THE EFFECTS OF SHINNERY OAK REMOVAL ON LESSER PRAIRIE CHICKEN SURVIVAL, MOVEMENT, AND REPRODUCTION

A Thesis

by

JOHN PETER LEONARD

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

MASTER OF SCIENCE

May 2008

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Chair of Committee,	Nova J. Silvy
Committee Members,	Fred E. Smeins
	Roel R. Lopez
Head of Department,	Thomas E. Lacher, Jr.

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ABSTRACT

The Effects of Shinnery Oak Removal on Lesser Prairie Chicken Survival, Movement and Reproduction. (May 2008)

John Peter Leonard, B.A., University of Dallas

Chair of Advisory Committee: Dr. Nova J. Silvy

The lesser prairie chicken (*Tympanuchus pallidicinctus*; LPC) has declined in numbers since the late 1800s. Reasons for this decline have been attributed to habitat degradation (decreased forb and grass cover and increased woody cover) and fragmentation caused by overgrazing and conversion of native rangelands to croplands. The herbicide, Tebuthiuron, has been used extensively throughout the LPC's range to reduce dominance of woody shrubs and allow growth of forbs and grasses. Tebuthiuron treatment of shinnery oak (*Quercus havardii*) rangelands has been reported as being both beneficial and detrimental to LPC populations. My study evaluated the effects of Tebuthiuran treatment of shinney oak on LPC survival, movement, and reproduction.

I trapped (48), radio-tagged (38), and monitored LPC survival, movements, reproduction, and habitat use during spring and summer 2006 and 2007. I also determined potential LPC nest predators using dummy nests (domestic chicken eggs) and motion-sensitive infrared cameras.

No differences were found in survival between ages, sexes, or years. Range size did not differ by age, sex, or year. Female LPC moved greater distances from lek of capture than did males. Females nested almost exclusively in non-grazed rangeland and under sand sagebrush (*Artemisia filifolia*). Nest-sites had higher obstruction of vision (OV), higher (%) woody cover, and lower (%) bare ground than surrounding areas. All LPC were found to use non-grazed rangeland areas more than all other vegetation types, and to use tebuthiuron-treated, grazed areas slightly more than non-treated, grazed areas. Non-grazed rangeland had higher OV than all other vegetation types. Tebuthiuron treatment lowered woody plant dominance and increased forbs and grasses. Fire reduced vegetation height and OV and increased growth of grasses and forbs, but did not kill woody vegetation as did tebuthiuron-treatment. The most common dummy nest predator found was the Chihuahuan raven (*Corvus cryptoleucus).*

DEDICATION

To Leslie

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Nova Silvy, for providing me with this incredible research opportunity, and for seeing to it that I had all the resources needed to carry out my research effectively. I also sincerely appreciate the efforts of my committee members, Dr. Roel Lopez and Dr. Fred Smeins, in reviewing and editing my thesis. Eddie Lyons and Jared Pollard deserve my thanks for providing me with invaluable advice and for assisting me with data collection.

I also would like to thank my parents for constantly encouraging my scientific curiosity, and for spending so much time with me in the outdoors. I also should acknowledge my undergraduate biology professor, Dr. Marcy Brown-Marsden, whose interesting lectures and frequent field excursions helped to foster in me an interest in Wildlife Science. Finally, I would like to thank my wife, Leslie, for her patience and support during those long stints in the field.

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INTRODUCTION

The lesser prairie chicken (*Tympanuchus pallidicinctus*, LPC) has declined dramatically, both in numbers and in distribution, since the late 1800s (Crawford 1980, Taylor and Guthery 1980). Though still found in all 5 historically occupied states of New Mexico, Colorado, Kansas, Oklahoma, and Texas, remaining LPC populations are increasingly fragmented and reduced in abundance (Giesen 1998). It is widely believed this decline is due primarily to habitat loss resulting from overgrazing and the conversion of native rangelands to croplands (Crawford 1980, Taylor and Guthery 1980, Pittman 2003, Silvy et al. 2004).

Litton (1978) estimated that between 1900 and 1974, LPC in Texas declined from 2 million to about 17,000. At their peak in distribution and abundance, LPC were present in 100 Texas counties. They are now present in only 11 counties (Litton 1978). Based on these trends, it is believed that LPC are currently declining at a faster rate than did the federally endangered Attwater's prairie chicken (*Tympanuchus cupido attwateri*; Silvy et al. 2004). In 1995, a petition to list LPC as threatened under the Endangered Species act was submitted to the U.S. Fish and Wildlife Service (USFWS). In 1998, the USFWS issued a "warranted but precluded" listing for the species (Federal Register 1998). The LPC is currently listed as "threatened" by the IUCN (2006).

In order to adopt an effective management plan for LPC and prevent population numbers from declining further, it is imperative the species' habitat requirements be fully

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The style of this thesis follows the Journal of Wildlife Management.

understood. In the southwestern Texas Panhandle, LPC populations are confined mainly to shrublands dominated by shinnery oak (*Quercus havardii*). Shinnery oak is a woody shrub usually <1 m in height that can form dense stands throughout much of the LPC's range. It is unclear what benefits LPCs derive from shinnery oak. LPC have been reported as dependent on shrublands across their range (Copelin 1963, Olawsky and Smith 1991, Boyd and Bidwell 2001, Fuhlendorf et al. 2002). Shinnery oak has likewise been reported as providing essential food (catkins and acorns) and cover for LPC (Jackson and DeArment 1963, Davis et al. 1980, Bell 2005). However, dense stands of shinnery oak may crowd out grasses and forbs which also provide food (seeds and grasshoppers) and shelter (Pettit 1979).

Because of the detrimental effect (reduced grass and oak poisoning) shinnery oak can have on cattle grazing, many ranchers have used herbicides such as Silvex, Picloram, or Tebuthiuron to control the plant. Since these herbicides are used extensively for shrub control throughout the LPC's range, it is important to understand its effects on LPC populations. Jackson and DeArment (1963) reported shinnery oak removal negatively affects LPC populations by removing a food source and a protective cover. Conversely, Doerr and Guthry (1983) found intermediate levels of tebuthiuron treatment resulted in an increase in grass cover and seed production. Riley (1978) and Wisdom (1980) both found LPC's prefer areas of high grass to areas of high shinnery oak for nesting sites. Olaesky and Smith (1991) found winter densities of LPC to be greater in areas treated with herbicide than in areas not treated with herbicide.

In 2004, Texas A&M University initiated a study to examine the effects Tebuthiuron treatment of shinnery oak rangelands has on LPC survival, reproduction, and movement in portions of northern Yoakum and southern Cochran counties. Field activities for my research took place in spring and summer 2006 and 2007. The purpose of my study was to evaluate changes in vegetative structure occurring 2 and 3 years post-treatment and determine what effects these changes had on LPC behavior and population dynamics. Specific objectives were to (1) use radio-telemetry to examine adult movements between treated and non-treated areas and to determine seasonal range and habitat selection, (2) evaluate LPC breeding season survival, (3) compare vegetative characteristics of successful and unsuccessful nest sites to randomly-selected non-use sites to determine if LPC select nest sites based on specific vegetative characteristics, (4) evaluate changes in vegetative structure resulting from tebuthiuron treatment, cattle grazing, and small-scale burning, and (5) determine differential nest predation rates between treated and non-treated areas through the use of motion-sensitive cameras and dummy nests.

METHODS

Study Area

Field activities were conducted approximately 15 km north of Plains, Texas in northern Yoakum and southern Cochran counties, within the High Plains ecoregion (Gould 1962) of the Texas Panhandle (Fig. 1). The High Plains ecoregion has an elevation of 914–1,372 m and an average annual rainfall of 38–53 cm (Gould 1962).

The study area was located within native rangelands dominated primarily by shinnery oak with sand sagebrush (*Artemisia filifolia*) occurring in lesser amounts. Common herbaceous species included little bluestem (*Andropogon hallii*), sand lovegrass (*Eragrostis tichodes*), sand dropseed (*Sporobolus cryptandrus*), and three-awn (*Aristida sp*.). Common forbs included camphorweed (*Heterotheca pilosa*), Texas croton (Croton texensis), western ragweed (*Ambrosia psilostachya*), and queensdelight (*Stillingia sylvatica*). Taxonomic nomenclature follows Gould (1962).

Soils were consistent with the Brownfield-Tivoli association which produced deep undulating sands (Dittenmore and Hyde 1960). Topography was mostly flat land interspersed by vegetated and active sand dunes (Dittenmore and Hyde 1960).

Primary field activities were conducted on the Frost Ranch in northern Yoakum County and surrounding areas. The Frost Ranch consists of 4 pastures, each approximately 500 ha in size (total area 2,010 ha.). Approximately 728 ha of the Northwest and Southwest Frost Ranch pastures were treated (April-March 2004) with an aerial application of tebuthiuron pellets, at a concentration of 113.4 g/ha active ingredient. A significant portion of field activities took place on the ranch directly north of the Frost Ranch in Cochran County dubbed "Cochran Ranch". The Cochran Ranch

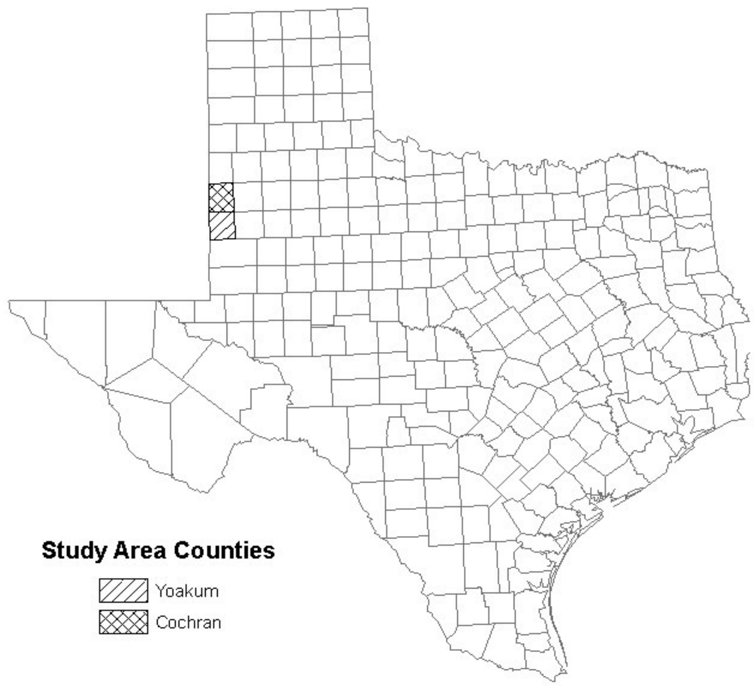

Fig. 1. Yoakum and Cochran counties in the High Plains of Texas where study area was located.

totaled 1,177 ha in size. In May 2006, a low-intensity fire burned 16 ha of the Cochran Ranch.

Land use within the study area was primarily grazing, with limited amounts of petroleum extraction. The Frost Ranch was grazed heavily prior to initiation of the study, however, it was non-grazed from 2003–2005, but was again heavily grazed during fall

2006 and during 2007. The Cochran Ranch had been left non-grazed for approximately 10 years (Byron West, local rancher, personal communication). Land uses of surrounding areas included cattle-grazing and crop production. In addition, several surrounding fields (especially south of the Frost Ranch including one field which was part of the Frost Ranch) were enrolled in conservation reservation program (CRP) contracts, primarily planted in monoculture stands of weeping lovegrass (*Eragrostis curvula*).

Trapping and Monitoring

Field activities took place in spring and summer 2006 and 2007. All individual LPC were captured on leks in the early morning or late evening using non-explosive, rectangular-shaped drop nets (Silvy et al. 1990).

Immediately upon capture, LPC were sexed and aged. Age was determined by barring patterns on the outermost primary feather (Campbell 1972). Individuals were classified as juvenile (~10 months) or adult (≥12 months). All captured LPC were weighed to the nearest gram with a spring scale. Numbered aluminum leg bands were attached to each bird. All females and most males captured were fitted with radio transmitters. Four different models of radio transmitters were used during the study. All featured 8-hour motion-sensitive switches, and weighed approximately 12 g, with a nominal power supply of 9–12 months. Frequency range was between 150.000–151.999 MHz.

All radio-collared LPC were monitored daily using either a 3-element handheld yagi antenna or a 5-element yagi antenna mounted through the roof of a truck. Individuals were located either by "homing-in" on the individual or by triangulating the bird's position from at least 3 locations. Homing-in involved following an individual's signal until it flushed, at which point its exact location was recorded using a handheld Global Positioning System (GPS) unit. Triangulation involved estimating an individual's location using $\geq$3 azimuths at georeferenced receiving stations marked with a GPS unit (White and Garrott 1990). Azimuths were collected <20 min apart and as close to the signal source as possible to minimize the size of associated error ellipses (Heezen and Tester 1967). The computer program, Locate III, was used to generate estimated locations using the Maximum Likelihood Estimator (MLE) procedure for estimating angular error (Nams 2006). Error ellipses were constructed at the 95% confidence level, and the area of the ellipse for each location event recorded. Average error ellipse size was 183 ha (*SE* = 2.4).

Seasonal Survival

To calculate survival rates, I used the Kaplan-Meier estimator modified for staggered entry (Pollock et al. 1989). Survival estimates were limited to the breeding seasons of 2006 and 2007. Birds that experienced radio failure or could not be located were censored and removed from further analysis.

Movement, Range, and Habitat Selection

To investigate range, habitat use, and daily movements, all locations obtained either through homing-in or triangulation were entered into a digital ArcView map. Seasonal range for the 2006 and 2007 breeding seasons was calculated using Mohr's (1947) 95% minimum convex polygon. Since telemetry work was conducted only during spring and summer 2006 and 2007, all locations for each radio-collared individual were pooled by year and used to calculate breeding season range. Two separate measurements were used to calculate movements: greatest distance and mean distance. Greatest distance is a measure of the greatest distance an individual LPC was found from its lek of capture, reported in meters. Mean distance was calculated by measuring the distance between an individual LPC's lek of capture and each independent location event recorded during that season, reported in meters. All location events were summed and divided by the total number of independent location events to give a mean distance value for the LPC. Range size, greatest distance, and mean distance were calculated only for individuals having $\geq$10 locations. Greatest distance, mean distance, and range were tested for normality using a Shapiro-Wilks test. Greatest distance and mean distance were found to be normally distributed ($P = 0.663$, $P = 0.187$, respectively). Range size, however, was found to be non-normally distributed ($P = 0.051$). It was therefore rank-transformed before being analyzed. A General Linear Model was used to test for differences in greatest distance, mean distance, and range size between sex and age classes.

To determine habitat selection all vegetation types falling within the study area were converted to shapefiles and classified as one of the following vegetation types (Fig. 2): (1) non-grazed, non-treated rangeland, (2) grazed, treated rangeland, (3) grazed, non-treated rangeland, (4) non-grazed, non-treated, burned rangeland, (5) conservation reserve program fields (CRP), (6) cropland, and (7) lands with unknown history of grazing, herbicide and/or fire (hereafter "unknown treatments"). These classifications were based on prior knowledge of the land-use patterns of each property. All CRP and cropland were fairly easy to delineate using satellite imagery. The entire Frost Ranch was classified as grazed since it was heavily grazed prior to initiation of this study and also was grazed during fall 2006 and 2007. Areas within the Frost Ranch treated with tebuthiuron were classified as grazed treated while areas left non-treated with tebuthiuron

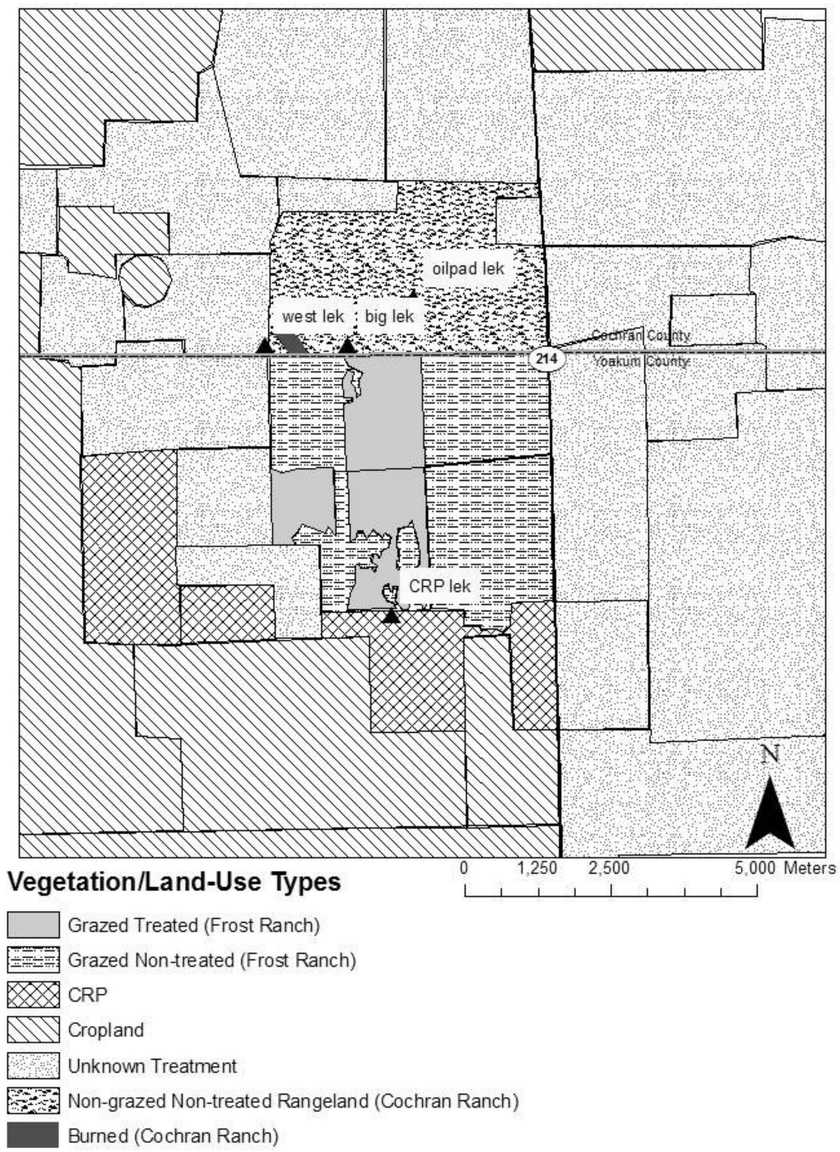

Fig. 2. Map showing relative availability of different vegetation/land-use types within Cochran and Yoakum counties and locations of active leks.

were classified as grazed non-treated. Only the Cochran Ranch was classified as non-grazed and non-treated since conversations with local ranchers have indicated the property had not been grazed for approximately 10 years (Fig. 2).

The areas (ha.) covered by each of these vegetation types were calculated. The area available to each LPC was assumed to be a circle of 4.8-km radius centered at the lek on which that LPC was trapped. Previous studies have indicated a strong tendency for LPC to remain within 4.8 km of their lek (Taylor and Guthery 1980, Giesen 1994, Riley et al. 1994). The percent cover of each vegetation type within the circle of available habitat was calculated. Location events for all birds trapped at a given lek were pooled by season. Each independent location event was separated based on the vegetation type it fell inside within the 4.8-km buffer zone. Location events that occurred further than 4.8 km from the lek of capture were censored.

Location events were pooled by year and by lek of capture. That is, all location events for birds trapped at a given lek were pooled and used to calculate habitat use for that lek. Expected counts for each vegetation type were calculated based upon the relative area within the lek-based buffer zone comprised by that vegetation type. A Chi-square test was performed to determine if LPC use vegetation types differently than what would be expected were they using all habitats within the lek-based buffer zone at random.

The Chi-square test rejected the null hypothesis of independence ($X^2 = 816.46$, $df = 15$, $P = 0.05$). This indicates that LPC do not use habitat at random, but select for certain habitat types. A Cox and Key test (Cox and Key 1993) was used to conduct a series of pair-wise comparisons to determine which habitat types were selected significantly more or less than others. With this test, Chi-square values for each cell were computed and compared with the calculated Chi-square values for each other cell within that column. If the difference in calculated values for the 2 cells was found to be greater than the table value of the Chi-square statistic ($df = 1$, $P \leq 0.05$) the cells were considered to differ significantly.

Vegetative Response to Tebuthiuron Treatment

To investigate vegetative responses to Tebuthiuron treatment, a series of random points was laid out in the 4 Frost Pastures and in the Cochran Ranch. Each point was georeferenced with a GPS unit and superimposed, using ArcView, on shapefiles showing Tebuthiuron-treated areas. Points located in the Northwest (NW) and Southwest (SW) Frost pastures were separated and analyzed based on whether or not they fell within the Tebuthiuron-treated area. Points located within the Cochran Ranch were separated and analyzed based on whether or not they fell within the May 2006 burned area.

At each randomly-selected point, visual obstruction (OV) measurements were taken from 4 cardinal directions (N, E, S, W), at a height of 1 m and a distance of 4 m, using a Robel range pole (Robel et al. 1970), marked at 10-cm intervals. The height of the tallest plant was measured with a 0.9-m ruler marked at 2.5-cm intervals. A 1 m^2 Daubenmire (1959) frame was placed at each point to determine percent composition of woody plants, grasses, forbs, and bare ground. The percent composition of each cover type was estimated as falling within one of the following categories: (1) 0–5%, (2) 6–25%, (3) 26–50%, (4) 51–75%, (5) 76–95%, and (6) 96–100%. In addition, the dominant plant species, number of shinnery oaks, number of dead oaks, and number of acorns inside the frame was recorded. Litter depth was measured using a ruler marked at 2.5-cm intervals.

Measurements of OV, plant height, and litter depth were tested for normality using a Shapiro-Wilkes test (Ott 1993). If normally distributed, they were compared using an ANOVA and Fisher's LSD test used to determine which means differed significantly from others. If they were found to be non-normally distributed, they were compared, along with all other vegetative characteristics, using a Kruskal-Wallis test. A Mann-Whitney test (Ott 1993) was used to determine which treatment types differed significantly from others.

In May of 2006, a 16 ha fire burned a portion of the Cochran Ranch (Fig. 2). In order to investigate the changes in vegetative characteristics caused by fire after 1 year, 45 random points were placed within the non-burned portions of the Cochran Ranch, and 26 were placed within the burned area.

All 2006 and 2007 vegetation data were combined into the following categories: Frost Ranch non-treated, Frost Ranch treated, Cochran pasture non-burned, and Cochran pasture burned. All variables (OV, plant height, litter depth, woody rank, forb rank, grass rank, bare ground rank, number live oaks, number dead oaks) were found to be non-normal. A Kruskal-Wallis test was therefore used to determine whether or not at least one of the pastures differed from the others in each vegetative characteristic. A Mann-Whitney U test was used to conduct a series of pair-wise comparisons to determine which pasture types differed from the others in each vegetative characteristic.

For every vegetation point taken from 2006–2007, the dominant plant was recorded. To investigate the changes in dominant plant cover resulting from different land-use/treatment regimes, all dominant plant data were separated by pasture type, counted, and analyzed using a Chi-square test. In order to avoid unacceptably low expected cell values 2006 and 2007 data were combined.

The null hypothesis of independence was rejected ($P < 0.001$), indicating treatment has an effect on dominant plant types. In order to determine which pastures had significantly more or fewer dominant plant counts for each plant type a Cox and Key post-hoc test was performed (Cox and Key 1993).

Nest-site Selection

During the nesting season, incubating females were located by homing in using a 3-element handheld antenna. The locations of the nests were marked using a GPS unit. The fate of each nest was determined to be abandoned, destroyed, or hatched. After each nest fate had been determined, an OV reading was taken from 4 cardinal directions using a Robel range pole. A 0.1-m^2 Daubenmire frame was used to determine percent composition of each cover type. Vegetation height and litter depth also were recorded. Similar measurements were taken in 8 compass directions (N, NE, E, SE, S, SW, W, NW) at a distance of 25 m from the nest bowl. Data obtained from all 9 points were averaged together to give vegetative characteristics of the nest-site location.

To determine how nest-site locations differ from the surrounding landscape, identical vegetation measurements also were collected from randomly selected points, determined by selecting a random direction (1 of 8 directions) and random distance (200–800 m in 100-m increments). Nest vegetation data from 2006 and 2007 were combined and analyzed to determine if significant differences exist between the vegetative characteristics of nest sites and randomly-selected non-use areas. A 2 sample *t*-test was used to determine if significant ($P < 0.05$) differences in vegetation height, OV, and litter depth exist between nest-site locations and randomly selected non-use sites. A Mann-Whitney test was used to determine if significant ($P < 0.05$) differences exist in percent composition of woody plants, forbs, grasses and bare ground, between nest site locations and randomly selected non-use sites. A Chi-square test was used to determine if dominant plant species differed between nest site locations and randomly selected non-use sites.

Nest Predation

To determine differential nest-predation rates between pasture types a series of dummy nests with motion-sensitive cameras (Game Spy 100, Moultrie Feeders, Alabaster, Alabama, USA) was set up randomly in 2007 in both treated and non-treated portions of the northwest Frost pasture and in burned and unburned portions of the Cochran Ranch. In 2006, 3 dummy-nest sites were set up within the Cochran Ranch. At each site, 4 small domestic hen's eggs were placed in a manmade depression in the ground, and a motion-sensitive camera was set up such that it took pictures of any animal approaching the dummy nest. Nests were checked weekly and restocked with eggs as needed. The frequency of different types of predators was recorded. Only predator visitations that were followed immediately by a disappearance of the eggs were considered to be predation events. If a single predator was photographed multiple times during a single predation event, this was recorded as 1 predation event. Animals that were photographed at the dummy nests but which were not observed to destroy the eggs were not counted.

RESULTS

Trapping and Monitoring

Thirty-seven birds were trapped from 2–9 April 2006. Three of these birds were recaptures. Twenty-nine of the birds trapped were fitted with radio transmitters. Two of the birds radio-collared were never located again. The rest were located at least once. A total of 310 location events was recorded during the 2006 breeding season. Two of the birds were observed to have failed transmitters, and one lost its collar. All 3 were censored from survivorship calculations. Seven dead birds were found during the 2006 breeding season.

During the 2007 breeding season, 11 birds were trapped from 11 April–11 May 2007. Nine were radio-collared. Eight of the radio-collared birds were males; 1 was female. All 9 LPC were located at least once after being released. Six of the 9 LPC were found dead during the 2007 breeding season. A total of 101 location events was recorded during the 2007 breeding season. One location event was removed because of a large error ellipse.

Fourteen LPCs were located ≥10 times during 2006, and 4 were located ≥10 times in 2007. These individuals were used to calculate seasonal range using Mohr's minimum convex polygon. They also were used to calculate greatest distance and mean distance.

Survival

Survivorship curves were calculated for all 2006 LPC, all 2007 LPC, all LPC trapped during both years, all 2006 males, and all 2006 females. LPC trapped in 2007 were not separated and analyzed by sex because of the low number ($n = 9$) trapped that year. Survivorship did not differ significantly ($P > 0.05$) by sex or by year (Table 1).

Table 1. Seasonal survivorship (%) of lesser prairie chicken (LPC) in Cochran and Yoakum counties, Texas, 2006–2007.

LPC	*N*	Seasonal survival	95%C.I.
2006 LPC	29	71	49–94
2007 LPC	9	42	10–74
2006 males	5	80	45–100
2006 females	24	71	13–96
All LPC	37	61	41–80

Movement and Range

Greatest distance, mean distance, and range size were calculated for all individual LPC (2006, $n = 14$; 2007, $n = 4$). Because of the relatively small number of birds located a sufficient number of times in 2007, data from 2006 and 2007 were pooled. LPC ranges in 2006 were, on average, larger than in 2007 (Fig. 3). No significant ($P > 0.05$) differences were found between age classes in greatest distance, mean distance, or range size (Table 2). Greatest distance and mean distance were found to differ significantly ($P = 0.042$, $P = 0.004$, respectively) by sex with females having significantly higher values than males. The interaction between age and sex was found to have no significant ($P > 0.05$) effect on any of the 3 variables tested.

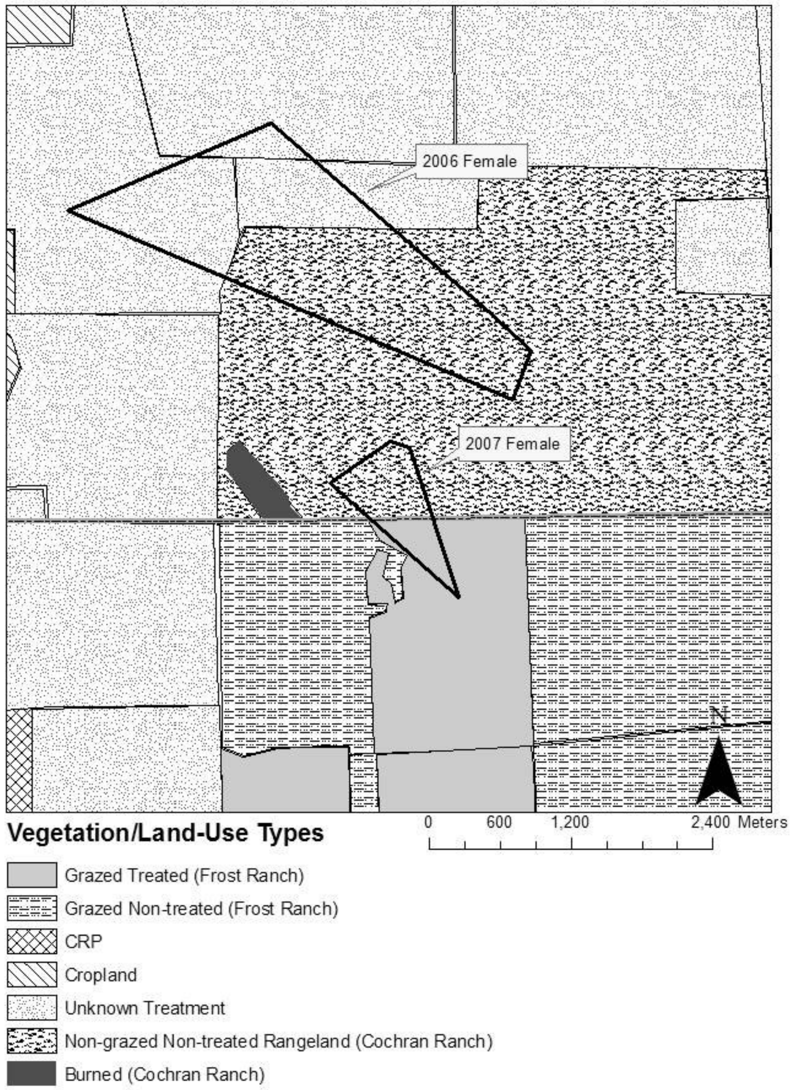

Figure 3. Map showing range polygons for a female with brood in 2006 and a female with brood in 2007.

Table 2. Mean range size (ha), mean greatest distance (m), and mean distance (m) of lesser prairie chickens (LPC) in Cochran and Yoakum counties, Texas, 2006–2007.

		Range		Greatest distance		Mean distance	
	N	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*
2006 all	14	312	95	3,203	564	1,348	167
2007 all	4	102	23	1,338	120	667	119
All Males	5	83	26	1,085	218	525	142
All Females	13	336	99	3,443	554	1,455	142
All Adults	11	287	112	2,475	449	1,065	116
All Juvenile	7	232	97	3,280	1,023	1,404	273
All LPC	18	265	76	2,788	475	1,197	148

Habitat Selection

The area and percentages of vegetation types within each lek-based buffer zones were similar except for the CRP based lek (Table 3). The CRP based lek had more CRP and cropland and less unknown treatment vegetation types than the other lek-based buffer zones.

Within the oil-pad lek buffer zone the non-grazed non-treated vegetation type was selected significantly ($P < 0.05$) more than all other habitat types (Table 4). The unknown treatment vegetation type was used significantly ($P < 0.05$) less than all other vegetation types. Grazed non-treated was used significantly ($P < 0.05$) less than grazed treated, cropland, or other rangeland. The CRP fields were not present within this lek-based buffer zone.

Within the big-lek buffer zone the non-grazed non-treated vegetation was selected significantly ($P < 0.05$) more than all other vegetation types (Table 4). The unknown treatment vegetation type was used significantly ($P < 0.05$) less than all other vegetation types. Grazed treated was used significantly ($P < 0.05$) more than grazed non-treated, CRP, cropland, or unknown treatment. Grazed non-treated was used significantly ($P < 0.05$) less than all other vegetation types except for unknown treatment.

Within the CRP-lek based buffer zone the CRP vegetation type was selected significantly ($P < 0.05$) more than all other vegetation types (Table 4). Cropland was selected significantly ($P < 0.05$) less than grazed treated, grazed non-treated, CRP, or non-grazed, non-treated. There was no significant ($P > 0.05$) difference between cropland

Table 3. Area and percentage of vegetation types within lek-based buffer zones, 2006–2007.

	Oil-pad lek		Big lek		CRP lek		West lek	
Vegetation types	ha	%	ha	%	ha	%	ha	%
Grazed treated	547	8	610	8	610	8	587	8
Grazed non-treated	1,145	16	1,277	18	1,369	19	963	13
CRP	0	0	231	3	980	14	463	6
Cropland	96	1	190	3	2,369	33	877	12
Unknown treatment	4,279	59	3,759	52	1,838	25	3,207	44
Non-grazed, non-treated	1,171	16	1,171	16	72	1	1,141	16
Total	7,238	100	7,238	100	7,238	100	7,238	100

and other rangeland. Other rangeland was selected significantly ($P < 0.05$) less than non-grazed non-treated, CRP, or grazed treated.

Within the west-lek based buffer zone, non-grazed non-treated was used significantly ($P < 0.05$) more than was expected (Table 4). No other vegetation types were selected for or against.

Table 4. The number of observed (Obs.) and expected (Exp.) radio location within each lek-based buffer zone (2006–2007).

	Oil-pad lek		Big lek		CRP lek		West lek		
Vegetation types	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	*N*
Grazed treated	1	8	24	8	3	2	0	3	28
Grazed non-treated	0	15	0	18	2	6	5	5	7
CRP	0	0	0	0	22	4	0	2	22
Cropland	0	1	0	3	1	10	4	4	5
Unknown treatment	9 [a]	56	2 [a]	52	0	7	11	15	22
Non-grazed, non-treated	85[a]	15	73[a]	16	1	3	15	6	174
Total	95		99		29		35		258

[a]Habitat used differed significantly ($P < 0.05$) from expected within the lek-based buffer zone.

Vegetative Response to Tebuthiuron Treatment

In 2006, 40 random points were placed in the NW pasture. Of these, 18 fell in the sprayed area, and 22 fell in the non-sprayed area. In the SW pasture, 16 random points were taken. Of these, 9 fell within the sprayed area, and 7 fell within the non-sprayed area.

In 2007, 50 random points were placed within each of the 4 Frost Ranch pastures: NW, SW, NE, and SE. In the NW pasture, 31 points fell within the non-treated area, and 19 fell within the treated area. In the SW pasture, 17 points fell in the non-treated area, and 33 fell within the treated area. All points in both the NE and SE pastures fell within the non-treated area since both of these pastures were left completely non-treated with tebuthiuron.

All vegetative characteristics except number of dead oak plants were found to differ significantly ($P < 0.05$) by pasture (Table 5). On the non-treated portions of the Frost Ranch, OV was found to be significantly ($P = 0.001$) greater than in the treated portions of the Frost Ranch, but significantly ($P = 0.02$) lower than in the non-burned portions of the Cochran Ranch. The OV on the treated portions of the Frost Ranch was significantly ($P < 0.001$) lower than in non-burned portions of the Cochran Ranch. The OV on the non-burned portions of the Cochran Ranch was significantly ($P = 0.001$) greater than in burned portions of the Cochran Ranch.

Plant height was significantly ($P < 0.001$) greater in non-burned portions of the Frost Ranch than in burned portions of the Cochran Ranch, and significantly ($P < 0.001$) greater in treated portions of the Frost Ranch than in burned portions of the Cochran Ranch (Table 5). Plant Height also was significantly ($P < 0.001$) greater in non-burned portions of the Cochran Ranch than in burned portions of the Cochran Ranch.

Litter depth was significantly ($P < 0.001$) greater in the non-treated portions of the Frost Ranch than in treated portions of the Frost Ranch, and significantly ($P = 0.047$) greater in non-treated portions of the Frost Ranch than in non-burned portions of the Cochran Ranch (Table 5). Litter depth also was significantly ($P < 0.001$) greater in non-treated portions of the Frost Ranch than in burned portions of the Cochran Ranch. Litter depth in the treated portions of the Frost Ranch was significantly ($P = 0.003$) lower than in non-burned portions of the Cochran Ranch, but significantly greater ($P < 0.001$) than in burned portions of the Cochran Ranch. Litter depth also was significantly ($P < 0.001$) greater in non-burned portions of the Cochran Ranch than in burned portions of the Cochran Ranch.

Woody cover was significantly ($P < 0.001$) greater in non-treated portions of the Frost Ranch than in treated portions of the Frost Ranch, and significantly ($P = 0.01$) greater than in burned portions of the Cochran Ranch (Table 5). Woody cover was significantly ($P < 0.001$) lower in treated portions of the Frost Ranch than in non-burned portions of the Cochran Ranch, and significantly ($P = 0.01$) greater in non-burned portions of the Cochran Ranch than in burned portions of the Cochran Ranch.

Forb cover were significantly ($P < 0.001$) lower in the non-treated portions of the Frost Ranch than in treated portions of the Frost Ranch, and significantly ($P < 0.001$) lower in non-treated portions of the Frost Ranch than in burned portions of the Frost Ranch (Table 5). Forb cover were significantly ($P < 0.001$) greater in treated portions of the Frost Ranch than in non-burned portions of the Cochran Ranch, and significantly ($P < 0.001$) lower in non-burned portions of the Cochran Ranch than in burned portions of the Cochran Ranch.

Table 5. Mean ($\bar{x}$) and standard error (*SE*) of vegetative characteristics (OV = obstruction of vision) on treated and non-treated areas of the Frost Ranch during 2006 and 2007 and on burned and non-burned areas of the Cochran Ranch during 2007.

	2006 Frost				2007 Frost				2007 Cochran Ranch			
	Treated $n = 27$		Non-treated $n = 29$		Treated $n = 54$		Non-treated $n = 146$		Non-burned $n = 45$		Burned $n = 26$	
Vegetation characteristics	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*	$\bar{x}$	*SE*
OV (dm)	0.43	0.08	0.75	0.13	0.58	0.10	0.92	0.07	1.20	0.14	0.58	0.10
Plant height (cm)	48.30	3.80	41.50	2.60	34.5	1.40	37.4	34.5	40.50	30.20	30.20	2.40
Litter depth (cm)	0.98	0.35	3.98	0.38	2.13	0.30	3.43	0.22	2.78	0.35	0.33	0.15
Woody rank	2.07	0.26	3.52	0.23	2.17	0.22	3.07	0.12	3.31	0.24	2.46	0.24
Forb rank	1.67	0.15	1.00	0.05	1.44	0.14	0.90	0.04	0.78	0.08	1.65	0.18
Grass rank	2.41	0.24	1.38	0.12	1.80	0.14	1.12	0.04	1.20	0.09	1.62	0.12
Bare ground rank	3.00	0.23	2.83	0.19	2.89	0.17	3.16	0.11	2.56	0.19	2.23	0.16
Dead oak/m^2	2.00	0.93	1.83	0.54	0.93	0.17	0.76	0.15	0.33	0.08	0.31	0.14
Live oak/m^2	5.52	1.60	17.69	1.29	4.26	0.64	6.47	0.33	7.56	0.48	7.62	0.61
Acorns/m^2	0.59	0.45	3.34	0.90	0.61	0.21	5.06	0.65	3.75	1.43	0.23	0.10

Grass cover was significantly ($P < 0.001$) lower in non-treated portions of the Frost Ranch than in treated portions of the Frost Ranch, significantly ($P < 0.01$) lower in non-treated portions of the Frost Ranch than in burned portions of the Cochran Ranch (Table 5). Grass cover was significantly ($P < 0.001$) greater in treated portions of the Frost Ranch than in non-burned portions of the Cochran Ranch, and significantly ($P < 0.007$) lower in non-burned portions of the Cochran Ranch than in burned portions of the Cochran Ranch.

Bare ground was significantly ($P = 0.03$) greater in non-treated portions of the Frost Ranch than non-burned portions of the Cochran Ranch, and significantly ($P < 0.001$) lower in non-treated portions of the Frost Ranch than in burned portions of the Cochran Ranch (Table 5). Bare ground also was significantly ($P < 0.014$) greater in treated portions of the Frost Ranch than in burned portions of the Cochran Ranch.

The number of live shinnery oak plants was significantly ($P < 0.001$) greater in non-treated portions of the Frost Ranch than in treated portions of the Frost Ranch (Table 5). The number of live shinnery oak plants also was significantly ($P < 0.001$) lower in treated portions of the Frost Ranch than in burned portions of the Cochran Ranch.

The number of acorns was significantly ($P < 0.001$) greater in non-treated portions of the Frost Ranch than in treated portions of the Frost Ranch, significantly ($P < 0.001$) greater in non-treated portions of the Frost Ranch than in burned portions of the Cochran Ranch (Table 5). The number of acorns was significantly ($P < 0.001$) lower in treated portions of the Frost Ranch than in non-burned portions of the Cochran Ranch, and significantly ($P < 0.001$) greater in non-burned portions of the Cochran Ranch than in burned portions of the Cochran Ranch.

Shinnery oak density was significantly ($P < 0.05$) higher in the non-treated Frost pastures than in all other treatment types (Table 6). Shinnery oak density was significantly ($P < 0.05$) lower in the treated Frost pastures than in all other treatment types. Sand sagebrush density was significantly ($P < 0.05$) higher in the non-burned portions of the Cochran Ranch than in all other treatments. Little bluestem density was significantly ($P < 0.05$) lower in the non-treated Frost pastures than in all other vegetation types. Little bluestem density was significantly ($P < 0.05$) higher in the treated Frost pastures than in all other vegetation types. Weeping lovegrass density did not differ significantly ($P > 0.05$) across treatment types. Yucca density was significantly ($P <$ 0.05, respectively) greater in the treated Frost pastures than in the both the non-burned and burned portions of the Cochran Ranch. Yucca density was not, however significantly ($P > 0.05$) greater in the treated Frost pastures than in the non-treated Frost pastures.

Forb density was significantly ($P < 0.05$) greater in the treated frost pastures than in all other pastures (Table 6). Forb density was significantly ($P < 0.05$) lower in the non-treated Frost pastures than in all other treatment types except for the non-burned Cochran Ranch.

Nest-site Characteristics

In 2006, a total of 10 nesting females was located. No renesting events were observed. Of these nests, 4 hatched successfully, 4 were destroyed by predators and 2 were abandoned. In 2007, 1 female nested twice. The first nesting attempt was unsuccessful; the second was successful.

The OV was found to be significantly ($P = 0.045$) higher at nest-sites than at randomly-selected areas. Percent woody cover was found to be significantly ($P = 0.003$)

higher in nest-sites than in randomly-selected areas. Percent bare ground was found to be significantly ($P = 0.008$) lower in nest site areas than in randomly-selected areas. No significant differences were found in plant height ($P = 0.639$), litter depth ($P = 0.432$), percent cover forbs ($P = 0.876$), or percent cover grass ($P = 0.432$). No significant ($P >$ 0.05) differences were found in any of the measured vegetative characteristics between successful and unsuccessful nests. The nearest plant to each nest was sand sagebrush in 9, shinnery oak in 2, and weeping lovegrass in 1 of the 12 nest sites. The nearest plant in the randomly-selected sites was shinnery oak in 10 and sand sagebrush in 2 of the sites.

Table 6. Observed (Obs.) and expected (Exp.) dominant plant densities in each vegetation type, 2006–2007.

	Non-treated Frost		Treated Frost		Non-burned Cochran		Burned Cochran	
Dominant plants	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.	Obs.	Exp.
Shinnery oak	149[a]	122	28[a]	57	33	31	18	18
Sand sagebrush	3	8	2	4	8[a]	2	2	1
Little bluestem	8[a]	19	21[a]	9	3	5	3	3
Western lovegrass	10	11	9	5	0	3	0	2
Yucca	0	2	3	1	0	0	0	0
Forbs	5	14	18[a]	7	1	4	3	2

[a]Plants were observed significantly ($P < 0.05$) more or less than expected.

Nest Predation

In 2006, 3 dummy nests were placed in the non-burned portions of the Cochran Ranch. Nests were started on 7 June 2006 and monitored more or less weekly until 30 July 2006. In 2007, 3 dummy nests were placed in the non-burned portion of the

Cochran Ranch, 3 in burned portions of the Cochran Ranch, 3 in the non-treated portion of the NW pasture of the Frost Ranch, and 5 in the treated portion of the NW pasture of the Frost Ranch. Nests were started on 1 May 2007 and monitored more or less weekly until 23 June 2007. The Chihuahuan raven was, by far, the most commonly observed nest predator in all vegetation types (Table 7, Figure 4). The observation of a porcupine (*Erethizon dorsatum*) at one of the dummy nest sites was unexpected.

Table 7. Predators observed at dummy nest sites within each vegetation type using digital infrared cameras, 2006–2007.

Vegetation type	Raven	Hog	Raccoon	Badger	Porcupine	Rat	Other[a]	Total
Burned Cochran (2007)	12	1	0	1	0	0	6	20
Non-burned Cochran (2007)	12	1	0	0	0	1	10	24
Non-treated Frost (2007)	11	0	0	1	0	0	12	24
Treated Frost (2007)	20	1	0	0	0	0	10	31
Non-burned Cochran (2006)	3	2	1	1	1	0	0	8
Total	58	5	1	3	1	1	38	107

[a] Other includes non-predator birds, thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), deer, mice, or unknown predators (eggs eaten but no picture of predator).

Fig. 4. Common predators of dummy nests, 2006–2007. Top left: Chihuahuan raven, top right: gray woodrat (*Neotoma micropus*), bottom left: feral hog, bottom right: raccoon (*Procyon lotor*).

DISCUSSION

No differences in LPC survival were detected between years or sex. Insufficient sample size made it impossible to test for differences between age classes or for differences between sexes within the 2007 breeding season. Breeding season survival was calculated as 71.2% and 42.0% for 2006 and 2007, respectively. Toole (2005) reported breeding seasonal survival values of 62.7% and 70.5% for populations located in shinnery oak and sand sagebrush rangelands, respectively.

Seasonal range did not differ between sex or age classes. Mean distance and greatest distance were both greater for females than for males. There were no differences between age classes. Previous research has suggested that breeding-season ranges tend to be larger for females than for males (Giesen 1998, Jamison 2000, Walker 2000).

Female LPCs were found to select nest sites with higher OV than surrounding areas. This finding is in line with previous research that has found that LPC females tend to select nest sites with high OV (Robel et al. 1970) and that successful nests have higher OV than unsuccessful nests (Riley et al. 1992, Pitman 2003). It is likely that areas with high obstruction of vision provide superior concealment from nest predators. No differences in vegetation height were found between nest sites and surrounding areas. This is in contrast to previous studies that found female LPCs select nest sites with higher vegetation than surrounding areas (Davis et al. 1979, Wisdom 1980, Haukos and Smith 1989, Riley et al. 1992, Giesen 1994, Pitman 2003). Hagen et al. (2004) reported successful nesting generally required taller and denser stands of vegetation.

LPCs also selected nest sites with a higher percentage of woody cover and a lower percentage of bare ground than surrounding areas. This indicates some level of woody plant cover may be essential in preserving ideal nesting habitat. LPC selected nest sites directly under sand sagebrush in 9 of the 12 observed nest sites, despite shinnery oak being much more abundant than sand sagebrush throughout the entire study area. This suggests that sand sagebrush may be more important to nesting LPCs than shinnery oak. Only 1 nest was found directly under a grass (weeping lovegrass). This contrasts sharply with Wisdom (1980) and Riley (1992), who found female LPC selected bluestem grasses for nest sites preferentially over shrubs. On the other hand, Giesen (1994) reported hens within his study area selected sand sagebrush for nest sites over all other vegetation types. LPC have widely been reported to nest under shrubs in heavily-grazed rangeland (Merchant 1982, Sell 1979, Riley et al 1992). Eleven of the 12 observed nests were located within non-burned portions of the Cochran Ranch, all of which was non-grazed. One was located in native rangeland outside both the Frost Ranch and the Cochran Ranch, in an area classified as unknown treatments. This indicates LPC may select sand sagebrush for nest sites, even in non-grazed rangeland where bluestem grasses are available.

The non-burned portions of the Cochran Ranch, all of which had been non-grazed for approximately 10 years, had significantly higher OV than all other pastures. Plant height was greater in the non-burned portions of the Cochran Ranch than in the burned, but did not differ between the non-burned Cochran Ranch areas and the Frost Ranch. Since intensity and duration of cattle grazing was the main difference between the Cochran Ranch and the Frost Ranch, this suggests that cattle grazing serves to lower overall OV (i.e., reduces forbs and grasses) of a shinnery-oak dominated pasture, but has no effect on vegetation height (i.e., shinnery oak). Sand sagebrush was found at higher concentrations in the non-burned portions of the Cochran Ranch than in all other pastures. This, along with the fact that the non-burned Cochran Ranch had higher overall OV than all other pastures, may explain why nearly all observed nests were located within the Cochran Ranch. Burning was observed to lower OV and plant height, and increased the growth of forbs and grasses. However, it did not greatly reduce woody plant cover like tebuthiuron treatment did.

Tebuthiuron treatment of the Frost Ranch served to lower the dominance of shinnery oak, decrease the percent composition of woody vegetation, and increase the percent composition of forbs and grasses. This is entirely in line with previous research that has found tebuthiuron to be very effective at permanently removing woody vegetation and increasing the dominance of grasses and forbs (Doerr and Guthery 1983, Pettit 1979, Olawsky 1987).

LPC were found to select non-grazed, non-treated rangeland more than any other vegetation type in 3 of the 4 lek-based buffer zones. In the CRP lek-based buffer zone, CRP was selected more than any other vegetation type. The grazed-treated vegetation type was used significantly more than the grazed-non-treated vegetation type in 2 of the 4 lek-based buffer zones. The grazed-non-treated vegetation type was never selected more than the grazed-treated vegetation type. These results suggest that non-grazed rangeland provides superior habitat to grazed rangeland in my area under conditions of my study. Merchant (1982) also found that LPC tend to avoid heavily grazed rangeland. The Cochran Ranch, which was non-grazed and non-treated, had higher OV and more sand sagebrush than all other vegetation types. It may be that LPC selected this area because its denser plant cover provided superior thermal and/or escape cover.

While the non-grazed Cochran Ranch was used more than other areas, the tebuthiuron-treated portions of the Frost Ranch were selected more than the non-treated portions of the Frost Ranch. The treated portions of the Frost Ranch were found to have higher dominance of grasses and forbs than all other vegetation types. It is possible that this characteristic attracts LPC because it provides superior forage (forbs and insects).

The most common predator found with the dummy nests was the Chihuahuan raven. Few data are available on nest predators of LPC. Coyotes (*Canis latrans*), striped skunk (*Mephitis mephitis*), badger (*Taxidea taxus*), ground squirrel (*Spermophilus spilosoma*), and bull snake (*Pituophis melanoleucus*) have been reported as nest predators (Riley et al. 1992, Davis et al. 1979, Haukos 1988). No photographs of coyotes were captured by the nest cameras even though coyotes were observed multiple times in the study area. Ground squirrels were observed many times attempting to predate nests, but were never able to break the eggs. The hen's eggs used to bait dummy nests were slightly larger than LPC eggs. It is possible that ground squirrels would have been found to be significant nest predators had smaller eggs been used. It is unclear whether Chihuahuan ravens predate actual LPC nests at the same rate that they predated the dummy nests. Since the Chihuahuan raven is a visual predator, it is likely that it would be more attracted to the unprotected hen's eggs used for the dummy nests than to a camouflaged LPC on a nest. However, during the laying period, LPC eggs would be just as exposed as eggs in dummy nests. Future studies should look into the use of infrared-digital cameras to monitor actual LPC nests.

SUMMARY AND MANAGEMENT RECOMMENDATIONS

Summary

Survivorship of LPC was found not to differ between sex, age, or season. Range size was not found to differ between sex, age or year. Female LPC were found to move farther than males from their lek of origin, even though this difference did not apparently affect range size. LPC females selected nest sites with higher OV, greater woody cover, and less bare ground than what was generally available in the surrounding areas. Most LPC nests were in non-grazed rangeland and directly under sand sagebrush. LPC were located most frequently in non-grazed rangeland than in all other vegetation types. LPC were found to use the tebuthiuron-treated portions of the Frost Ranch slightly more than non-treated portions of the Frost Ranch. Tebuthiuron treatment decreased shinnery oak abundance and woody cover, and increased forb and grass cover. The non-grazed pasture had higher OV and sand sagebrush dominance than all other pastures. Burning increased forb and grass growth but did not reduce the dominance of shinnery oak. The Chihuahuan raven was found to be the most common predator of dummy nests.

Management Recommendations

1. LPC management efforts should focus on preserving and expanding existing areas of native rangeland. When adjacent croplands are placed into CRP they should be replanted with native forbs and grasses.
2. In deep-sand shinnery oak areas, grazing should be limited on areas occupied by LPC populations.

3. The use of tebuthiuron can be used to reduce woody plant dominance and increase grass and forb cover. LPC hens did not use treated areas for nesting sites but did use treated portions more than non-treated portions of the Frost Ranch.
4. Infrared-digital cameras were beneficial for detecting predators at dummy nests, however, they should be tested on LPC nests to determine if predators on dummy nests are the same ones that destroy active LPC nests.

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