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EFFECTS OF WIND FARMS ON SANDHILL CRANE PLAYA OCCUPANCY ON THE TEXAS HIGH PLAINS

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Abstract: Wind energy is essential for a shift to carbon-emission free energy, however there has been very little research investigating the disturbance caused by wind farms on the landscape. Texas is a leading state in wind power capacity, and the High Plains of Texas support over 80% of the midcontinent population of sandhill cranes (*Grus canadensis*) every winter. Historically, cranes used saline lakes for fresh water and predator protection, but recent hydrological changes due to agricultural practices have reduced the availability of the lakes for wintering birds. Playa wetlands currently represent the main source of water and roosting habitat in the High Plains. We examined crane occupancy of playa wetlands in 4 counties of Texas during the fall and winters of 2009-10 and 2010-11. In addition to recording presence/no presence, we recorded multiple variables and used information theory and AIC*c* to develop models which best explained crane occupancy. Using occupancy modeling methods to survey playas in Texas resulted in no combination of variables explaining crane presence or absence in playas, most likely because cranes likely move between playas freely on their winter habitat. As playas are a vital part of their winter ecology, sandhill crane use and movement between them should be further examined to better describe crane use of their winter landscape and better plan and manage for large scale habitat alterations, such as the large increase in the number of wind turbines across the High Plains.

Wind energy is a major component of the carbon-emission free energy policy, and is one of the fastest growing energy technologies in the world (American Wind Energy Association 2011). Texas currently accounts for one-third of the nation's installed wind power. Wind farms are ideally situated along wind corridors in rural agricultural areas (Wiser and Bolinger 2008), which puts them in direct conflict with migrating and wintering birds. The High Plains of Texas support over 80% of the midcontinent population of sandhill cranes (*Grus canadensis*, hereafter cranes) every winter. Multiple studies have suggested that wind farm development and maintenance have the potential to disturb daily movements and can displace birds (Drewitt and Langston 2006, Kuvlesky et al. 2007, Langston and Pullen 2003). Cranes are easily disturbed by the presence of cars, and human activity in the vicinity of roost sites increases the probability they will abandon those sites (Bautista et al. 1992, Burger and Gochfeld 2001, Lewis 1974). Consequently cranes may be disturbed by wind farms because of turbine movement and farm maintenance.

Crane flocks generally spend the majority of their day foraging in agricultural fields (Ballard and Thompson 2000) and the evening roosting in one of the many playa wetlands, which provide fresh water and predator protection (Lewis 1974). Winter wetland habitat preservation, including the prevention of displacement from areas of disturbance (Drewitt and Langston 2006), is vital to prevent crane population declines (Lewis 1974, Safina 1993).

Historically, saline lakes in Texas provided winter roosting sites and the freshwater streams connected to them provided water for the sandhill cranes. However, recent hydrological changes due to agricultural practices have reduced the availability of the saline lakes and freshwater streams (D. Haukos, personal communication). The current predominant hydrological features on the high plains are playa wetlands which occur in high numbers across the southern High Plains. They are hydrologically unconnected and receive the majority of their water from direct rainfall and runoff (Casula 1995). Consequently, though the Texas High Plains contain 19,340 playa basins, the amount of playa habitat available to cranes is dependent on yearly precipitation and can vary widely (Haukos and Smith 1994).

Cranes prefer to roost in wetlands that are shallow, on level terrain, bordered by sparse vegetation or lacking vegetation altogether and in an isolated location, away from human disturbance (Kessel 1984, Lewis 1976, Lovvorn and Kirkpatrick 1981, Safina 1993,

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Soine 1982). Sandhill cranes winter in family groups containing the adult female, adult male, and juveniles born just a few months prior; hence, the predator protection playas provide is vital to their survival (Lewis 1974). It has been noted in some studies that the cranes exhibit strong site fidelity to specific areas in their range and juveniles will often return to the areas where they wintered with adults, indicating they learned these use areas from their parents (Drewien et al. 1999, Meine and Archibald 1996, Tacha 1981). Returning to familiar habitat and roost sites probably increases the chances of survival for these long-lived birds and illustrates the importance of maintaining crane habitat.

Human activity in the vicinity of a roost site can cause cranes to abandon the area (Bautista et al. 1992, Kessel 1984, Lewis 1974), so understanding how the presence of wind turbines affects the use of this necessary resource is needed when managing winter habitat for cranes. We examined crane occupancy of playa wetlands in 4 counties of Texas, each of which contained 1 or more wind farms. Our hypothesis was that the presence of wind farms will cause cranes to avoid otherwise acceptable playas, negatively affecting crane occupancy of playas within wind farms.

STUDY AREA

We conducted this study in the High Plains region of Texas, which is composed mainly of short-grass prairie (elevation 1,000-1,500 m). The north and west regions of the High Plains are a plateau of 80,000 km^2 and one of the largest and flattest areas of contiguous geography in the world (Casula 1995). This area has mostly been converted from short and mid-grass prairie to food and fiber production with its main exports being cotton, sorghum, and wheat (Bolen et al. 1989).

For this study we surveyed within the Texas counties of Carson, Floyd, Crosby, and Dickens. Three of these counties contained wind farms which include the Pantex wind farm (Carson County), Llano Estacado wind farm (Carson County), Whirlwind wind farm (Floyd County), and MacAdoo wind farm (Dickens County). These wind farms range from 26 to 100 turbines, and all wind farms contained at least 1 wet playa during the years (October through February, 2009-2011) in which they were surveyed. All 4 counties contained more than 50 available roosting playas each survey year. The land use in the area consisted of urban, fallow pasture/playa, winter wheat, cotton, sorghum, corn, and soybeans.

METHODS

Using Google Earth, the National Wetlands Inventory (U.S. Fish and Wildlife 2011) and ArcMap 9.3 (ESRI, Redlands, CA) to identify potential playas, we ground-truthed all identified playas in each of the study counties in each year to determine whether they held water that year. Sandhill cranes arrive in the Texas High Plains as early as late September. Generally, precipitation during the months of May - July has a large influence on the amount of playa habitat available to the cranes when they first arrive. The first year of the study (2009) was a fairly dry year for the area, receiving only 32.7 cm in precipitation, compared to the regional long term average of 47.5 cm (National Weather Service 2009), and we were able to survey all the wet playas in the study counties (51 total). During the second year (2010) the Texas high plains received almost twice as much precipitation (67.2 cm) in the Floyd, Crosby, and Dickens area as the previous year, and there were too many playas to survey with available personnel (National Weather Service 2010).

After identifying all wet playas, we numbered them, and using a random number generator, randomly chose 40 playas from those 3 study counties for a total of 71 playas surveyed in all 4 study counties (Figure 1, 2). Using occupancy modeling methods, a technician and LN surveyed each playa 3 times, either twice in the morning and once in the evening or vice versa, or until we detected crane presence. Detection probability for cranes was equal to 1 due to their visibility on the flat landscape and their tendency to be vocal. After we determined cranes were roosting in a playa we did not survey it again (MacKenzie et al. 2006).

All playas were on private land, so we surveyed them from the closest county road or highway. Morning surveys began 1 hour before sunrise, and evening surveys began 1 hour before sunset (Iverson et al. 1985, Tacha 1986). If we heard cranes at a playa, we recorded it as occupied; however, if we did not hear cranes and it was too dark for cranes to be visible, we did not record it as unoccupied. Once we determined cranes were occupying a playa, or had spent 30 minutes observing the playa with no sign of cranes arriving or leaving, we moved to the next playa (Bennett 1978). We concluded surveying when we observed cranes leaving the playas in the morning and when it became too dark to see cranes in the evening.
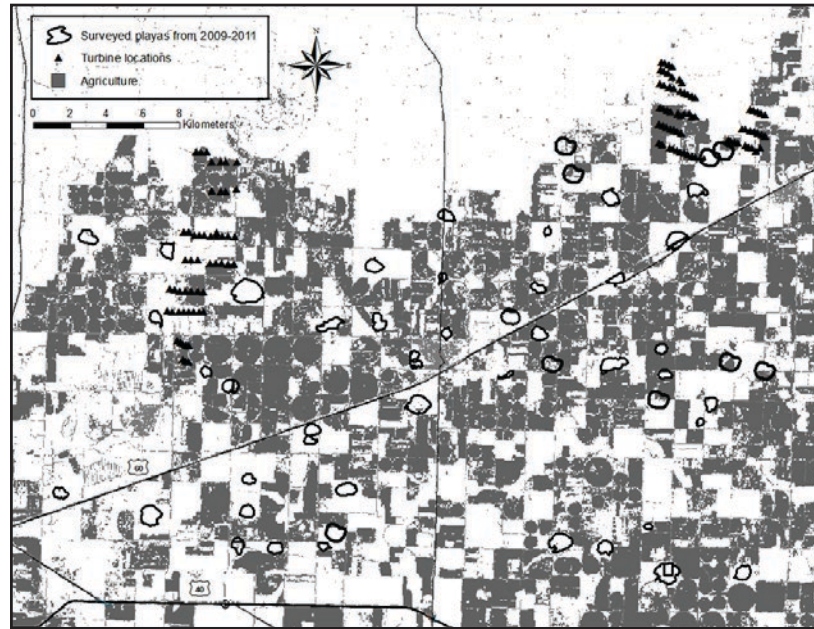
Figure 1. Playas surveyed for sandhill crane occupancy, Carson County, Texas, 2009-2011.

The majority of playas existed on private land and we were not able to access them, so to the best of our ability, we recorded the following variables to create models for a logistic regression using Akaike's Information Criteria for small sample sizes (AIC*c*) (Burnham and Anderson 2004): size (determined from the NWI); vegetation height as either low, medium, or high; slope as either low, medium, or high; and visibility as either low, medium, or high. These measurements were not exact and were recorded relative to the surrounding area. We also recorded the distance to the nearest road (DR), the distance to the nearest highway (DH) ,the distance to the nearest turbine (DW) measured from the middle of the playa, the distance to the nearest foraging area (DNF), as well as the patch size of the field (PS). All distances were determined using ArcMap 9.3 (ESRI, Redlands, CA).

Using SAS/STAT software (SAS Institute, Inc., 2000) we used descriptive statistics to compare variables between occupied and non-occupied playas and used analysis of variance to test for differences. We calculated logistic regression using the program R (R Development Core Team, 2004) to estimate the contribution of each individual measured variable and all possible combinations of the variables (models) to the occupancy of each playa. We then calculated second order AIC*c* values, differences between AIC*c* values of all models and the lowest scoring model (Δ_i)

and Akaike weights (ω_i) for each model (Burnham and Anderson 2004).

RESULTS

The only differences between the variables of occupied playas and unoccupied playas was the size of the playa ($n = 102$, $P = 0.003$) and the height of the vegetation ($n = 102$, $P = 0.01$) (Tables 1 and 2). We were unable to identify a model, using logistic regression and AIC*c* criteria that had sufficient strength to explain crane occupancy. Models having their ΔAIC within 1-2 of the minimum have substantial support (Anderson 2008, Burnham and Anderson 2004). Analyzing the models using AIC*c* resulted in 9 models with the ΔAIC between 1 and 2; however, when the model probabilities (ω_i) were calculated, none had a probability larger than 0.06 (Table 3). Most ranked models contained playa size, vegetation height, and slope.

DISCUSSION

Wintering sandhill cranes in Texas roosted in playa wetlands with features fairly similar to roosts used by cranes in other studies in the western U.S. (Iverson et al. 1985; Lewis 1974, 1976; Lovvorn and Kirkpatrick 1981), i.e., large, flat and with good visibility. A comparison between the characteristics of occupied

Our goal was to discover if distance to disturbance (road or wind turbine) had an effect on the occupancy of a playa, but analysis of the collected data did not yield any combination of variables that explained playa occupancy or non-occupancy by sandhill cranes. Our methods of determining occupancy were based on an assumption that cranes would return to the same roost site during the time they occupied the area. The results of this study, coupled with field observations, suggest that some playas that were recorded as unoccupied were in reality, occupied. This would result in false negatives and would explain why the ANOVA analysis, regression analysis and AIC did not explain variation in occupancy.

Playa wetlands in west Texas have never been formally surveyed for crane occupancy. The few studies conducted in west Texas observed sandhill cranes in the saline lakes (Iverson et al. 1985). During these studies (1985), cranes were not observed using playa wetlands. This is in stark contrast to 2009-2011, when cranes were found occupying over 37% of surveyed playas within 4 counties. With the continuing disappearance of the saline lakes due to changing hydrology, playa wetlands are becoming increasingly important for freshwater access and roosting habitat. Based on previous studies (Bennett 1978, Davis 2003, Iverson et al 1985, Lewis 1976) done in different areas, we made the assumption that sandhill cranes return to the same roost each night, so if cranes were not seen or heard at a roost sight after 3 visits, that roosting site was recorded as not occupied. These previous studies differed from ours because they included large, permanent lakes, and most were conducted at staging areas. However, Iverson et al. (1987) found that during spring migration, radio-marked sandhill cranes had little site fidelity. Our

Figure 2. Playas surveyed for sandhill crane occupancy, Floyd, Carson, and Dickens counties, Texas, 2009-2011.

and unoccupied playas revealed the only significant differences between them was the size of the playa and the height of the vegetation (Tables 1 and 2). In both cases, it was unoccupied playas that possessed characteristics expected to be seen at occupied playas; larger size and lower vegetation.

Table. 1 Descriptive statistics on playa wetlands occupied by sandhill cranes in the Texas High Plains, 2009-2011. Vegetation height, slope, and visibility data evaluated categorically: 1 = Low, 2 = Med, 3 = High. Significant differences at the 0.05 level between occupied and unoccupied playas shown in bold ($P \leq 0.01$). Other differences were not significant ($P \geq 0.06$).

	Size (ha)	Veg	Slope	Visibility	Nearest road (m)	Nearest turbine (m)	Nearest highway (m)	Nearest foraging area (m)	Foraging patch size (ha)
Mean	**36**	**1.6**	1.4	2.5	372	8,646	4,153	548	87
SE	**3**	**0.1**	0.1	0.1	60	993	499	51	21
Median	**29**	**2**	1	3	318	8,441	3,742	479	48
SD	**20**	**0.6**	0.6	0.6	369	6,122	3,073	314	129
Min.	**8**	**1**	1	1	10	486	659	127	4
Max.	**91**	**3**	3	3	2,006	23,074	14,361	1,456	773
n	**38**	**38**	38	38	38	38	38	38	38

Table 2. Descriptive statistics on playa wetlands unoccupied by sandhill cranes in the Texas High Plains, 2009-2011. Vegetation height, slope, and visibility data evaluated categorically: 1 = Low, 2 = Med, 3 = High. Significant differences between occupied and unoccupied playas shown in bold ($P \leq 0.01$). Other differences were not significant ($P \geq 0.06$).

	Size (ha)	Veg	Slope	Visibility	Nearest road (m)	Nearest turbine (m)	Nearest highway (m)	Nearest foraging area (m)	Foraging patch size (ha)
Mean	**67**	**1.4**	1.5	2.5	477	9,664	3,250	471	76
SE	**8**	**0.1**	0.1	0.1	115	823	344	42	9
Median	**49**	**1**	1	3	260	10,718	3,072	398	52
SD	**65**	**0.6**	0.6	0.6	927	6,588	2,755	341	75
Min.	**2**	**1**	1	1	0	113	0	100	2
Max.	**409**	**3**	3	3	5,178	26,809	10,805	1,798	316
n	**64**	**64**	64	64	64	64	64	64	64

Table 3. Top ΔAIC*c* (ΔAIC*c* = 0-2) and model probabilities exploring sandhill crane playa occupancy in the Texas High Plains, 2009-2011.

Model[a]	ΔAIC	ω_i (model probability)
Size,veg,slope	0	0.062
Size,veg,slope.DH	0.739	0.043
Size,veg	0.808	0.041
Veg,slope	1.211	0.034
Veg,slope,DH	1.237	0.033
Size,veg,DH	1.407	0.031
Size,veg,vis	1.754	0.026
Size,veg,slope,DNF	1.965	0.023

[a] Size = playa size (ha); veg = vegetation height as either low, medium, or high; slope = playa slope as either low, medium, or high; vis = visibility around playa as either low, medium, or high; DH = distance to nearest highway; DNF = distance to the nearest foraging area.

observations during the course of the study suggest that wintering cranes similarly move among the playas and do not return to the same roost spot every night. Multiple times while scouting potential survey routes we would see cranes occupying playas. A few weeks later, while conducting official surveys we would survey those playas 3 times without ever detecting cranes. It is very probable that even after surveying a playa 3 times with no detection of cranes, cranes occupied that playa at some point during the winter season.

Though we were unable to determine if wind farm disturbance affects crane occupancy of playas, we observed roosting behavior which suggests that cranes use a hierarchical selection of playas. Other studies have demonstrated that good roosting playas are very large with good visibility. During 2009, a very dry year, the number of wet playas was limited. There were 2 playa wetlands within wind farms that had the attributes of

preferred wetlands described in other studies. These playas were consistently occupied by cranes during the dry year of 2009. However, in 2010 when precipitation was higher and more playas were available, no playas within a wind farm were occupied. Our observations suggest that cranes are not roosting in playas near wind farms, unless there are very few playas to choose from. Once more playas are available, cranes abandon the playas near and within the wind farms, suggesting a cost associated with using roosting habitat within wind farms.

While previous studies in West Texas have focused on the saline lakes (Iverson et al. 1985), we observed during our 2-year study that cranes occupying the playas did not move to the saline lakes until almost all of the playas were frozen. Furthermore, some cranes stayed in the playas all winter, never moving to the saline lakes before starting their northward migration in the spring. Crane use of the playas has increased since the 1990s as the freshwater springs discharging into the saline lakes have dried up (D. Haukos, U.S. Fish and Wildlife Service, personal communication). If the saline lakes are further degraded in the future, cranes may start relying even more on the playas for roosting and fresh water in the winter, especially during warm years when playas are available as roosting habitat all winter long.

Multiple roosting studies have commented on the fact that cranes are easily disturbed from roosting sites by human activity and many times do not return (Bennett 1978; Lewis 1974, 1976; Lovvorn and Kirkpatrick 1981; Stephen 1967), suggesting that increased human activity and increased road traffic in wind farms may affect crane occupancy. Future research should be done to better determine what influences the occupancy of a playa, how cranes move among them, and what causes abandonment of certain playas and fidelity to others.

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