15 (0.94)	81	2.87 (1.50) L	10
Sand Sagebrush	0.1 (0.02)	123	0.09 (0.04)	15	0.11 (0.03)	53	0.15 (0.07)	28	0.04 (0.03)	81	0.07 (0.07)	10
Mesquite	0 (0.00)	123	0.02 (0.02)	15	0.04 (0.03)	53	0 (0.00)	28	0 (0)	81	0.10 (0.07) H	10
Other	0.1 (0.02)	123	0.31 (0.15)	15	0.45 (0.09)	53	0.71 (0.18) H	28	0.28 (0.06)	81	0.70 (0.30) H	10
Total Woody Stem	16.04 (0.55)	123	14.22 (1.96)	15	13.11 (1.03)	53	11.25 (1.72)	28	12.19 (0.94)	81	3.03 (1.47) L	10
Angle of Obstruction	68.09 (0.88)	98	69.08 (3.44)	8	66.41 (1.86)	22	71.32 (1.55)	16	67.86 (1.08)	50	65.51 (3.17)	8
TEMPERATURE °C												
Cool Time Periods	26.25 (0.96)	36	25.06 (0.94)	36	25	1	23.07	1	28.64 (0.94)	14	26.30 (1.46)	14
Warm Time Periods	31.99 (0.67)	71	34.83 (0.81) H	71	33.80 (0.62)	15	37.58 (0.90)	15	30.88 (0.78)	41	33.06 (0.85)	41
Variables Different From Brood Locations		3 of 25				5 of 25				10 of 25		

Figure 1. Demonstrates the selection of temperatures by broods that are counter in terms of what temperature is available at random locations. Temperature at brood locations with corresponding random average temperature according to time of day (a) and temperature difference according to random average temperature (b) for brood locations in southeastern New Mexico, summers of 2002 – 2003. Graph b was used to separate brood locations into 2 categories of temperature selection as indicated by the vertical line that separates the graph into "cool" and "warm" time periods.


(a)
Random
y = -181.75x² + 222.78x - 30.12
r² = 0.67
Bird
y = -126.36x² + 154.54x - 12.48
r² = 0.54
Temperature °C
Time of Day
38
33
28
23
18
13
6:00
9:00
12:00
15:00
18:00
21:00
0:00

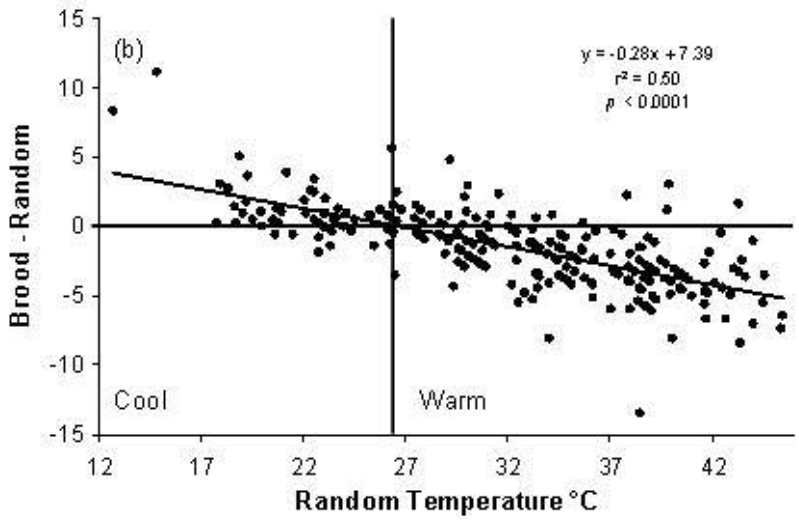

(b)
y = -0.28x + 7.39
r² = 0.50
p < 0.0001
Cool
Warm
Brood - Random
Random Temperature °C
15
10
5
0
-5
-10
-15
12
17
22
27
32
37
42

Figure 2. Differences of habitat use at multiple spatial scales and temperature categories by lesser prairie-chicken broods. Broods selected higher rod contacts (i.e. tallest rod contacts), more rod contacts 10-50 cm and > 50 cm during "warm" time periods at the point scale. The importance of sand shinnery oak is demonstrated by looking at its stem density; broods always selected higher stem densities of sand shinnery oak regardless of spatial scale or temperature. Vertical lines represent 1 SE.

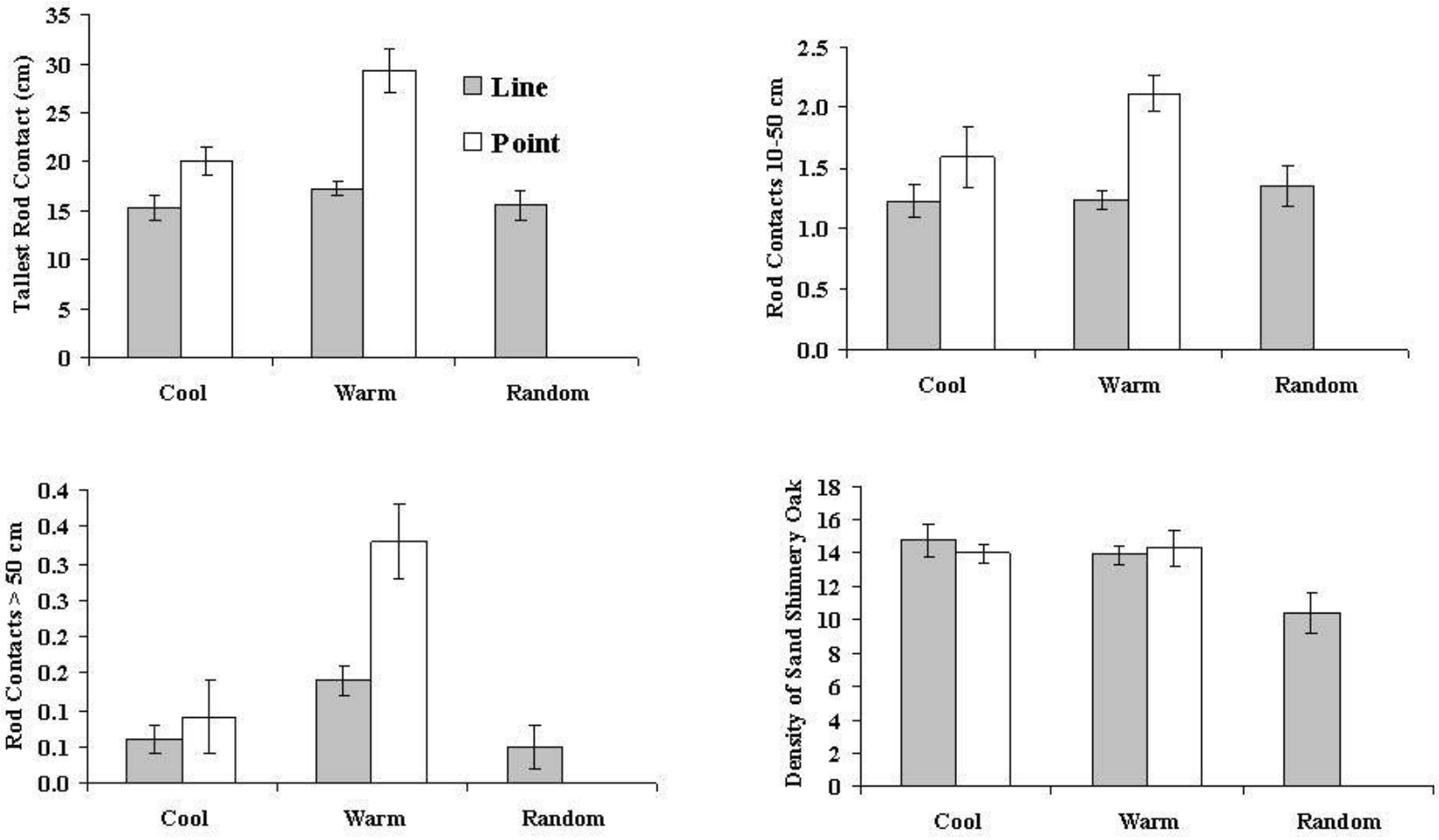
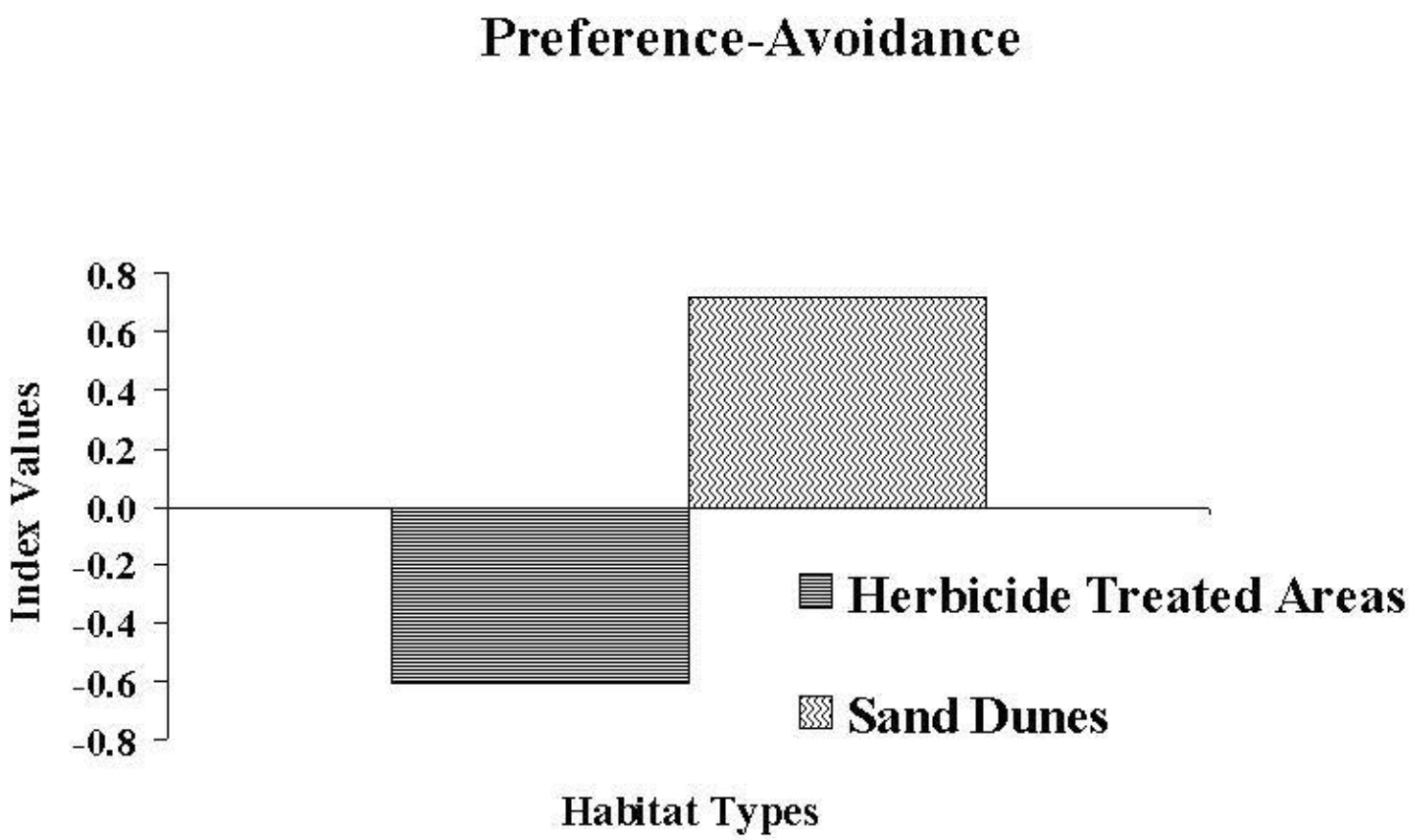

Tallest Rod Contact (cm)
35
30
25
20
15
10
5
0
Line
Point
Cool
Warm
Random
Rod Contacts 10-50 cm
2.5
2.0
1.5
1.0
0.5
0.0
Cool
Warm
Random
Rod Contacts > 50 cm
0.4
0.4
0.3
0.3
0.2
0.2
0.1
0.1
0.0
Cool
Warm
Random
Density of Sand Shinnery Oak
18
16
14
12
10
8
6
4
2
0
Cool
Warm
Random

Figure 3. Brood habitat selection within ungrazed herbicide area using Ivlev's Electivity Index for habitat preference-avoidance analysis on lesser prairie-chicken broods in New Mexico. Ivlev's index varies from -1.0 to +1.0, with positive values indicating preference, negative values avoidance, and 0 indicating random use. Broods (n = 6) located on ungrazed herbicide area selected sand dunes that were not treated with herbicide. Only 17% of brood locations (n = 81) found on ungrazed herbicide sites used areas treated with herbicide and these locations were during cool times of the day.


Preference-Avoidance
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
Index Values
Herbicide Treated Areas
Sand Dunes
Habitat Types

CHAPTER II

GROWTH AND DEVELOPMENT OF LESSER PRAIRIE-CHICKEN BROODS IN SOUTHEAST NEW MEXICO

ABSTRACT -- The ability to describe or compare growth rates across a species distribution, especially for a species of concern that has isolated populations separated by hundreds of kilometers, is essential baseline information for captive breeding efforts or examining genetic influences on adjacent populations of the same genus (i.e. potential to hybridize), respectively. We examined growth rates and the physical development of four body characteristics (mass, wing chord length, bill length, and head width) of lesser prairie-chickens (*Tympanuchus pallidicinctus*) <120 days post hatch in southeast New Mexico. New Mexico juvenile lesser prairie-chickens achieved 90% of their asymptotic body mass faster than lesser prairie-chickens in Kansas. However, growth rates, inflection points, and growth patterns (logistic and Gompertz) were the same in New Mexico as in Kansas for juvenile lesser prairie-chickens for body mass and wing growth.

INTRODUCTION

Given the alarming decline in many of North America's prairie grouse populations (Silvy and Hagen 2004), natural history information is becoming increasingly important for these species. In particular, the population size of the lesser prairie-chicken has decreased by 97% since the 1800s; there has also been a 92% reduction in the species' historic range and a 78% reduction in occupied range since 1963 (Crawford 1980, Taylor and Guthery 1980). Until recently growth data for juvenile lesser prairie-chickens was not published. Now that natal growth rates have been described for Kansas's northeast extent of lesser prairie-chicken's distribution (Pitman et al. 2005), growth rates from New Mexico's disconnected population may provide insight to geographical variation. Morphometric data from across a species' distribution is important for taxonomy and for comparisons of growing condition and other life-history

traits. The 1995 petition to list the lesser prairie-chicken as threatened or endangered under the Endangered Species Act warrants a clear concern over this species and as it becomes more fragmented it is necessary to consider the importance of discrete populations.

Our objectives were to (1) report growth estimates at 5 day time intervals for body mass, bill length, wing chord, and head width for juvenile lesser prairie-chickens in southeast New Mexico, (2) to describe growth rates of body mass and wing chord from hatch to reproduction, and (3) to compare growth rates between New Mexico and Kansas lesser prairie-chicken populations. This information will be useful for captive breeding programs and identifying long term changes in populations associated with their increased isolation through fragmentation.

METHODS

Our study was conducted on 24,484 ha of relatively intact sand shinnery oak (*Quercus havardii*) in southern Roosevelt County, New Mexico (33° 40'N, 103°06'W) during the summers of 2002 and 2003. The area is primarily used for grazing and 86% of the land is privately owned. Governmental land includes 3,296 ha of prairie-chicken management areas owned by New Mexico Game Commission.

Sand shinnery oak plant communities dominate the region (Peterson and Boyd 1998). Climate is semi-arid continental with an average frost-free growing period of 200 days extending from mid April to late October (Wright 2003). Average annual precipitation is 41 mm with 85% falling as rain from April through October. Average annual temperatures are 14°C to 16°C with lows of –34°C and highs > 40°C. Soil surface textures vary from sand to sandy clay loam. Topography is level to undulating

with slopes ranging from 0 to 5%, but usually less than 3%. Elevation ranged from 1,080 m to 1,300 m.

We captured 3- to 5-day old chicks 1.5 hours after sunrise by locating and flushing radio-tagged females to collect broods. Two chicks from each brood were marked with radio transmitters (Holohil Systems, Ltd., weighing 0.75 g, 30-day battery life, Larson et al. 2001). We measured body mass of all captured chicks to 0.5 g using a Pesola® spring scale. Calipers were used to measure bill length and head width and a wing-chord ruler was used to measure wing-chord lengths to the nearest 1 mm. Bill length was measured from the edge of the cere to the tip of the bill, and head width was measured directly behind the eyes (Baldwin et al. 1931). Wing-chord length was measured from the distal end of the carpal joint to the tip of the longest primary with wing not pressed flat against ruler (Pyle 1997).

Radio-tagged chicks were recaptured at 30 and 90 days post hatch. Thirty-day-old chicks were fitted with a larger radio collar transmitter (Holohil Systems Ltd., weighing 2.0 g, 90-day battery life), and measured using the procedures described for 3- to 5-day old chicks. Ninety-day-old chicks were also measured and fitted with an adult sized radio collar transmitter (Telemetry Solutions, 15 g, 20 months battery life) and tracked until the following spring. Chicks both 30 and 90 days old were recaptured at night via long-handled nets and spotlights using radio signals from the brood hen and chick transmitters.

STATISTICAL ANALYSIS

To analyze our first objective we compiled a table of means and standard errors for body mass, bill length, wing-chord, and head width measurements along with their

ages for 5- or 6-day growth intervals. Our second and third objectives were analyzed by previously published procedures (Pitman et al. 2005, Ricklefs 1973) to develop growth curves for four lesser prairie-chicken body characteristics (body mass, wing chord length, bill length, and head width) using SAS version 9.1 (SAS Institute 2003). This approach fits growth data by using 2 commonly applied growth equations for birds (Ricklefs 1973):

(1) Gompertz: $W = ae^{-e^{-K(t-I)}}$

(2) logistic: $W = \frac{A}{1+e^{-K(t-I)}}$

where W represents size at time t (days), A the final size or asymptote, I the inflection point at which 37% (Gompertz) and 50% (logistic) of the asymptotic size is achieved, and K a constant proportional to the overall growth rate (Ricklefs 1968, Zack and Mayoh 1982). We compared growth rates between morphological measures using an alternative parameter ($t_{50\text{-}90}$) that represents growth from 10 to 90% of the asymptote (Ricklefs 1967) since K is not directly comparable between the Gompertz and logistic models. We used $t_{50\text{-}90}$ as the parameter for wing chord because 10% of the calculated asymptote is less than the mean measurement at the 0- to 5-day growth interval. Not enough data was collected for bill length and head width for the modeling process.

Measurements collected from known-age birds (of unknown gender) were fit to the logistic and Gompertz models for each of the four body characteristics. We pooled data across both years because of small sample sizes. Parameters (K and I) were estimated by least squares using the Marquardt algorithm. We fixed A (asymptotic mass and wing chord) using the mean values of an equal number of randomly selected spring-caught juvenile male and female lesser prairie-chickens from another ongoing study.

Model fit was most closely examined for birds <50 days post hatching because these models were developed primarily to predict the age of juvenile lesser prairie-chickens. Due to heterogeneous variance between birds of different ages (morphometrics were more variable for older birds), model fit was often poor for this portion of the curve (measured from residual plots). Therefore, we placed greater weight on smaller observations during the modeling process (Draper and Smith 1981) forcing the curve to more accurately describe growth of younger birds. The model and weighting (if necessary) combination that provided the best fit (measured from residual plots and least sums of squares error) for birds <50 days post-hatching was selected as the final model.

Since our models were created with non-independent observations (i.e. multiple measurements from broods and individual birds) we used a bootstrap-resampling procedure (Manly 1998) to obtain 95% confidence intervals for each estimated parameter. We conducted 5000 iterations where broods were resampled with replacement to match the total number of broods in the original data set. The selected model was refit to the resampled data set and all parameters re-estimated. Sampling distributions were developed for each estimated parameter and 95% bootstrap bias-corrected and accelerated (BCA) confidence intervals were taken from the resulting distributions (Pitman et al. 2005).

RESULTS AND DISCUSSION

Growth Estimates

Growth estimates were calculated for body mass from 46 chicks in 15 broods, bill length from 43 chicks in 15 broods, wing chord from 43 chicks in 15 broods, and head width from 11 chicks in 4 broods. We recorded measurements from birds ranging from 3

days to 111 days post-hatching. Means were calculated at 5- or 6-day intervals (depending on sample size) for 11 growth periods prior to 111 days post-hatch (Table 2). Data was not collected at 16-24, 46-60, 66-100, and 106-110 days post-hatch.

Description of Juvenile Growth Rates

The logistic equation best described gains in lesser prairie-chicken mass (Fig. 1A), whereas change in wing chord during the first 111 days post-hatching was best described with the Gompertz equation (Fig 1B). Change in wing chord occurred at a much faster rate than did mass, as reflected by the number of days for growth to reach 90% of the calculated asymptote. Bill length and head width did not converge to either model; therefore we report the mean ± SE for these 2 measures at each time interval in Table 2.

Geographic Comparison Juvenile Growth Rates

Similar to Kansas juvenile lesser prairie-chickens (Pitman et al. 2005), observations in New Mexico follow the logistic and Gompertz growth patterns for body mass and wing growth, respectively. Although New Mexico juvenile lesser prairie-chickens reached 90% of their asymptotic mass in fewer days than Kansas birds, growth rate estimates *K* and *I* did not differ, indicating rates of growth are the same but asymptotic potential for mass is different. Pitman et al. (2005) reports mean mass estimates for male and female juvenile birds to be (mean ± SE) 789 ± 4 and 719 ± 6, respectively, but our mean pooled estimate of male and female birds 713 ± 7 is more comparable to Kansas females, this further supports our results that New Mexico birds have less potential to achieve the body mass size of Kansas's northern population of lesser prairie-chickens. Differences in body mass, between these 2 sites, may be

attributed to Bergman's Rule (populations in colder climates (higher latitudes) have larger bodies than population in warmer climates (lower latitudes)), food availability, or from genetic influences on Kansas birds from greater prairie-chicken (*Tympanuchus cupido*) hybridization; however we did not collect any data to substantiate such speculation.

An inflection point marks the beginning of a significant move along a curve, and wing growth inflection point in this study corresponded to when juvenile lesser prairie-chickens begin to fly. For instance, wing growth inflection points from Kansas (Pitman et al. 2005) and our study (12 and 13 days, respectively) occur at an age in which juveniles prairie-chickens begin to fly, 7-14 days depending on how one defines flight (Ricklefs 1973, Giesen 1998). Other galliform researchers report similar flight ages ranging from 7-11 days, but fail to give inflection points to further support our conclusions about inflection points being indicative of flight capabilities in galliformes (Milby and Henderson 1937, Lewin 1963). Unfortunately, we were unable to locate other published inflection points on gallinaceous birds to support such a hypothesis.

Our study provides the first information on the growth and development of juvenile lesser prairie-chickens for southeast New Mexico. We documented mean morphological measurements at 5- or 6-day time intervals and juvenile growth rates for body mass and wing chord. Since growth rates between Kansas and New Mexico did not differ, but asymptotic potential for body mass was higher in Kansas, further supports Bergman's rule, however, food availability and genetic influences from greater prairie-chickens cannot be dismissed. Most importantly, the data provide a baseline of

information for future comparisons of juvenile lesser prairie-chickens within New Mexico and across their distribution.

LITERATURE CITED

Baldwin, S. P., H. C. Oberholser, and L. G. Worley. 1931. Measurements of birds. Cleveland Museum of Natural History. No. 2.

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

Draper, N. R., and H. Smith 1981. Applied regression analysis. John Wiley & Sons Inc., New York.

Giesen, K. M. 1998. Lesser prairie-chicken (*Tympanuchus pallidicinctus*) in A. P. a. F. Gill, editor. The birds of North America. The Birds of North America Inc, Philadelphia, PA.

Larson, M. A., M. E. Clark, and S. R. Winterstein. 2003. Survival and habitat of ruffed grouse nests in northern Michigan. Wilson Bulletin 115:140-147.

Lewin, V. 1963. Reproduction and development of young in a population of California Quail. Condor 65:249-278.

Manly, B. F. J. 1998. Randomization, bootstrap and Monte Carlo methods in biology. Chapman & Hall, London, UK.

Milby, T. T., and E. W. Henderson. 1937. The comparative growth rates of turkeys, ducks, geese and pheasants. Poultry Science 16:155-165.

Peterson, R. S., and C. S. Boyd. 1998. Ecology and management of sand shinnery communities: a literature review. USDA Forest Service General Technical Report. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.

Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2005. Gender identification and growth of juvenile Lesser Prairie-Chickens. Condor 107:87-96.

Pyle, P. 1997. Identification guide to North American birds. Part I. Columbidae to Ploceidae. Braun-Brumfield Inc., Ann Arbor, MI.

Ricklefs, R. E. 1967. A graphical method of fitting equations to growth curves. Ecology 48:978-983.

Ricklefs, R. E. 1968. Patterns of growth in birds. Ibis 110:419-451.

Ricklefs, R. E. 1973. Patterns of growth in birds II. Growth rate and mode of development. Ibis 115:177-201.

SAS Institute. 2003. SAS/STAT user's guide. Version 9.1 SAS Institute, Cary, North Carolina.

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

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

Wright, E. 2003. Ecological Site Description. Pages 1-15. United States Department of Agriculture Natural Resources Conservation Service.

Zach, R., and K. R. Mayoh. 1982. Weight and feather growth of nestling tree swallows. Canadian Journal of Zoology 60:1080-1090.

FIGURE 1. Growth curves and relationships between morphological attributes of juvenile lesser prairie-chickens as described by the logistic (mass) (n = 46) and Gompertz growth equations (wing chord) (n = 43).

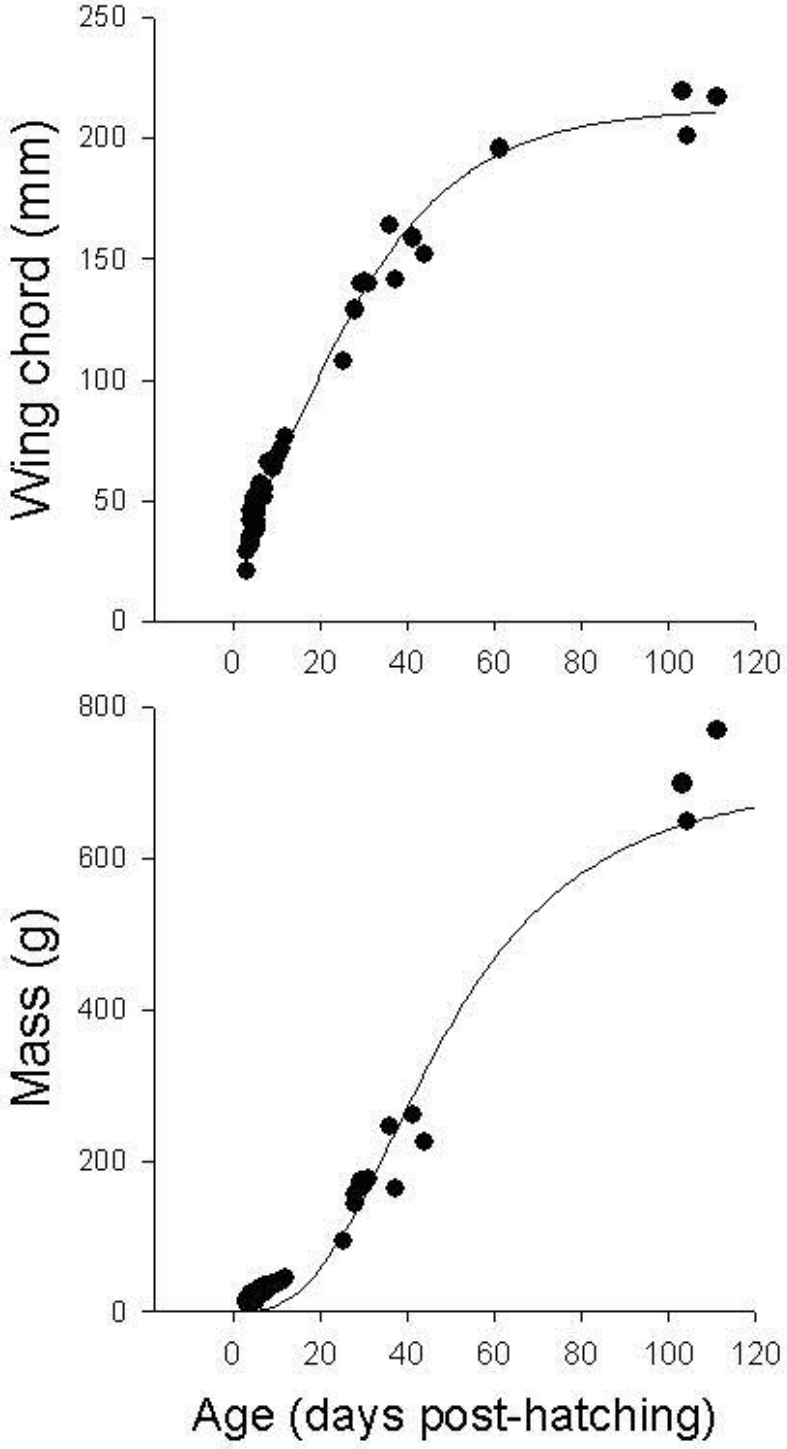

Wing chord (mm)
250
200
150
100
50
0
0
20
40
60
80
100
120
Mass (g)
800
600
400
200
0
0
20
40
60
80
100
120
Age (days post-hatching)

TABLE 1. Parameter estimates and 95% bootstrap bias-corrected accelerated confidence intervals (CIL, CIU) for equations describing growth of Lesser Prairie-Chickens in southeast New Mexico. Growth rate (K) and inflection point (I) were estimated through modeling using the logistic equation for mass and Gompertz equation for wing chord. Time (t) needed to grow from 10 to 90% of the asymptote is presented for mass and 50 to 90% of the asymptote wing chord.

	K			*I*			*A*[a]			
Morphometric Variable	Estimate	CI_L	CI_U	Estimate	CI_L	CI_U	Estimate	CI_L	CI_U	*t*
Mass (g)	0.088	0.078	0.096	44	41	48	713	698	727	50
Wing chord (mm)	0.053	0.047	0.059	13	13	14	210	207	213	35

[a]All asymptotes (A) were fixed in our modeling efforts. We estimated asymptotes by randomly selecting an equal number of male and female juvenile birds from the following spring seasons of each sampled summer. We then pooled these values across genders and years to calculate a mean, standard error, and sample size for each measure; the values for body mass and wing chord are as follows: (713 ± 7 g, n = 32) and (210 ± 1 g, n = 32) for juvenile lesser prairie-chickens captured in spring seasons of 2003 and 2004 for southeast New Mexico.

TABLE 2. Measurements (mean ± SE) of body mass, bill length, head width, and wing chord length for juvenile lesser prairie-chickens from 0 to 115 days post-hatching in southeastern New Mexico. Time intervals of 5 days were used to summarize the data.

Age (days post-hatch)[a]	*n*	Average Age	Mass (g)	*n*	Average Age	Bill length (mm)	*n*	Average Age	Head width (mm)	*n*	Average Age	Wing chord (mm)
0-5	27	4.3 ± 0.2	19.4 ± 0.7	23	4.5 ± 0.1	8.7 ± 0.3	6	5.0 ± 0	15.3 ± 0.2	23	4.5 ± 0.1	40.1 ± 1.6
6-10	11	7.4 ± 0.4	32.0 ± 1.5	11	7.4 ± 0.4	10.3 ± 0.3	0	-	-	11	7.4 ± 0.4	59.1 ± 1.8
11-15	2	11.5 ± 0.5	44.0 ± 2.0	2	11.5 ± 0.5	11.5 ± 0.5	0	-	-	2	11.5 ± 0.5	74.5 ± 2.5
25-30	6	28.2 ± 0.7	151.1 ± 12.1	6	28.2 ± 0.7	15.1 ± 1	3	27.7 ± 1.3	21.0 ± 1.5	6	28.2 ± 0.7	131.3 ± 5.1
31-35	1	31.0	177.0	1	31.0	16.0	0	-	-	1	31.0	140.0
36-40	2	36.5 ± 0.5	205.0 ± 41.0	2	36.5 ± 0.5	18.5 ± 0.5	2	36.5 ± 0.5	21.5 ± 1.5	2	36.5 ± 0.5	153.0 ± 11.0
41-45	2	42.5 ± 1.5	243.0 ± 18.0	2	42.5 ± 1.5	17.5 ± 0.5	1	41.0	24.0	2	42.5 ± 1.5	155.5 ± 3.5
61-65	0	-	-	1	61.0	20.0	0	-	-	1	61.0	196.0
101-105	2	103.5 ± 0.5	675.0 ± 25.0	2	103.5 ± 0.5	21.1 ± 1.1	2	103.5 ± 0.5	26.7 ± 1.9	2	103.5 ± 0.5	210.5 ± 9.5
111-115	1	111.0	770.0	1	111.0	16.9	1	111.0	26.4	1	111.0	217.0

[a] No data were collected from chicks between 16-20, 46-60, 66-100, and 106-110 days post-hatching.

VITA

LUKE A. BELL

Candidate for the degree of

Master of Science

Thesis: HABITAT USE AND GROWTH AND DEVELOPMENT OF LESSER PRAIRIE CHCKEN BROODS IN SOUTHEAST NEW MEXICO

Major Field: Rangeland Ecology and Management

Biographical:

Education: Graduated from McAlester High School, McAlester, OK in May of 1998; received a Bachelor of Science degree in Conservation Wildlife and Fisheries in May 2002 from Southeastern Oklahoma State University, Durant, OK. Completed the requirements for the Master of Science degree in Rangeland Ecology and Management also from Oklahoma State University, Stillwater, OK in May of 2005.

Experience: Worked as teaching assistant during the fall semester of 2002 for BIOL 1114 "General Biology" taught by Dr. Donald French. Worked as teaching assistant during the spring semester of 2003 for ZOOL 5463 "Stream Ecology" taught by Dr. Bill Fisher. Worked as teaching assistant during the fall and spring semesters of 2003 and 2004 respectively for BIOL 1604 "Animal Biology" taught by Dr. Larry Talent. Employed by Rural Alliance for Improving Science Education (RAISE) through the Geography Department at Oklahoma State University from fall semester of 2004 through the spring semester of 2005.

Activities:

- Conservation Biology – Student Member (2004-2005)