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Avoidance Behavior by Prairie Grouse: Implications for Development of Wind Energy

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Abstract: *New wind-energy facilities and their associated power transmission lines and roads are being constructed at a rapid pace in the Great Plains of North America. Nevertheless, little is known about the possible negative effects these anthropogenic features might have on prairie birds, one of the most threatened groups in North America. We examined radiotelemetry tracking locations of Lesser Prairie-Chickens (*Tympanuchus pallidicinctus*) and Greater Prairie-Chickens (*T. cupido*) in two locations in Oklahoma to determine whether these birds avoided or changed movement behavior near power lines and paved highways. We tracked 463 Lesser Prairie-Chickens (15,071 tracking locations) and 216 Greater Prairie-Chickens (5,750 locations) for 7 and 3 years, respectively. Individuals of both species avoided power lines by at least 100 m and Lesser Prairie-Chickens avoided one of the two highways by 100 m. Prairie-chickens crossed power lines less often than expected if birds moved randomly (*$p < 0.05$*) but did not appear to perceive highways as a movement barrier (*$p > 0.05$*). In addition, home ranges of Lesser Prairie-Chickens overlapped the power line less often than would be expected by chance placement of home ranges; this result was supported by kernel-density estimation of home ranges. It is likely that new power lines (and other tall structures such as wind turbines) will lead to avoidance of previously suitable habitat and will serve as barriers to movement. These two factors will likely increase fragmentation in an already fragmented landscape if wind energy development continues in prairie habitats*.

Keywords: avoidance, fragmentation, power lines, prairie-chicken, roads, wind energy

Conducta Elusiva por Urogallos de Pradera: Implicaciones para el Desarrollo de Energía Eólica

Resumen: *En las Grandes Llanuras de Norteamérica se están construyendo a gran velocidad nuevas instalaciones de energía eólica y las líneas de transmisión de energía y caminos asociados. Sin embargo, se conoce poco de los posibles efectos negativos de estos atributos antropogénicos sobre los urogallos, uno de los grupos más amenazados en América del Norte. Examinamos localidades de registro con telemetría de* Tympanuchus pallidicinctus *y* T. cupido *en dos sitios en Oklahoma para determinar sí estas aves eludían o cambiaban su comportamiento cerca de las líneas de energía y los caminos pavimentados. Seguimos a 463* T. pallidicinctus *(15,071 localidades de registro) y 216* T. cupido *(5,750 localidades) durante 7 y 3 años respectivamente. Individuos de ambas especies eludían las líneas eléctricas a por lo menos 100 m y* T. pallidicinctus *eludió una de las dos carreteras por 100 m. Los urogallos cruzaron las líneas de energía menos seguido que lo esperado si las aves se movían de manera aleatoria (*$p < 0.05$*) pero aparentemente no percibieron a las carreteras como una barrera de movimiento (*$p > 0.05$*). Adicionalmente, los rangos de hogar de* T. pallidicinctus *traslapó la línea de energía menos seguido que lo esperado por ubicación aleatoria de los rangos de hogar; este resultado fue soportado por la estimación de los rangos de hogar por densidad kernel. Es probable que nuevas líneas de energía (y otras estructuras elevadas como turbinas eólicas) conduzcan a la elusión de hábitat previamente adecuado y servirán como barreras al movimiento. Estos dos factores probablemente incrementarán*

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la fragmentación en un paisaje ya fragmentado sí el desarrollo de la energía eólica continua en los hábitats de pradera.

Palabras Clave: caminos, elusión, energía eólica, fragmentación, líneas eléctricas, urogallo

Introduction

In the Great Plains of North America, there is extensive new development of wind-energy facilities and a concomitant increase in associated power lines and roads (Krauss 2008). Yet, there has been little or no environmental oversight of the placement of wind farms and power transmission lines relative to sensitive species of wildlife (CEIWEP 2007). The possible negative effects of tall structures (e.g., wind turbines, power-line poles) on the behavior of prairie vertebrates therefore has become an important conservation issue (CEIWEP 2007), especially because grassland obligates are one of the most threatened groups in North America (Knopf & Samson 1997; Rich et al. 2004). Indeed, despite a wealth of data on the effects of wind turbines on avifauna (CEIWEP 2007; de Lucas et al. 2007), nearly all studies have been on direct impacts such as collisions with blades or towers. The few studies that have addressed avoidance behavior relate to how flying birds or bats detect and avoid moving turbines (e.g., Chamberlain et al. 2006). Virtually nothing is known about how erection of tall structures influences how open-country species perceive habitat suitability.

Two species of grouse are year-round residents in the southern Great Plains, the Greater (*Tympanuchus cupido*) and Lesser (*T. pallidicinctus*) Prairie-Chickens. These species depend on large tracts of unfragmented grassland habitat. As a result of extensive loss and fragmentation of prairie (Samson & Knopf 1994), both species are of conservation concern in portions of their range (Schroeder & Robb 1993; Hagen & Giesen 2005), and the Lesser Prairie-Chicken is currently a candidate for listing under the U.S. Endangered Species Act. Lesser Prairie-Chickens nest farther away from and are wary of anthropogenic features even when suitable habitat exists near these structures (Robel et al. 2004; Pitman et al. 2005; Pruett et al. 2009). The reason for this avoidance is unclear, but another open-country bird, the greater sage-grouse (*Centrocercus urophasianus*), is thought to avoid power lines because of predation pressure from perching raptors (Graul 1980; Lammers & Collopy 2007). In addition, power lines and other tall structures might serve as barriers to movement as a result of this avoidance behavior (Leddy et al. 1999; Robel et al. 2004; Desholm & Kahlert 2005).

To determine whether future power line and wind turbine development will negatively affect prairie-chickens and serve as an additional agent of habitat fragmentation, we sought to quantify and evaluate avoidance and movement behavior of Lesser and Greater Prairie-Chickens in response to power lines within their ranges. We placed radiotelemetry devices on prairie-chickens to track movement of birds near two power lines and two paved two-lane highways (Oklahoma highways 412 and 283) to answer the following questions: Do prairie-chickens avoid power lines and highways? Do power lines or highways affect movement of prairie-chickens, and will birds cross a power line or road? and Is there a difference in avoidance distance or in movement behavior between birds near power lines versus those near highways? Because the prairie-chickens are umbrella species in their respective prairie habitats (Rich et al. 2004), our findings could provide useful information that will guide conservation biologists and policy makers when determining impacts of and regulations on wind development.

Methods

From February 1999 through April 2008, we captured and radio collared 463 Lesser Prairie-Chickens in shortgrass prairie of Beaver, Ellis, and Harper counties in northwestern Oklahoma. We also captured and radio collared 216 Greater Prairie-Chickens between April 1997 and July 2000 in tallgrass prairie of Osage County in northeastern Oklahoma. We captured birds on leks (communal breeding areas) with drift fences and modified walk-in traps (Schroeder & Braun 1991). We deployed traps on leks throughout the study areas. For further trapping and study-area details, see Patten et al. (2005*a*, 2007). Prairie-chickens were fitted with bib-mounted, tuned-loop radio transmitters (Telemetry Solutions, Concord, California, or Wildlife Materials, Carbondale, Illinois). Radio-tagged birds were tracked usually once or twice each week, for a total of 15,071 tracking locations for Lesser Prairie-Chickens and 5,750 locations for Greater Prairie-Chickens. Only one tracking location per day was included to minimize temporal autocorrelation. Bird locations were determined by observation of radio-tagged birds; measurement error (from GPS readings) was considered to be within 10 m. On average, birds were tracked approximately 30 times, with most birds surviving 1–3 years. Birds were tracked year round. All radio transmitters were equipped with a 12-h delay-mortality switch, which allowed for rapid detection of dead birds.

We used ArcGIS 9.2 (ESRI, Redlands, California) to examine the location and movement of individuals relative to two power lines and two highways. We determined home range size for each bird based on kernal-density estimates of 95, 75, and 50% isopleths in the program Abode (Laver 2005). We also calculated home ranges based on minimum convex polygons in the program Hawth's Tools (Beyer 2004). We used least-squares cross-validation to determine smoothing factors. We included birds in our calculations if they had at least 20 tracking locations and if their home ranges (at 95% or greater isopleth) overlapped one of two large power lines in the study areas. The power line in the Lesser Prairie-Chicken study area was 15 m tall, and the line in the Greater Prairie-Chicken area was 12 m tall. Twenty-three Lesser Prairie-Chickens had home ranges that overlapped the power line in western Oklahoma, and our reduced data set had 1056 tracking locations. Nine Greater Prairie-Chickens had home ranges that encompassed the power line in eastern Oklahoma, and our reduced data set had 435 tracking locations in this area. We also examined 1070 (19 birds near Hwy 412) and 2552 (46 birds near Hwy 273) tracking locations of Lesser Prairie-Chickens with home ranges that overlapped two paved, moderately to heavily traveled highways (approximately 800–2000 vehicles/day; Oklahoma Department of Transportation). No highways bisected the Greater Prairie-Chicken study area (Patten et al. 2007). Suitable habitat for prairie-chickens occurs on both sides of the power lines and highways (Sutton Avian Research Center, unpublished data); therefore, we assumed birds had an equal probability of being on either side of these features because both leks and birds occurred on both sides.

We determined how many birds had at least one tracking location within 100 m and within 101–500 m of each power line and highway to see whether prairie-chickens exhibited avoidance behavior of either power lines or roads. This is a conservative measure given that we only examined birds that had home ranges that overlapped the feature and thus had a high probability of having tracking locations near the feature. We assumed birds had an equal chance of occurring within each distance class, so we used the binomial distribution based on the number of prairie-chickens with home ranges that overlapped the feature to determine the significance of avoidance. In addition, we determined whether birds moved across the power line or highway and tallied the number of times they moved and the number of nests and leks within 2 km of the power line or highway.

We performed Monte Carlo simulations to determine whether prairie-chickens crossed the power lines and highways less often than by chance. We assumed an individual was within 2 km (we only examined individuals that had locations within 2 km of each feature and had crossed the feature) of the power lines or road and could move as far as 4 km (2 km on each side of the structure). For both species, 99% of all movements were <4 km (Sutton Avian Research Center, unpublished data). Points outside this boundary were removed from the model. We randomly generated connections between points based on the number of tracking locations near each feature and on the average movement distance for each species of 871 m for Lesser Prairie-Chickens and 914 m for Greater Prairie-Chickens (these are the mean distance moved; Sutton Avian Research Center, unpublished data). We used Microsoft Excel 2007 to simulate linked, random x–y coordinates and determined how many movements crossed the 2000-m mark. Distributions of the number of random crossings, based on 1000 simulated data sets, were compared with observed values for prairie-chickens that had crossed the power line. These tests were one tailed ($\alpha = 0.05$) because movement toward a feature is always the inverse of movement away from it.

We also examined minimum convex polygons of home range size for birds that had tracking locations within 2 km of the feature and determined the center of these polygons and an average edge distance from the center. We used these measures to develop a Monte Carlo simulation to see if the home ranges of birds overlapped the feature as often as would be expected with random placement of a home range. We determined the average distance of centroids from each anthropogenic feature for birds that had locations within 2 km of the feature. We doubled this value, used it as the largest distance a centroid could be from the feature, and randomly generated centroids. We then added the average edge-distance values to randomly placed centroids and determined how often these home ranges overlapped the feature. We performed 1000 simulations for each structural feature. These values were compared with the number of prairie-chicken home ranges (based on minimum convex polygons) that overlapped each feature.

Results

Lesser Prairie-Chicken

Individuals with home ranges that encompassed the power line at the 95% or greater isopleth overlapped the power line significantly less at 75% and 50% isopleths (Table 1). Lesser Prairie-Chickens near highway 283 had home ranges that overlapped significantly less often at the 50% than at the 75% isopleth, but birds near highway 412 did not appear to avoid the road (Table 1) because there was a high density of tracking locations near the highway.

Lesser Prairie-Chickens avoided the power line by at least 100 m, with few birds having at least one tracking location within 100 m of the feature (Table 1; Fig. 1). Sixteen nests were found within 2 km of the power line

Table 1. Number of prairie-chickens with home ranges that overlap the power lines and highways and the number of birds with at least one tracking location near the feature.[a]

			Isopleth[b]		Distance class (m)[b]	
Species	*Feature*	n	*75%*	*50%*	*<100*	*101-500*
Lesser Prairie-Chicken	power line	23	7*	2**	4**	12
	Highway 412	19	11	9	8	14
	Highway 283	46	19	5**	13**	30
Greater Prairie-Chicken	power line	9	1*	1*	0**	3

[a] *Only birds with home ranges that overlapped the feature at the 95% or higher isopleth are included in the analyses.*
[b] *Significance:* *$p < 0.05$; **$p < 0.005$.

out of a total of 107 nests found in the entire study area; 6 of these nests produced offspring. The closest nest was 201 m from the line, and the closest lek was 1003 m from the line. There were two leks within 2 km out of a total of 23 in the entire study area.

Seventeen of the 81 (21%) birds that had locations within 2 km of the power line crossed the power line at least once. No bird crossed the line more than four times in a year. Lesser Prairie-Chickens crossed the power line less often than would be expected by chance (Table 2). In addition, home ranges overlapped the power line less often than would be expected with random placement of home ranges ($p < 0.002$). The average distance that centroids were from the power line was 2370 m with an average edge distance of 1974 m for Lesser Prairie-Chickens.

Few birds had at least one tracking location within 100 m of highway 283 but did not appear to avoid highway 412 (Table 1; Fig. 1). There was a similar avoidance distance of power lines and one of the two highways by Lesser Prairie-Chickens. Two leks and four nests were found within 2 km of highway 412, with only one of the nests being successful; this level of success is similar to that found throughout the study area (Patten et al. 2005*b*). The closest lek and nest were 990 m and 150 m, respectively, from this highway. Four leks were within 2 km of highway 283, the closest being 585 m away from the road. The nearest nest location was 457 m, with 23 total nests being within 2 km of highway 283. Of these nests, only seven were successful.

Forty-one percent (21 of 51 birds) and 33% (48 of 144) of Lesser Prairie-Chickens found within 2 km of the roads moved across highways 412 or 283, respectively. Individuals crossed roads one to eight times/year based on tracking locations. On an assumption of random movements, Lesser Prairie-Chickens moved across the road as often as would be expected (Table 2). Home ranges overlapped both highways as often as would be expected with random placement of home ranges ($p > 0.50$; Highway 183 and $p = 0.60$; Highway 412). The average distance centroids were from Highway 183 was 2304 m and 2217 m from Highway 412.

Greater Prairie-Chicken

Greater Prairie-Chickens avoided the power line: fewer birds had a single tracking location than would be expected within 100 m of the line (Table 1; Fig. 1), and almost all tracking points were >1 km from the power line. Moreover, there were no tracking locations within 100 m of the power line (Table 1; Fig. 1). We found seven leks (two to three in any given year), of 74 total, within 2 km of the power line, the closest being 570 m away. Of 74 nests found in the study area, only one was within 2 km of the line, and it was 1.8 km from the line. This nest was successful.

Eight birds crossed the power line. These prairie-chickens crossed the line between two and five times per year depending on the individual. Greater Prairie-Chickens moved across the power line less often than was expected by chance (Table 2). Nevertheless, home ranges of Greater Prairie-Chickens overlapped the power line as often as would be expected based on random placement of home ranges ($p > 0.999$); average centroid distance was 2614 m from the line and had an edge distance of 1306 m. Most birds found within 2 km of the power line crossed the line at least twice but avoided areas near the line (Fig. 1)—there were no tracking locations within 100 m of the line and only five within 500 m. These findings are supported by kernel-density estimates, and significantly fewer home ranges overlapped the power line at 75% and 50% isopleths (Table 1). In all but one case, home ranges were split into two home ranges per bird, with each occurring >350 m from the power line.

Discussion

The majority of studies of the negative effects of power lines and wind turbines on wildlife have focused on collision risks to migratory species (Drewitt & Langston 2006; Kunz et al. 2007; cf. Stewart et al. 2007). Nevertheless, prairie-chickens are nonmigratory and seldom collide with power lines. In our studies only 4 of 128

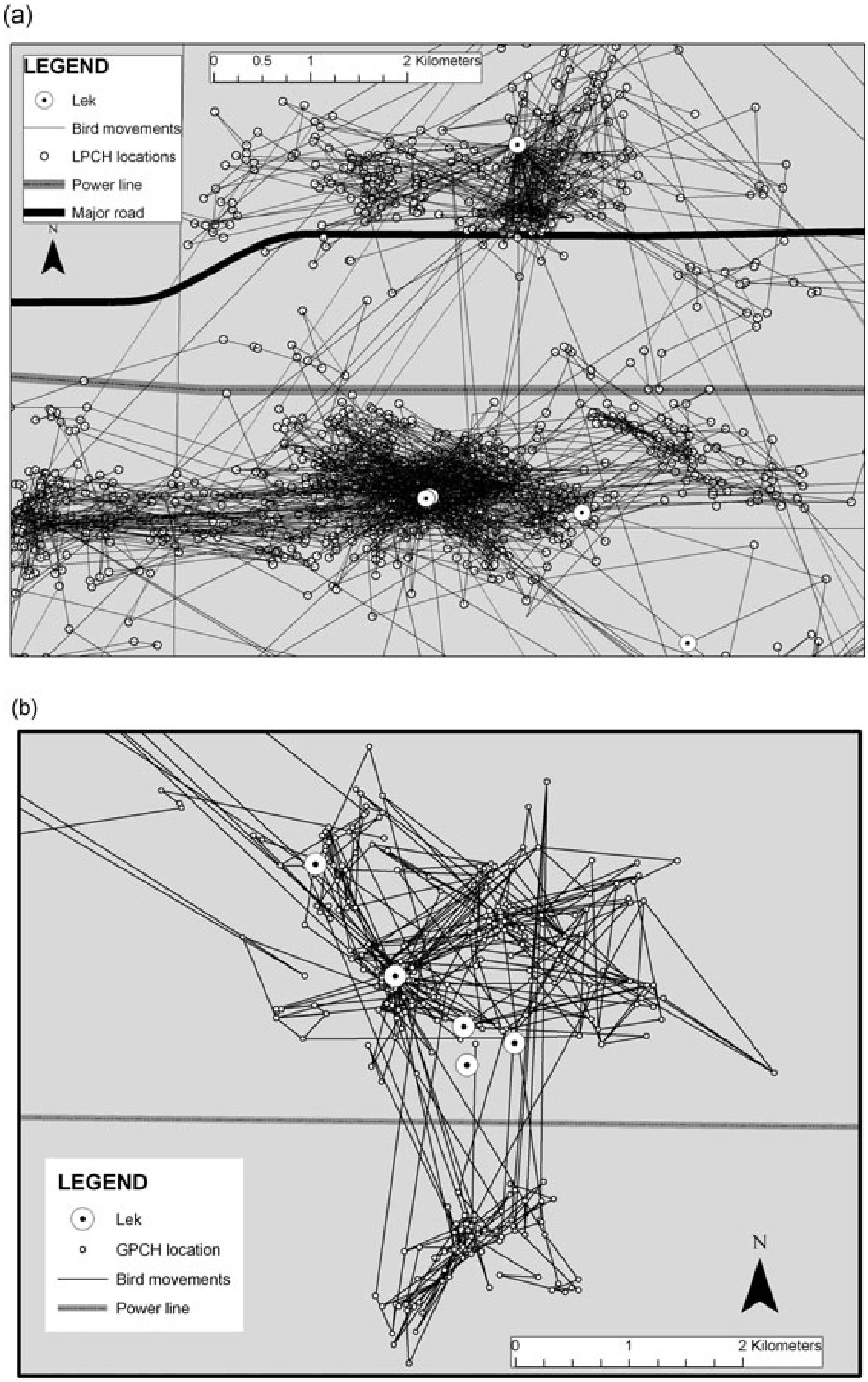

Figure 1. (a) Lesser Prairie-Chicken and (b) Greater Prairie-Chicken movements and lek locations in relation to a power line and a highway in shortgrass prairie of Harper County, Oklahoma (U.S.A.), and in the tallgrass prairie of Osage County, Oklahoma (U.S.A.), respectively.

Table 2. Movements of Lesser and Greater Prairie-Chickens in relation to structural features.*

Species	*Feature*	n	*Movements*	*Crossings*	p
Lesser Prairie-Chicken	power line	17	760	41	<0.023
	Highway 412	21	1009	75	>0.206
	Highway 283	48	2290	159	>0.057
Greater Prairie-Chicken	power line	8	402	20	<0.045

**Key:* n, *number of birds that crossed the structure; movements, total number of movements by these birds; crossings, number of crossings;* p, *whether or not these values differed from a signal of random movement based on simulations.*

(3.1%) Lesser Prairie-Chicken and 4 of 75 (5.3%) Greater Prairie-Chicken mortalities were caused by power line collisions (Wolfe et al. 2007; Sutton Avian Research Center, unpublished data). Collision with wind turbines has never been reported in these species. The much greater impact to prairie-chickens is the possibility of further fragmentation of already fragmented landscapes (Patten et al. 2005*b*) because of avoidance of otherwise suitable habitat found adjacent to structures. Both Greater and Lesser Prairie-Chickens avoided power lines, and Lesser Prairie-Chickens avoided highways somewhat. This avoidance created an unintentional buffer along the transmission lines and roads of at least 100 m in width for prairie-chickens. They also appeared to place nests and leks away from transmission lines. Similar avoidance behavior of human-made structures has been reported for other prairie birds (Leddy et al. 1999; Robel et al. 2004; Pitman et al. 2005).

Habitat fragmentation leads to the isolation of populations and a greater chance of extinction because of small population size and inbreeding depression (Frankham et al. 2002). The rescue of isolated populations through gene flow is possible. Nevertheless, power lines appear to limit prairie-chicken movements. Of birds that had tracking locations within 2 km of the power line, only 21% of Lesser Prairie-Chickens crossed the transmission line. In addition, the birds that did cross did so infrequently. We found that power lines served as obstructions to the free movement of prairie-chickens, which further fragments the landscape. New wind-energy facilities and power lines will probably further isolate populations of prairie-chickens, species that are already of conservation concern (Bird Life International 2007). For example, there is a proposed 765 kV transmission line that will bisect occupied Lesser Prairie-Chicken range; the power line these birds currently avoid is 69 kV (Southwest Power Pool, http://www.spp.org/).

Lesser Prairie-Chickens avoided the power line and one of the two highways by a similar margin of 100 m; however, birds crossed roads more frequently than power lines and thus many birds had home ranges that overlapped the highways, even at the 50% isopleth level. There is a greater level of sound disturbance near highways, but the power line is a taller feature. We suggest that tall structures may have a greater impact on prairie-chicken movements than do heavily traveled roads. Even though birds continued to avoid one of the two highways, they did not see either highway as a barrier to movement. If a power line is perceived as a barrier primarily because of its height, it is likely that prairie-chickens will similarly avoid other tall objects (e.g., wind turbines). Prairie-chickens are among a suite of animals evolved in prairie ecosystems that are almost devoid of trees and other tall features. Raptors are key predators of prairie-chickens, and raptors perch on tall objects to survey hunting areas (Schroeder & Robb 1993; Hagen & Giesen 2005). Prairie-chickens may thus avoid structures because of this perceived threat. In addition, placing unusual objects in an environment can elicit a sizeable fear response in birds (Richard et al. 2008). Predation pressure and fear are probably linked, and we hypothesize that both have led to strong avoidance behavior of tall structures. If this response is evolutionary rather than learned, it is unlikely that prairie-chickens will approach wind turbines, even if raptors cannot perch on the devices (Lammers & Collopy 2007).

Increased production of wind facilities and associated power transmission lines is a potential threat to populations of both species of prairie-chickens (Pruett et al. 2009). The auditory disturbance associated with new roads and construction could also have a negative effect. It is probable that other grassland-dependent species will also be affected (Leddy et al. 1999). Tall structures serve as avoidance buffers (in individual movement and home range placement) and limit dispersal; thus, they further habitat fragmentation. A good mitigation measure would be to bury power lines in areas where open prairie remains the dominant ecosystem. Another measure would be to cluster wind turbines rather than erect them in a long row. In the absence of management efforts or cooperation between developers and conservation biologists, we predict prairie-chickens, and perhaps many other species of open prairie, will decline markedly in areas where wind facilities and large power lines are constructed. These declines would be caused by increased habitat fragmentation, which is a likely cause of population declines in prairie-chickens (Woodward et al. 2001; Fuhlendorf et al. 2002).

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