

Impacts of Anthropogenic Features on Habitat Use by Lesser Prairie-Chickens

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Abstract. Suitable habitat for the Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*) has been reduced markedly over the past 100 years. The remaining habitat is widely used for petroleum exploration and extraction, cattle grazing, power line easements, and the generation of electricity. Given the tenuous status of the species and recent demands on land use in remaining habitat, it is imperative that Lesser Prairie-Chicken avoidance behavior of anthropogenic features be quantified for impact assessment and conservation planning. We examined the relationship of several anthropogenic features as they pertained to habitat use of radiomarked female Lesser Prairie-Chickens ($N = 227$) in southwestern Kansas from 1997 to 2002. We used Poisson rate regression and contingency tables to examine spatial use patterns of monthly home ranges (95% fixed kernels, $N = 539$) and estimated the likelihood that anthropogenic features (i.e., power lines, wells, roads, and buildings) occurred within aggregates of all monthly home ranges (monthly use ranges). We calculated the distance from the centroids of home ranges to anthropogenic features and, using Monte Carlo simulations, evaluated whether or not they were farther than would be expected at random. There was temporal variation in the average odds of each feature occurring

within monthly use ranges, but generally there was a pattern of avoidance. Monte Carlo simulations of expected distances indicated that the nearest 90% of Lesser Prairie-Chicken centers of use were farther from anthropogenic features than would be expected at random. We also had the opportunity to evaluate changes in habitat use (or avoidance behavior) 1 year post-construction of a power line using a before–after control-impact design. Post–power line construction analysis indicated that Lesser Prairie-Chicken monthly use areas were less likely to include power lines than non-use areas. However, centers of use were closer to power lines than would be expected at random in the impact area. The discrepancies between short- and long-term results suggest a lag period between power line construction and avoidance by Lesser Prairie-Chickens, possibly due to site fidelity of the species. Our study provides some minimum behavioral avoidance distances for mitigating energy developments in Lesser Prairie-Chicken habitats, and we recommend clustering these features to maximize available habitats.

Key Words: avoidance behavior, energy development, habitat use, Monte Carlo randomizations, *Tympanuchus pallidicinctus*.

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Suitable habitat for the Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*) has been markedly reduced over the past 100 years. What remains is highly fragmented throughout the species' range, and the remaining habitat is widely used for fossil fuel exploration and extraction, cattle grazing, power line easements, and generation of electricity (Hagen and Giesen 2005). The cumulative loss of habitat, declining population trends, and imminent threats led to a recent increase in priority ranking of the 1995 "warranted but precluded" listing under the Endangered Species Act (USFWS 2008). Recent demand on domestic energy production has provided additional human disturbances to the southern Great Plains (Pruett et al. 2009b), and the intermountain West (Naugle et al. in press). Specifically, increased development of oil and natural gas reserves and electrical generation from wind turbines are creating new challenges to wildlife conservation (Ingelfinger and Anderson 2004, Sawyer et al. 2006, Arnett et al. 2008). In some cases, the rate of development has outpaced conservationists' ability to evaluate the impacts of these disturbances to wildlife. Recent work on Greater Sage-Grouse (*Centrocercus urophasianus*) and prairie chickens (*Tympanuchus* spp.) has demonstrated avoidance behavior, and in some cases negative demographic consequences of development (Naugle et al. in press, Pruett et al. 2009a). Negative consequences suggest there is a larger ecological footprint associated with energy development than the immediate area disturbed by infrastructure. A clearer understanding of these impacts is necessary for more effective conservation measures and mitigation efforts for grouse populations.

The Lesser Prairie-Chicken's dependency on native rangeland has been well studied, at micro- (Jones 1963, Crawford and Bolen 1974, Riley et al. 1992, Jamison et al. 2002, Pitman et al. 2005, Patten et al. 2005a), and macroscales (Jamison 2000, Woodward et al. 2001, Fuhlendorf et al. 2002, Hagen et al. 2007b). However, limited information exists on the effects of anthropogenic features on Lesser Prairie-Chicken habitat use, most of which has focused on nesting and lek locations (Robel et al. 2004, Pitman et al. 2005, Pruett et al. 2009a). Habitat use studies from southwestern Kansas indicated that generally, Lesser Prairie-Chickens utilized sand sagebrush (*Artemisia filifolia*) throughout the year, but exhibited higher selection ratios for this cover

type during the summer months (Jamison 2000, Hagen et al. 2007b). Despite the apparent importance of sagebrush, there were several areas within the prairie fragment (~5,000 ha) which appeared suitable for prairie chickens, but where radiomarked birds were not located, and unmarked individuals were not flushed or observed in these areas (Jamison 2000). The proximity of anthropogenic features, the apparent adequacy of vegetative cover, and the concomitant lack of habitat use in these areas afforded us an opportunity to test hypotheses of behavioral avoidance of landscape features by Lesser Prairie-Chickens in southwestern Kansas.

Our objectives were to: (1) examine if Lesser Prairie-Chickens avoided anthropogenic features (i.e., power lines, paved roads, oil wells, and buildings) in their monthly use of habitat; (2) estimate minimum distances from features to the center of monthly activity; and (3) in cases of apparent avoidance, estimate minimum distances and provide them as conservation guidelines setback distances in siting of future anthropogenic infrastructure.

METHODS

Study Area

The study region was comprised of two 5,000-ha fragments of native sandsage prairie near Garden City, Finney County, Kansas (37°52' N, 100°59' W). We began work on site I (southwest of Garden City) in 1997, and we expanded trapping and monitoring efforts to include site II (southeast of Garden City) in 2000. Prior to 1970, these two areas were part of a large contiguous tract of native sandsage prairie (Robel et al. 2004). The development of center pivot irrigation for row-crop agriculture left these areas as two fragments with about 19 km of non-habitat between patch centroids (Waddell and Hanzlick 1978). Shrub and grass vegetation in the prairie fragments was comprised of sand sagebrush, yucca (*Yucca* spp.), sandreed grasses (*Calamovilfa* spp.), bluestem grasses (*Andropogon* spp.), sand dropseed (*Sporobolus cryptandrus*), and sand lovegrass (*Eragrostis trichodes*). Primary forb species in the region included ragweed (*Ambrosia* spp.), sunflower (*Helianthus* spp.), and Russian thistle (*Salsola tragus*) (Hullett et al. 1988, Pitman et al. 2005, Hagen et al. 2007b). Land use was primarily livestock grazing, oil and natural gas

extraction, and electricity transmission. Livestock grazing was generally season-long. There were periodic sagebrush thinning treatments on various pastures.

Field Methods

We captured Lesser Prairie-Chickens at leks using walk-in funnel traps during March and April 1997–2002 (Haukos et al. 1990). We fitted each captured bird with a lithium battery-powered transmitter with a mass <12-g (battery life 12–14 months). During phase I (1997–2000), we tracked females daily from April to September. We tracked females daily from April to September during phase II (2000–2003). A truck-mounted null-peak twin-Yagi telemetry system was used to triangulate locations of individuals remotely from tracking stations georeferenced using global positioning systems.

Home Range Estimation and GIS

Study area polygons were delineated from native rangeland areas as classified by GAP data layers using ArcView 3.1 (ESRI 1998). We quantified the proportion of landscape features in monthly use ranges of radiomarked females for location data from 1997 to 1999 at site I and at both study sites from 2000 to 2002. Azimuths from fixed stations were entered into Locate II triangulation software, and locations of prairie chickens were estimated using Lenth maximum likelihood estimators (Nams 2002). Location data were then imported into a GIS database of the study area and home ranges were estimated using a 95% fixed kernel estimator in ArcView 3.1 (Worton 1989). We limited our sample to those birds that had ≥ 15 locations per month. While this criterion reduced the number of individuals, it ensured that observed range sizes were likely representative of the area covered in a month. Our data selection limited the seasons for which such an analysis could be conducted, because the number of individuals tracked decreased from premature battery failure and mortality as the year progressed. Thus, we focused our analyses on a 6-month period (April to September) when samples were relatively large and coincided with a peak usage of sagebrush habitats (Hagen et al. 2007b). All female locations at nest sites were excluded from home range estimates because the

relationship between nest site selection and distance to anthropogenic feature has already been examined (Pitman et al. 2005).

Locations of oil and gas wells (hereafter wells), paved roads (hereafter roads), power lines, and buildings were digitized into GIS from aerial photos and GPS locations recorded in the field. We included wells with pumping units powered by electric, natural gas, or diesel motors, but did not distinguish among these in our analyses. We included human dwellings, gas compressor stations, and a 380-MW coal-fired electric generating station in our GIS layer for buildings. For the power line layer, we primarily included 125-, 138-, and 345-kV double circuit conductors that distributed electricity from the generating station, but we also included all smaller power lines to homes and wellheads. Roads and power lines were digitized as line features in the GIS, and we buffered these features by 100 m and 20 m, respectively, to more accurately depict the disturbed area these features occupied. We calculated distances from home range centroids to features in the GIS using Nearest Features (version 3.8) in ArcView.

Monthly home ranges (hereafter home range) for each bird were computed separately by year and month (e.g., April 2000) to control for yearly and biological variation in monthly habitat use. We combined home ranges for all birds in a given year and month into a single overall “monthly use range” which was overlaid onto the study area. Each monthly use range was used as a sampling frame to calculate the number of wells, roads, power lines, and buildings occurring within (i.e., “success”) and outside of Lesser Prairie-Chicken monthly use ranges. Areas not overlapped by a monthly use range were referred to as non-use ranges, and served as the “failure” response (or expected frequencies) in our binomial sampling design. The number of wells occurring in use versus non-use ranges could be counted, but roads and power lines could not. Thus, following the procedure of Marcum and Loftsgaarden (1980), we generated 200,000 random points (site I = 100,000; site II = 100,000) across the study area, and tallied each point that occurred within or outside of a monthly use range and within or outside of a road or power line (see Pitman et al. 2005). We tabulated the numbers of points occurring in these four subsets. This approach resulted in count data that could be input into

contingency table or Poisson rate regression analyses.

Analysis

Monthly Use Ranges and Odds of Use

Phase I of our study only included one of the two study areas; thus we analyzed each phase as a separate data set. We chose month as our sampling unit as it provided reasonable sample sizes (i.e., spatially and temporally), enabled us to examine temporal changes in habitat use during spring and summer, and reduced the potential for serial correlation of daily telemetry locations. We expected that the multiple locations recorded for an individual bird would be serially correlated, and that the correlation would decrease as the time between locations increased. It was therefore anticipated that use of monthly ranges as the observational unit for each bird (as described above) would have the effect of reducing correlations between consecutive measurements, so that treating them approximately as independent was reasonable. Because the goal of the analysis was to examine general patterns of use with regard to anthropogenic landscape features, and not to differentiate the variation in usage across months, we controlled for the monthly variability by stratifying on month. There were 6 months in 1998–2001, 5 months in 1997, and 4 months in 2002.

We used contingency table analyses to examine the association between use of habitat and presence of anthropogenic features, stratified by month. We used the Breslow–Day test for homogeneity of odds ratios to evaluate whether the association was similar across months within each year (Agresti 1996). In 3 of 6 years no monthly use range overlapped with buildings, and this occurrence was rare in the other 3 years; thus we did not include a separate analysis of buildings. We used Poisson rate regression to model the number of wells present per hectare of monthly use and non-use ranges [offset = $\log(\text{monthly use range ha})$] as a function of use, month, and year. Starting from a saturated model in these three factors, backward elimination (using 0.05 significance level) was used to find the most parsimonious model, and the fit of the chosen model was assessed by examining the scale parameter (deviance/df) and residual plots.

Permutations of Distance to Anthropogenic Features

Because anthropogenic features were not randomly or uniformly located on the landscape in relation to home ranges (here we refer to ranges individually rather than as a collective distribution), we used a modified Monte Carlo simulation (Manly 1997) to test (one-tailed) whether the centroids of home ranges were farther from anthropogenic features than would be expected by chance (Pitman et al. 2005). If anthropogenic features had no impact on the birds' monthly home ranges (the null hypothesis), then one would expect the distances between these centroids and anthropogenic features to follow the same distribution as distances between randomly placed points and these features. If, on the other hand, the birds demonstrated some avoidance of these anthropogenic features, as hypothesized, then the centroids of home ranges should be farther away from anthropogenic features than random points.

We compared the lower 10th percentile of the distribution of observed distances to the random distances as follows. First, the 10th percentile was chosen because it represents that portion of the study population that tended to come closest to the anthropogenic features, but is not so extreme as to be subject to excessive random variation in its estimation. Under the null hypothesis, the observed 10th percentile should behave like the 10th percentile from an equal number of randomly placed points. We approximated the null sampling distribution for this 10th percentile from: (1) a random sample ($N = 539$) was drawn from the distribution of 200,000 random points and distances; (2) the lower 10th percentile of distances was recorded for the sample; (3) this was repeated 1,000 times; (4) the observed distribution of these 1,000 random 10th percentiles estimated the required sampling distribution. If the observed 10th percentile distance was too extreme in the upper tail of this sampling distribution, then the null hypothesis (features do not affect home range placements) was rejected. We computed a P-value as the proportion of estimated sampling distribution that lay above the observed 10th percentile of all centroids. The observed percentiles and the expected (mean) value of that percentile under randomness were compared. We chose to analyze distances to features separately for each

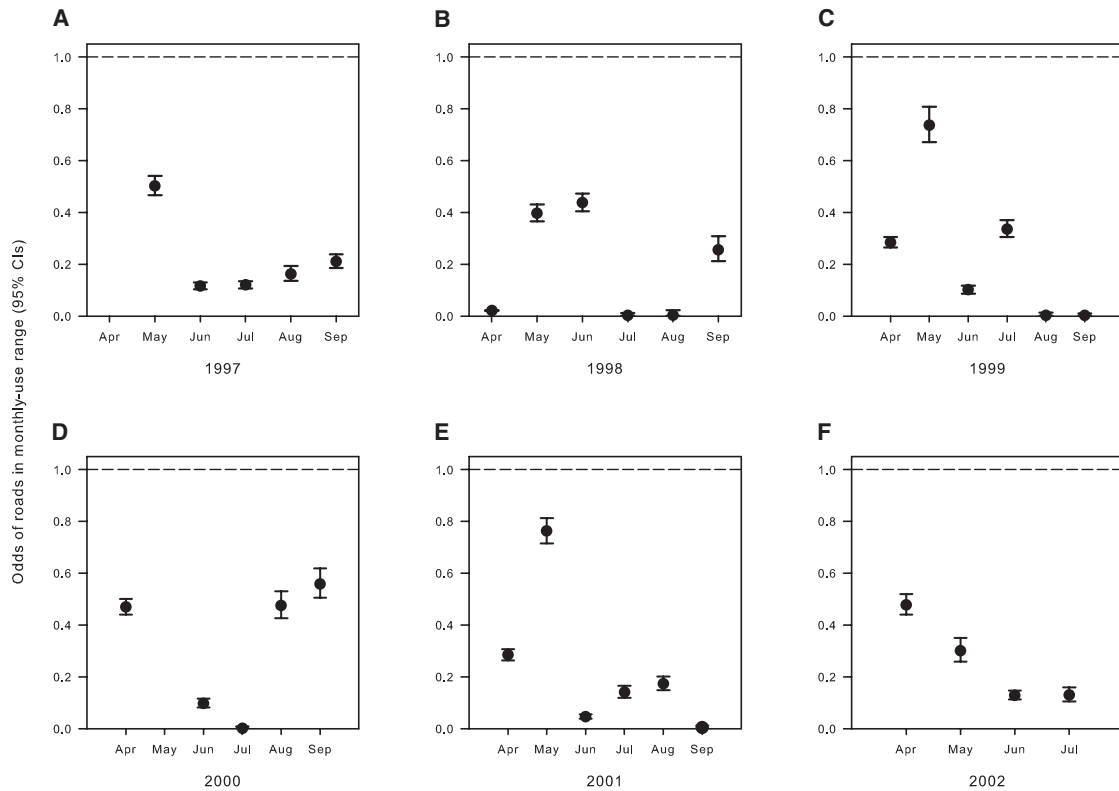


Figure 5.1. Odds ratios (95% CI) for roads occurring in Lesser Prairie-Chicken monthly use ranges in 1997 (A), 1998 (B), 1999 (C) 2000 (D), 2001 (E), and 2002 (F). The dashed line indicates odds of 1, and confidence limits intersecting this line indicate odds not different than expected by chance.

study site for ease of comparison, especially for power lines pre- and post-construction.

Impacts of Power Line Construction

A 138-kV power line was constructed on site I early in 2002; thus we employed an informal before-after control-impact (BACI) design to examine how the construction of the line may have affected monthly use. In this design, we used site I as the impact area and site II as the control and compared the differences in distances from centroids to power lines pre- and post-construction. Additionally, we estimated mean odds ratios by year and site to examine the potential avoidance of the new power line on habitat use.

RESULTS

We captured and radiomarked 226 female Lesser Prairie-Chickens; because of right censoring, we only included 190 in our analyses (phase I = 64,

phase II = 126). We recorded 21,047 (phase I = 7,524; phase II = 13,523) daily telemetry locations from 1997 to 2002. However, our effective sample size was reduced to 15,903 after removing nest locations, bird-months with <15 locations, and winter months (October–March). Thus, we estimated 539 home ranges (95% fixed kernel) and centroids to calculate avoidance distances from anthropogenic features, and used these home ranges to estimate the odds of these features occurring in 33 monthly use ranges.

Proportional Use

Phase I

The likelihood of roads occurring in monthly use ranges were significantly different across months in all 3 years of phase I (Breslow–Day test; 1997: $\chi^2 = 794.41$, $df = 4$, $P < 0.0001$; 1998: $\chi^2 = 4,881.69$, $df = 5$, $P < 0.0001$; 1999: $\chi^2 = 1,064.61$, $df = 5$, $P < 0.0001$; Fig. 5.1). The annual average odds

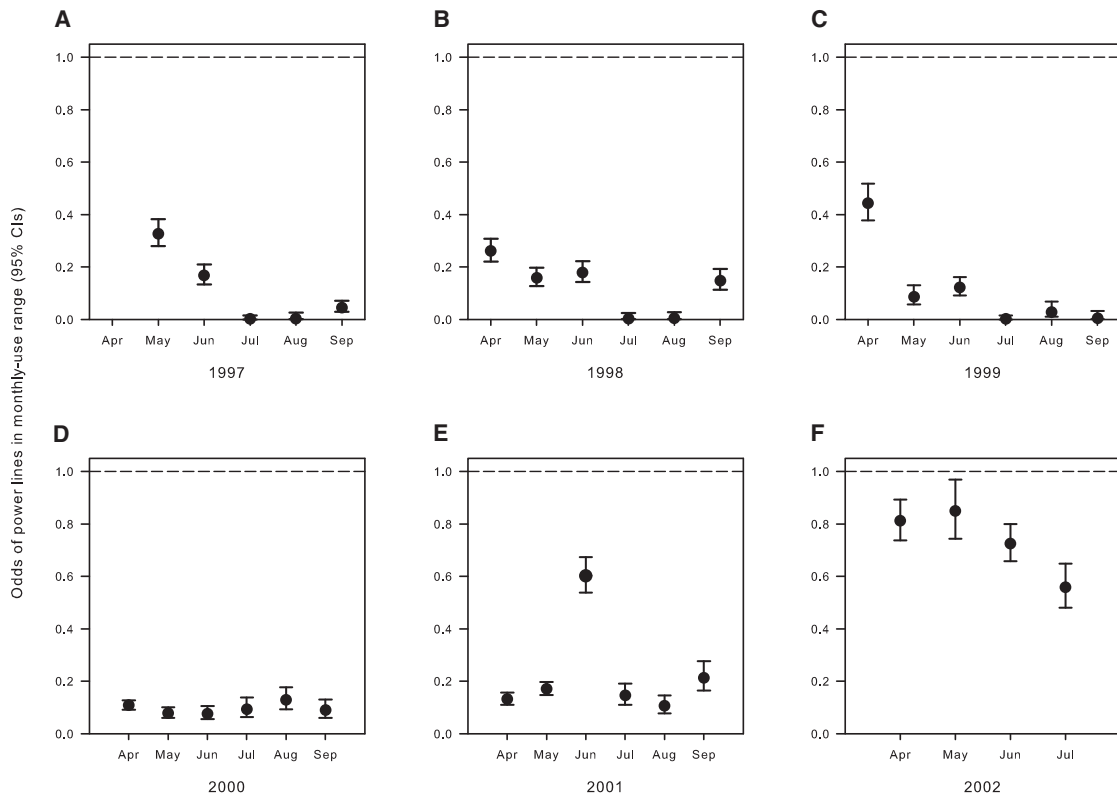


Figure 5.2. Odds ratios (95% CI) for power lines occurring in Lesser Prairie-Chicken monthly use ranges in 1997 (A), 1998 (B), 1999 (C) 2000 (D), 2001 (E), and 2002 (F). The dashed line indicates odds of 1, and confidence limits intersecting this line indicate odds not different than expected by chance.

of roads occurring in a monthly use range were between 4.1 and 5.3 times less likely than that of non-use ranges. The likelihood of power lines occurring in monthly use ranges was significantly different across months in all 3 years of phase I (1997: $\chi^2 = 307.25$, $df = 4$, $P < 0.0001$; 1998: $\chi^2 = 148.04$, $df = 5$, $P < 0.0001$; 1999: $\chi^2 = 396.19$, $df = 5$, $P < 0.0001$). The annual average odds of a power line occurring in a monthly use range were 11.1 to 15.9 times less likely than in a non-use range (Fig. 5.2).

Phase II

The Breslow–Day test for the odds of roads occurring in monthly use ranges indicated that the odds ratios were significantly different across months in all years of phase II (2000: $\chi^2 = 1,830.3$, $df = 5$, $P < 0.0001$; 2001: $\chi^2 = 2,005.3$, $df = 5$, $P < 0.0001$; 2002: $\chi^2 = 373.46$, $df = 3$, $P < 0.0001$; Fig. 5.1). The annual average odds of roads occurring in a monthly use range were 2.1 to 6.5 times less

likely than that of non-use range. The Breslow–Day test for the odds of power lines occurring in monthly use ranges indicated that the odds ratios varied throughout the sampling period in 2 of 3 years (2000: $\chi^2 = 9.61$, $df = 5$, $P = 0.087$; 2001: $\chi^2 = 403.73$, $df = 5$, $P < 0.0001$; 2002: $\chi^2 = 21.52$, $df = 3$, $P < 0.0001$). The annual average odds of a power line occurring in a monthly use range were between 6.0 and 10.8 times less likely than in a non-use ranges in 2000 and 2001, respectively (Fig. 5.2). Additionally, the odds of power lines occurring in monthly use ranges increased in 2002 relative to previous years, but on average was 1.4 times less likely to occur than in non-use ranges.

Wells

Backward selection of Poisson rate regression models of counts of wells per hectare of monthly use range as a function of prairie chicken use indicated that a model containing a month \times use

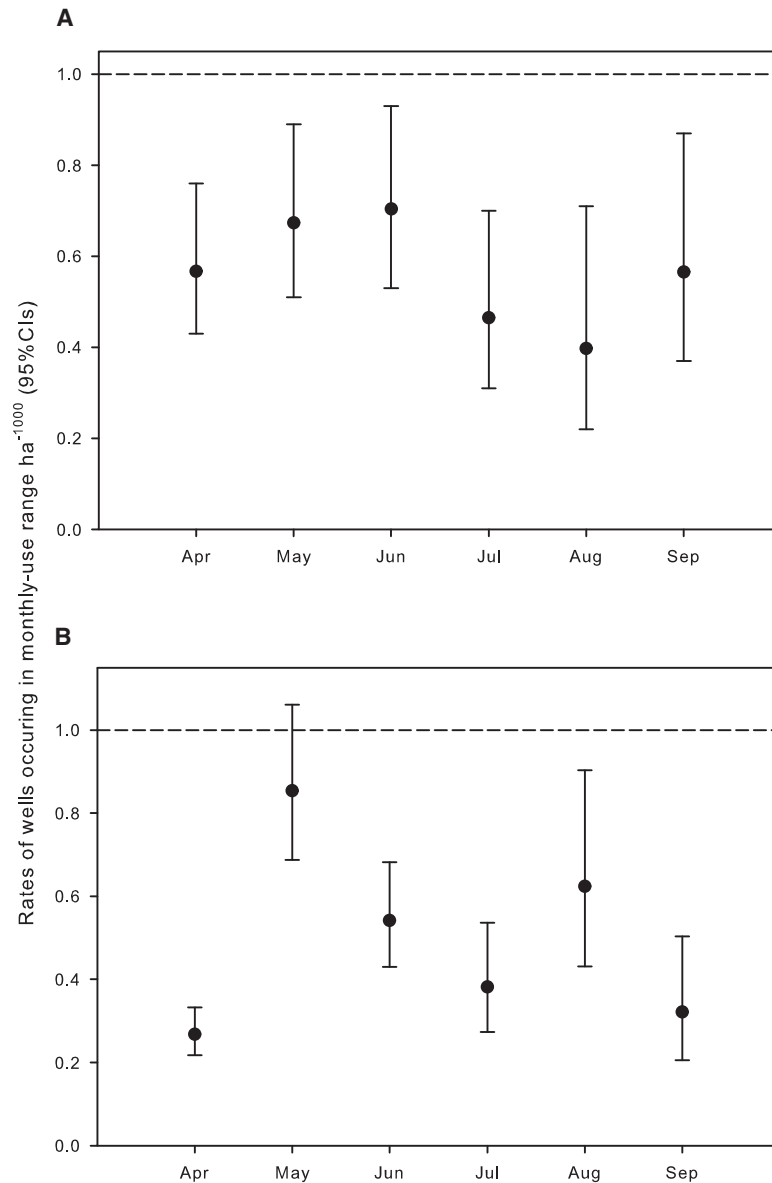


Figure 5.3. Odds ratios (95% CI) of wells $\text{ha}^{-1,000}$ between monthly and non-use ranges as determined from Poisson rate regression for phase I (A) and phase II (B) in Finney County, Kansas, 1997–2002. The dashed line indicates odds of 1, and confidence limits intersecting this line indicate observed values did not differ from those expected by chance.

interaction (deviance/df = 0.623) best described the data for phase I, and a model including year \times month and month \times use interaction and all main effects was the best model for phase II (deviance/df = 0.448). Estimated rates of number of wells per 1,000 ha of monthly use varied among months and ranged between 26 to 86% times less than non-use ranges (Fig. 5.3). Generally, the number of wells $\text{ha}^{-1,000}$ decreased in late summer with fewer wells

in monthly use ranges than non-use ranges in both phases of our study.

Distance to Features

Monte Carlo simulations of distances to features indicated that 90% of monthly centroids were farther than expected by chance for wells (242–320 m), buildings (1,132–1,666 m), and roads (715–990 m)

TABLE 5.1
Monte Carlo simulation tests.

Area/Feature	Summary Statistics				Randomization Test		
	Observed		Random		Observed	Expected	$P \leq \text{value}^a$
	\bar{x} (m)	SE	\bar{x} (m)	SE	10th P(m)	10th P(m)	
Site I ($n = 369$)							
Power lines	1,494	41	594	3	709	172	0.001
Post—new line ^b	751	90	582	3	123	273	0.434
Wells	559	14	490	1	242	240	0.011
Buildings	1,929	38	1,987	4	1,132	1,092	0.005
Roads	1,712	48	1,547	6	715	564	0.025
Site II ($n = 119$)							
Power lines	1,388	50	552	3	662	176	0.001
Post—new line ^b	1,015	137	567	6	272	269	0.026
Wells	559	17	551	1	320	230	0.007
Buildings	2,374	46	2,179	4	1,666	1,458	0.001
Roads	2,695	141	2,019	6	990	946	0.016

NOTE: Tests of distances (M) of the nearest 10th percentile (P) of all Lesser Prairie-Chicken monthly (Apr–Sep) home range centroids to anthropogenic features on two sand-sagebrush prairie areas in southwestern Kansas, USA, 1997–2002. Overall mean distances (SE) from observed centroids and random points ($N = 1,000$) to features are also reported.

^aWe calculated P -values as the proportion of distances in the random distribution that were \geq observed 10th P for a given feature.

^bSample sizes were 28 and 23 monthly home range centroids for sites I and II, respectively, post construction of a new power line at site I.

at both sites (Table 5.1). Similarly, distances from home range centroids to power lines were farther than expected at both sites (662–702 m) prior to the new power line construction in 2001.

Post–Power Line Construction

Using a BACI design, the observed distance to power lines decreased at both sites in 2002. However, the observed distance (173 m) was closer than expected (272 m) only at site I, where the power line was constructed (Table 5.1), despite the fact that the average observed distance (751 m) was greater than would be expected by chance (582 m). We summarized odds ratios by year and site to further examine the potential avoidance of power line construction on habitat use (Fig. 5.4). Power lines were less likely to occur in monthly use ranges on site II than site I for years that birds were monitored on both sites (Fig 5.4). On

average, odds ratios indicated that power lines were less likely to occur in monthly use ranges than non-use areas for all years and sites (range of odds ratios = 1.1–17.1 times less likely), but the likelihood of occurrence did increase the last 2 years of our study (1.1 and 1.6 times less likely).

DISCUSSION

Our study adds to growing evidence that anthropogenic features may act as barriers to use of otherwise suitable habitat for Lesser Prairie-Chickens and other grassland or shrubsteppe grouse (Robel et al. 2004, Pitman et al. 2005, Pruett et al. 2009b, Naugle et al. in press). Notably, we found support for avoidance for power lines, paved roads, buildings, and wells and identified minimum footprints that are likely to be avoided in habitat selection. Specifically, of the vertical features at our study sites, power lines and buildings appeared to be the least likely

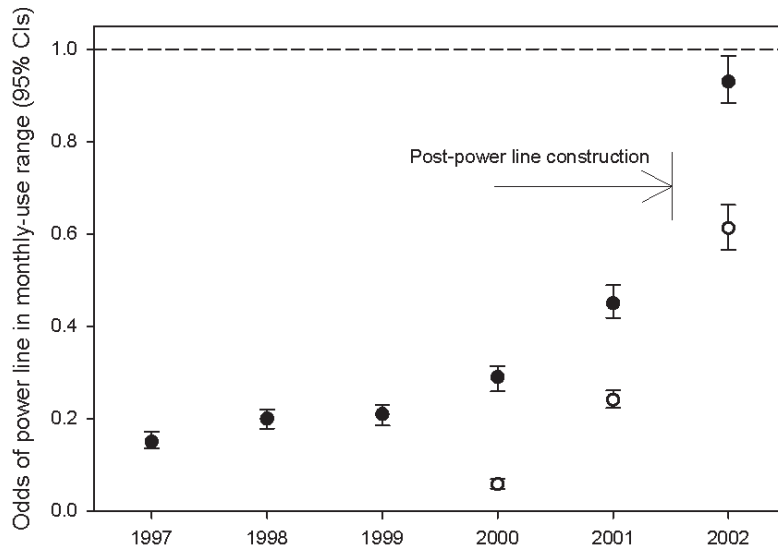


Figure 5.4. Odds ratios (95% CI) for power lines occurring in Lesser Prairie-Chicken average monthly use ranges pre- and post-construction (2002) of a power line at site I (filled circles) and site II (open circles), in Finney County, Kansas, 1997–2002. Power line construction did not occur at site II. The dashed line indicates odds of 1, and confidence limits intersecting this line indicate odds not different than expected by chance.

to occur within monthly use ranges and were the furthest from monthly centroids. We summarize our findings first in the context of seasonal variation and then in regard to each anthropogenic feature.

Annual variation in avoidance distances is described by individual heterogeneity of marked prairie chickens and their different monthly patterns of habitat use and movement. Generally, female movements are more wide-ranging during the breeding season (April and May) as they seek mates and a nest site (Hagen and Giesen 2005). Movements from breeding areas to summer habitat often occur in June and may result in larger monthly ranges and increase the likelihood of a range including a feature. However, from July to September, movements are minimized as Lesser Prairie-Chickens shift into summer use areas that are abundant with invertebrates (Jamison et al. 2002). Regardless of season of use, most habitats used by Lesser Prairie-Chickens tended to avoid anthropogenic features.

Roads

The presence of paved highways does not appear to serve as a barrier to movement by prairie chickens (Pruett et al. 2009a), but the noise and disturbance associated with roads can alter nest site

selection, habitat use, and lek persistence (Lyon and Anderson 2003, Holloran 2005, Pitman et al. 2005, this study). Direct mortality associated with vehicle collisions can occur year-round, but is a relatively small percentage of overall mortality (Aldridge and Boyce 2007, Wolfe et al. 2007). Perhaps of greater concern is the potential for displaced habitat use by the breeding cohort in a population. Nesting female Lesser Prairie-Chickens placed nest sites farther from paved roads than would be expected at random, even though vegetation characteristics were similar near these edges (Pitman 2003, Pitman et al. 2005). Lesser Prairie-Chickens exhibited greater tolerance (avoidance distances of >100 m) to one of two paved highways in Oklahoma than we documented in our study (Pruett et al. 2009a). Similarly, yearling female Greater Sage-Grouse appear to select nest sites farther from main haul roads in natural gas fields, as they do not exhibit the same site fidelity as older females (Holloran 2005). If net productivity is affected by displacement, lek persistence and patch occupancy may diminish. Greater Sage-Grouse lek persistence declined as a function of traffic volumes on haul roads in natural gas developments and resulted in lek abandonment in some cases (Holloran 2005). Gunnison Sage-Grouse (*Centrocercus minimus*) patch occupancy was best described by models of

landscape scale features (relative to models with microhabitat variables), and occupancy was positively correlated with distance from paved roads (Oyler-McCance 1999). Thus, roads may be one of a cumulative set of factors that impact population persistence of Lesser Prairie-Chickens (Patten et al. 2005b, Hagen et al. 2009).

Wells

Well density can affect habitat use by wildlife species (Sawyer et al. 2006, Walker et al. 2007, Doherty et al. 2008). The presence of oil and gas wells may also affect productivity and population viability through habitat displacement or changes in predator communities (Coates 2007). If suitable habitat is adjacent to such developments and the fragmentation effects increase mortality rates outside the range of natural variation, the result is an ecological trap (Aldridge and Boyce 2007). Alternatively, if critical habitats (e.g., winter range, nesting) are no longer used because of well density, it may prove detrimental to demographic rates (Holloran 2005, Doherty et al. 2008). The likelihood that Greater Sage-Grouse would use otherwise suitable winter range was diminished by 10% with the development of 1 well per 4 km² (Doherty et al. 2008). Our study indicated that number of wells affected habitat selection and nest site selection at one of two sites (Pitman et al. 2005), but this and other work from southwestern Kansas did not document any direct effects to demographic rates as a function of well density or distance.

Power Lines

Power lines serve as a barrier to prairie chicken movement, nest site selection, and general habitat use (Pitman et al. 2005, Pruett et al. 2009a). Lesser and Greater Prairie-Chickens (*Tympanuchus cupido*) avoided crossing power line right-of-ways even though these features frequently occupied their home ranges (Pruett et al. 2009a). However, Lesser Prairie-Chickens did cross power lines during winter to feed in agricultural fields in our study. Collisions with power lines resulted in approximately 5% of known mortalities in our study areas (Hagen et al. 2007b), similar to collision rates reported for Lesser (3%) and Greater Prairie-Chickens (5%) in Oklahoma (Wolfe et al. 2007, Pruett et al. 2009a). General avoidance of

these tall structures may result from prairie chickens experiencing predation attempts or predator presence with these features. Perching on power line structures increases a raptor's range of vision, allowing for greater speed and effectiveness in searching for and acquiring prey in habitats with low vegetation and relatively flat terrain (Ellis 1984, Steenhof et al. 1993). Thus, raptors may preferentially seek out transmission structures in areas where natural perches and nesting sites are limited. Increased abundance of raptors within occupied grouse habitats may result in elevated predation rates above the range of natural variation (Ellis 1984, Coates 2007). However, only 20% of Lesser Prairie-Chicken mortality was associated with raptor predation in our study areas (Hagen 2003), compared to >30% in Oklahoma and New Mexico (Wolfe et al. 2007). Differences in mortality from raptors between these studies suggest that either the observed avoidance distances in our study are adequate to alleviate excessive raptor predation from these structures, or raptor communities differ considerably. We do not have data on raptor populations to substantiate either of these scenarios, except that raptors were most abundant in winter months (Hagen 2003).

The presence of a power line may fragment grouse habitats even if raptors are not present. Our minimum avoidance distances (662 and 726 m) for Lesser Prairie-Chickens are similar to those observed for Greater Prairie-Chicken and Greater Sage-Grouse (Braun 1998, Pruett et al. 2009a). Braun (1998) documented use of suitable habitat within 600 m of a power lines, and habitat use increased as a function of distance from the power line.

A novel finding in our study was a reduction in avoidance distance after construction of a power line on site I, which suggested minimal behavioral avoidance. Our data were limited to 1 year post-construction and likely were not collected over a long enough period to fully assess long-term effects. Adult Lesser Prairie-Chickens exhibit strong site fidelity to breeding areas and nest sites (Hagen et al. 2005, Pitman et al. 2006), and we should expect a post-disturbance lag effect (Holloran 2005, Walker et al. 2007). The lag effect may be less than has been documented in Greater Sage-Grouse (3–5 years), because of shorter generation times in Lesser Prairie-Chickens (Hagen et al. 2009). However, avoidance of existing power lines (pre-1997) on our study areas may provide

future insight to likelihood of use and associated avoidance distances once the population has redistributed its habitat use relative to the new power line.

SUMMARY

Previous work indicated that changes in habitat composition at large scales (7,200 ha) explain most of the variability in declining Lesser Prairie-Chicken populations (Woodward et al. 2001, Fuhlendorf et al. 2002). Increases in habitat edge density can be a significant factor in declining populations at relatively small scales, and such changes may have negative impacts on breeding activity (Fuhlendorf et al. 2002). If increased edge density was correlated to power lines, wells, or buildings (in our study), it may help explain the declining population trends observed on our study sites (Hagen et al. 2009). While direct habitat loss has not occurred on our study areas in 15–20 years, the avoidance of anthropogenic features by prairie chickens may result in the functional elimination of habitat (Robel et al. 2004), potentially further explaining population declines.

Future impact assessments should consider the construction of new anthropogenic features as a potential detriment to habitat suitability for Lesser Prairie-Chickens. We offer the following siting guidelines to protect 90% of breeding and summer habitats of Lesser Prairie-Chickens: power lines ≥ 700 m, wells ≥ 300 m, buildings $\geq 1,400$ m, and paved roads ≥ 850 m. We hypothesize that future development of wind generation facilities likely will have effects on avoidance behavior similar to that of power lines and buildings, and we would recommend ≥ 1.4 km setback for wind generation until empirical data are available. Although our setback distances do not account for densities of anthropogenic features, clustering developments such that undisturbed native habitats are maximized would likely benefit populations. Additionally, the distances reported from our study areas are relative to populations that occupy habitats already fragmented by agriculture. Thus, additional measurements should be gathered from across the range to identify tolerance thresholds of feature densities within different patch sizes. Future work should evaluate population viability and the probability of patch occupancy as they relate to the density and configurations of anthropogenic features.

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LITERATURE CITED

- Agresti, A. 1996. An introduction to categorical data analysis. Wiley & Sons Inc. New York, NY.
- Aldridge, C. L. and M. S. Boyce. 2007. Linking occurrence and fitness to persistence: habitat based approach for endangered Greater Sage-Grouse. *Ecological Applications* 17:508–526.
- Arnett, E. B., W. K. Brown, W. P. Erickson, J. K. Fielder, B. L. Hamilton, T. H. Henry, A. Jain, G. D. Johnson, J. Kerns, R. R. Koford, C. P. Nicholson, T. J. O'Connell, M. D. Piorkowski, R. D. Tankersley. 2008. Patterns of bat fatalities at wind energy facilities in North America. *Journal of Wildlife Management* 72:61–78.
- Braun, C. E. 1998. Sage Grouse declines in western North America: what are the problems? Proceedings of the Western Association of State Fish and Wildlife Agencies 78:139–156.
- Coates, P. S. 2007. Greater Sage-Grouse (*Centrocercus urophasianus*) nest predation and incubation behavior. Ph.D. dissertation, Idaho State University, Pocatello, ID.
- Crawford, J. A. and E. G. Bolen. 1976. Effects of land use on Lesser Prairie-Chickens in Texas. *Journal of Wildlife Management* 40:96–104.
- Doherty, K. E., D. E. Naugle, B. L. Walker, and J. M. Graham. 2008. Greater Sage-Grouse winter habitat selection and energy development. *Journal of Wildlife Management* 72:187–195.
- Ellis, K. L. 1984. Behavior of lekking Sage-Grouse in response to a perched Golden Eagle. *Western Birds* 15:37–38.
- ESRI. 1998. Arc View GIS 3.1, online users manual. Environmental Systems Research Institute, Redlands, CA.
- Fuhlendorf, S. D., A. J. Woodward, D. M. Leslie, and J. Shackford. 2002. Multi-scale effects of habitat loss and fragmentation on Lesser Prairie-Chicken populations in US southern Great Plains. *Landscape Ecology* 17:617–628.

- Hagen, C. A. 2003. A demographic analysis of Lesser Prairie-Chicken populations in southwestern Kansas: survival, population viability, and habitat use. Ph.D. dissertation, Kansas State University, Manhattan, KS.
- Hagen, C. A., and K. M. Giesen. 2005. Lesser Prairie-Chicken (*Tympanuchus pallidinctus*). F. Gill and A. Poole (editors), The birds of North America No. 364. The Birds of North America Inc., Philadelphia, PA.
- Hagen, C. A., B. E. Jamison, K. M. Giesen, and T. Z. Riley. 2004. Guidelines for managing Lesser Prairie-Chicken populations and their habitats. *Wildlife Society Bulletin* 32:69–82.
- Hagen, C. A., J. C. Pitman, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2007a. Age-specific survival and probable causes of mortality in female Lesser Prairie-Chickens. *Journal of Wildlife Management* 71:518–525.
- Hagen, C. A., J. C. Pitman, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2007b. Niche partitioning by Lesser Prairie-Chickens *Tympanuchus pallidinctus* and Ring-necked Pheasants *Phasianus colchicus* in southwestern Kansas. *Wildlife Biology* 13(Suppl. 1):51–58.
- Hagen, C. A., J. C. Pitman, B. K. Sandercock, R. J. Robel, and R. D. Applegate. 2005. Age specific variation in apparent survival rates of male Lesser Prairie-Chickens. *Condor* 107:78–86.
- Hagen, C. A., B. K. Sandercock, J. C. Pitman, R. J. Robel, and R. D. Applegate. 2009. Spatial variation in Lesser Prairie-Chicken demography: a sensitivity analysis of population dynamics and management alternatives. *Journal of Wildlife Management* 73:1325–1332.
- Haukos, D. A., L. M. Smith, and G. S. Broda. 1990. Spring trapping of Lesser Prairie-Chickens. *Journal of Field Ornithology* 61:20–25.
- Holloran, M. J. 2005. Greater Sage-Grouse (*Centrocercus urophasianus*) population response to natural gas field development in western Wyoming. Ph.D. dissertation, University of Wyoming, Laramie, WY.
- Holloran, M. J., B. J. Heath, A. G. Lyon, S. J. Slater, J. L. Kuipers, and S. H. Anderson. 2005. Greater Sage-Grouse nesting habitat selection and success in Wyoming. *Journal of Wildlife Management* 69:638–649.
- Hulett, G. K., J. R. Tomelleri, and C. O. Hampton. 1988. Vegetation and flora of a sandsage prairie site in Finney County, southwestern Kansas. *Transactions of the Kansas Academy of Science* 91:83–95.
- Ingelfinger, F., and S. Anderson. 2004. Passerine response to roads associated with natural gas extraction in a sagebrush steppe habitat. *Western North American Naturalist* 64:385–395.
- Jamison, B. E. 2000. Lesser Prairie-Chicken chick survival, adult survival, and habitat selection and movement of males in fragmented landscapes of southwestern Kansas. Thesis, Kansas State University, Manhattan, KS.
- Jamison, B. E., R. J. Robel, J. S. Pontius, and R. D. Applegate. 2002. Invertebrate biomass: associations with Lesser-Prairie Chicken habitat use and sand sagebrush density in southwestern Kansas. *Wildlife Society Bulletin* 30:517–526.
- Jones, R. E. 1963. Identification and analysis of Lesser and Greater Prairie-Chicken habitat. *Journal of Wildlife Management* 27:757–778.
- Lyon, L. A. and S. H. Anderson. 2003. Potential gas development impacts on Sage Grouse nest initiation and movement. *Wildlife Society Bulletin* 31:486–491.
- Manly, B. F. 1997. Randomization, bootstrap and Monte Carlo methods in biology. Chapman & Hall, London, UK.
- Marcum, C. L., and D. O. Loftsgaarden. 1980. A non-mapping technique for studying habitat preferences. *Journal of Wildlife Management* 44:963–968.
- Nams, V. 2000. Locate II: user's guide. Pacer Computer Software, Truro, Nova Scotia, Canada.
- Naugle, D. E., K. E. Doherty, B. L. Walker, M. J. Holloran, and H. E. Copeland. In press. Energy development and Greater Sage-Grouse. *Studies in Avian Biology*.
- Oyler-McCance, S. J. 1999. Genetic and habitat factors underlying conservation strategies for Gunnison Sage-Grouse. Ph.D. dissertation, Colorado State University, Fort Collins, CO.
- Patten, M. A., D. H. Wolfe, E. Shochat, and S. K. Sherrod. 2005a. Effects of microhabitat and microclimate selection on adult survivorship of the Lesser Prairie-Chicken. *Journal of Wildlife Management* 69:1270–1278.
- Patten, M. A., D. H. Wolfe, E. Shochat, and S. K. Sherrod. 2005b. Habitat fragmentation, rapid evolution, and population persistence. *Evolutionary Ecology* 7:235–249.
- Pitman, J. C. 2003. Lesser Prairie-Chicken nest site selection and nest success, juvenile gender determination and growth, and juvenile survival and dispersal in southwestern Kansas. Thesis, Kansas State University, Manhattan, KS.
- Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughin and R. D. Applegate. 2006. Nesting ecology of the Lesser Prairie-Chicken in Kansas. *Wilson Journal of Ornithology* 118:23–35.
- Pitman, J. C., C. A. Hagen, R. J. Robel, T. M. Loughin, and R. D. Applegate. 2005. Location and success of Lesser Prairie-Chicken nests in relation to human disturbance. *Journal of Wildlife Management* 69:1259–1269.

- Pruett, C. L., M. A. Patten, and D. H. Wolfe. 2009a. Avoidance behavior by prairie grouse: implications for wind energy development. *Conservation Biology* 23:1253–1259.
- Pruett, C. L., M. A. Patten, and D. H. Wolfe. 2009b. It's not easy being green: wind energy and a declining grassland bird. *Bioscience* 59:257–262.
- Riley, T. Z., C. A. Davis, M. Ortiz, and M. J. Wisdom. 1992. Vegetative characteristics of successful and unsuccessful nests of Lesser Prairie-Chicken. *Journal of Wildlife Management* 56:383–387.
- Robel, R. J., J. A. Harrington, C. A. Hagen, J. C. Pitman, and R. R. Recker. 2004. Effect of energy development and human activity on the use of sand sagebrush habitat by Lesser Prairie-Chickens in southwestern Kansas. *Transactions of the North American Natural Resources Conference* 69:251–266.
- Sawyer, H., R. M. Nielson, F. Lindzey, and L. L. McDonald. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. *Journal of Wildlife Management* 70:396–403.
- Steenhof, K., M. N. Kochert, and J. A. Roppe. 1993. Nesting by raptors and Common Ravens on electrical transmission line towers. *Journal of Wildlife Management* 57:271–281.
- U.S. Department of the Interior, Fish and Wildlife Service. 2008. Endangered and threatened wildlife and plants; review of species that are candidates that are proposed for listing as endangered or threatened: the Lesser Prairie-Chicken. *Federal Register* 73:75719–75180.
- Waddell, B. and B. Hanzlick. 1978. The vanishing sandsage prairie. *Kansas Fish and Game Magazine* 35:1–4.
- Walker, B. L., D. E. Naugle, and K. E. Doherty. 2007. Greater Sage-Grouse population response to energy development and habitat loss. *Journal of Wildlife Management* 71:2644–2654.
- Wolfe, D. H., M. A. Patten, E. Shochat, C. L. Pruett, and S. K. Sherrod. 2007. Causes and patterns of mortality in Lesser Prairie-Chickens *Tympanuchus pallidicinctus* and implications for management. *Wildlife Biology* 13(Suppl. 1):95–104.
- Woodward, A. J., 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.
- Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. *Ecology* 70:164–168.

