THE EFFECTS OF WIND ENERGY ON OVERWINTERING GRASSLAND BIRDS

by

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INTRODUCTION

Grassland birds are the most threatened group of birds in North America (Knopf and Samson 1997, Peterjohn and Sauer 1999, Brennan and Kuvlesky 2005). Habitat loss in both breeding and wintering ranges is the leading cause of decline in North American grassland bird populations (Knopf 1994). Populations of some migratory passerines may be limited during the non-breeding portion of their life cycle (Fretwell 1980, Brooks and Temple 1990, Basili and Temple 1999, Rappole *et al*. 2003). For example, quality of winter habitat can determine arrival time at breeding grounds and breeding condition on arrival, two major determinates of reproductive success (Marra *et al*. 1998). Wintering grounds for many grassland birds have undergone major land use changes that threaten viability as suitable habitat (Igl and Ballard 1999, Baldwin *et al*. 2007, Conover *et al*. 2007, Butler *et al*. 2009, Macias-Duarte *et al*. 2009). For example, less than one percent of the historic coastal prairie ecosystem in Texas and Louisiana, an area with one of the highest diversities of overwintering grassland birds in North America (Rich *et al*. 2004), remains in pristine condition (Diamond and Smeins 1984, Arey *et al*. 1998). Land use changes and habitat loss are attributed to conversion of grasslands to agriculture, overgrazing of grasslands by livestock, and invasion of woody plant species due to the loss of natural burning cycles (Knopf and Samson 1997, Peterjohn and Sauer 1999, Askins *et al*. 2007).

Wind turbines may be another source of habitat loss or degradation for North American grassland birds (Leddy *et al*. 1999, Pruett *et al*. 2009). Texas has more installed wind capacity than any other state in the United States; as of June 2011, Texas had 10,135 MW of installed wind capacity, easily surpassing Iowa as the second highest state with an installed capacity of 3,675 MW (NREL). In comparison to the rest of the United States, Texas's southern location gives it a unique winter grassland bird community. Many grassland birds that breed in the northern U.S. and southern Canada overwinter in the grasslands of Texas and Mexico (Rich *et al*. 2004). Overwintering grassland bird diversity is greater than the diversity of breeding grassland birds throughout north and west Texas, and is double the diversity of breeding grassland birds in south Texas and along the Gulf Coast (Sibley 2000).

If the presence of wind turbines degrades surrounding habitat, birds may be displaced from areas near wind turbines. Studies on the displacement of entire grassland bird communities are rare. Displacement in a breeding North American bird community was found by Leddy *et al*. (1999) in southwest Minnesota, where densities of grassland passerines within 180 m of wind turbines were lower than densities in similar habitats without turbines. Pearce-Higgins *et al*. (2009) found displacement up to 800 m from wind turbines in some species within an upland bird community in the United Kingdom. Devereux *et al*. (2008), the only study to date investigating overwintering birds, found no displacement in farmland bird community in the United Kingdom.

I investigated potential wind turbine displacement in a north Texas overwintering grassland bird community. This study is the first to assess the possible indirect impacts of wind turbines on an overwintering bird in community in North America. A variety of species from the family *Embrerizide* (sparrows and longspurs) were common on grasslands at our study site. The genera *Sturnella* (meadowlarks), *Eremophila* (horned lark), and *Anthus* (pipits) were also well represented. I predicted that only those species that are sensitive to disturbance would be displaced from suitable habitat near turbines.

METHODS

Study Area

I conducted field work at Wolf Ridge Wind, LLC (N 33° 43' 53.538" W 97° 24' 18.186"), a 112.5 MW wind farm located ca. 10 km north of Muenster, Texas, within the Cross Timbers Ecoregion (Fig. 1;

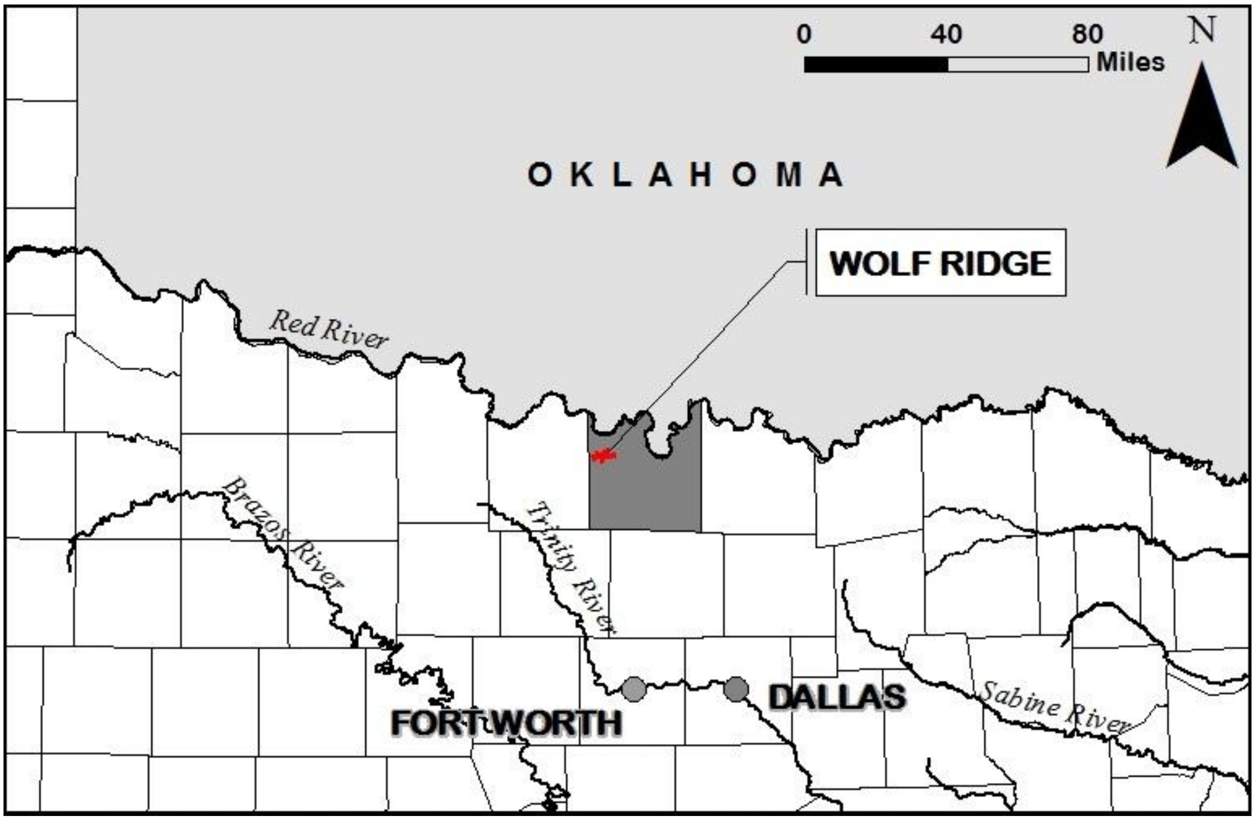


Figure 1. Wolf Ridge Wind, LLC, a 112.5 MW wind farm, Is located just south of the Red River in Cooke, County Texas.

Griffith *et al*. 2004). Wolf Ridge, owned and operated by NerxtEra Energy Resources, began operations in October 2008. Within a leased area of 48 km^2, the wind facility consists of 75 1.5-megawatt (MW) GE wind turbines arrayed in a west-to-east fashion along a ridge. To the north, the ridge descends into a series of forested valleys that drain to the Red River valley. The southern part of the wind farm descends slightly from the ridge and consists of a flat open prairie and scrub/oak savannah (Fig. 2). There are 14 different land owners within the wind resource area, each of whom has sub-divided his or her land into multiple parcels with different uses including cattle grazing, native hay harvesting, and winter wheat (*Triticum aestivum*) cultivation. Different land uses in each parcel, as well as differences in harvest rate and grazing pressure, have created a mosaic of parcels with variable vegetation types and dominant plant species. In fields used for grazing, meadow dropseed (*Sporobolus compositus var. drummondii*), silverbeard grass (*Bothriochloa saccharoides*), Bermuda grass (*Cynodon dactylon*), King Ranch bluestem (*Bothriochloa ischaemum*), tall forbs (*Amphiachyris dracunculoides* and *Ambrosia psilostachya*), and a variety of annual forbs are the most common plant species. Some grazed fields are dominated by monocultures of Bermuda grass or King Ranch bluestem. In fields that are harvested for native hay or left fallow, little bluestem (*Schizachyrium scoparium*), meadow dropseed (*Sporobolus compositus var. drummondii*), and tall warm season grasses (*Andropogon gerardii*, *Panicum virgatum, and Sorghastrum nutans*) are the most common species.

Survey Methods

We used an area-search method, which depends on flushing birds within search plots, to survey birds at Wolf Ridge. Although there is no single standardized method to survey winter grassland birds in North America (Fletcher *et al*. 2000, Roberts and Schnell 2006, Twedt *et al*. 2008), Roberts and Schnell (2006) have shown that wintering grassland birds can be accurately detected using an area-search method. This method does not rely on modeling a distance-based detection probability, thereby circumventing problems presented by cryptic and non-vocal winter grassland birds.

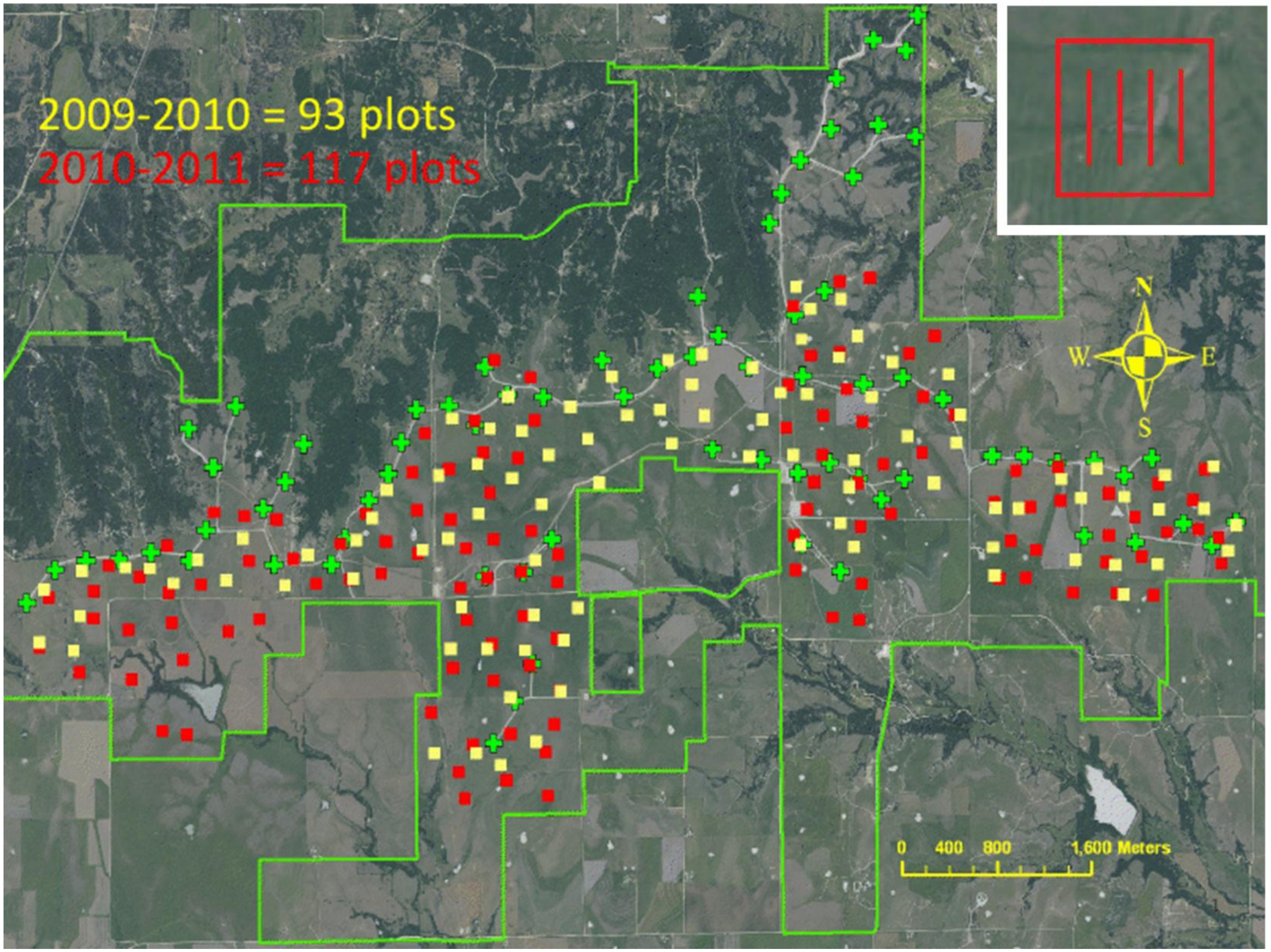


Figure 2. Location of 210 1-ha search plots at Wolf Ridge. Green crosses: 75 wind turbines; insert: design of a 1 ha area search plot.

I randomly placed 1-ha plots within accessible land at Wolf Ridge using Arc GIS software (Fig. 2). I chose plots 1-ha in size because they were found to be manageable by one searcher in southern Oklahoma, where similar prairie habitat and bird communities were present (Roberts and Schnell 2006). All plots were separated by at least 100 m within the same field season and were at least 100 m from the forest edge. By randomly placing plots under these parameters, we searched plots located 17 to 1423 m from the closest wind turbines. A new group of random plots was generated each field season, which resulted in some plots overlapping in area between years (Fig. 2). In 2009-2010, I searched all plots between 18 December and 14 February. In 2010-2011, I searched all plots between 29 December and 23 February. I used these search periods because they occurred when all study species were seen to be overwintering. I conducted all surveys between 1 hr after dawn and 1 hr before dusk CST (Gryzbowski 1982, Roberts and Schnell 2006, Devereux *et al*. 2008).

One or two searchers navigated the plots with the help of a handheld GPS (Trimble GeoXT). When two searchers were available, one navigated with the GPS while searching for birds while the other searched only for birds. Although the second searcher varied, one searcher (TKS) served as the primary bird identifier and searched every plot. I searched plots by first walking the 400 m perimeter, then walking the four 60 m lines bisecting the plot (Fig. 2). Using this method, we passed within 10 m of every point in the plot.

When I sighted a bird or group of birds within a plot, I placed a small flag at the location of the initial observation, recorded the time, number of birds, and species of birds associated with that observation, and then continued searching the plot. At the end of each search, I recorded data relevant to the entire 1-ha plot: temperature to the nearest tenth of a °C, wind speed to the nearest tenth of a m/s, wind direction to the nearest °, barometric pressure to the nearest Pa, percent cloud cover (0%, 1-10%, 11-25%, 26-50%, 51-75%, 76-90%, 91-99%, 100%), precipitation intensity if present (none, drizzle, light, moderate, heavy), precipitation form if present (rain, sleet, snow), precipitation duration if present (brief, intermittent, constant), presence or absence of fence lines, presence or absence of trees and bushes (fruiting trees vs. non-fruiting also noted), most common plant species, and land use (grazing, hay field, winter wheat field).

I collected a GPS point at each flag which represented either an observation of one bird or a flock of birds. I defined a flock as birds that responded similarly to being flushed by searchers or birds observed moving or foraging together prior to being flushed (Grzybowski 1983a). I centered a 1-m^2 quadrat on each bird location and measured vegetation microhabitat data that included floristic composition (% grass, % forb, % tree/shrub, % litter, % bare ground), plant species richness (total number of species present), maximum vegetation height (measured or estimated to the nearest cm), and the three most common plant species (recorded as a percentage of total ground cover; Knight 1994). Within each 1-ha plot, I also sampled a randomly placed quadrat measuring the same vegetation variables as we did in the bird location quadrats.

Statistical Analyses

Three species were analyzed for displacement by turbines and habitat associations; Savannah Sparrows (*Passerculus sandwichensis*), Le Conte's Sparrow, and Sprague's Pipit (*Anthus spragueii*). Two ecological groups, meadowlarks and flyers, were also analyzed. Eastern (*Sturnella magna*) and Western Meadowlarks (*S. neglecta*) were analyzed as one group due to difficulties in differentiating the species during the non-breeding season. The flyers included Horned Larks (Eremophilia alpestris), American Pipits (*Anthus cervinus*), McCown's Longspurs (*Calcarius mccownii*), Smith's Longspurs (*C. pictus*), and Chestnut-collared Longspurs (*C. ornatus*). These are gregarious and highly mobile species that typically forage in sparse open habitats (Grzybowski 1983a).

I used binary logistic regression to test for an effect of wind turbines on bird distributions. The explanatory variable was distance to turbine, measured in meters from the center of the plot to the nearest turbine. The response variable was presence or absence of a bird species or ecological group within each plot. Each plot was assigned a value of 0 (unoccupied) or a value of 1 (occupied). I preformed all statistical tests using JMP (v. 7.0.2) or Minitab Statistical Software (v.15.1.30).

I used a χ^2 goodness of fit test to look for non-random distributions of birds among habitat types. I tested for non-random distributions of bird observations by field use (pasture, hay, winter wheat) and by most common plant species (Bermuda grass, King Ranch bluestem, tall forbs - common broomweed and western ragweed, little bluestem, meadow dropseed, silverbeard grass, and tall warm season grasses - big bluestem, Indian grass, switchgrass, and winter wheat).

Ecological Niche Modeling

For species that were not randomly distributed among habitat types, I used ecological niche modeling (Maxent v.3.3.3e; Phillips *et al*. 2006) to determine which of the 210 search plots represented suitable habitat for these species, as logistic regression results could be biased by a non-uniform distribution of suitable or unsuitable habitat in relation to wind turbines. Maxent, a machine learning approach based on maximum entropy, has consistently outperformed other ecological niche modeling methods, particularly with small sample sizes (Elith *et al*. 2006, Hernandez *et al*. 2006, Pearson *et al*. 2007, Wise *et al*. 2008, Rebelo and Jones 2010). Plot characteristics and vegetation microhabitat data from occupied plots were used to create a probability of presence (POP) between 0 and 1 for all searched plots. I chose Maxent, a model that uses presence-only data for two reasons: our search methodology was not able to detect the presence of all study species with 100% efficiency (Roberts and Schnell 2006), and study species could be displaced from suitable habitat by wind turbines. These circumstances could lead to pseudo absences, plots that are unoccupied for reasons other than habitat suitability in that plot (e.g. displacement or crypsis; Pearson *et al*. 2007). Pseudo-absences cannot be used to determine habitat suitability (Phillips *et al*. 2006).

Ecological niche modeling methods, including Maxent, are usually used on a much larger geographic scale than what was relevant for this study. Nevertheless, I think that ecological niche modeling can be appropriately applied to our study design because of the clear distinctions between vegetation structure and composition in different parcels of land with different land uses. I used 15 different ecological variables to determine the probability of presence within the search plots for non-randomly distributed study species. Two of these variables, field use and most common vegetation species, pertained to the entire 1-ha plot, whereas the remaining 13 variables were taken from the randomly located 1-m^2 quadrat within each plot: maximum vegetation height, plant species richness, % ground cover, % grass, % forb, and the individual % for the eight most common plant species or groups (Bermuda grass, King Ranch bluestem, tall forbs, little bluestem, meadow dropseed, silverbeard grass, and tall warm season grasses, and winter wheat). I used all occupied plots to generate probability of presence values for species with less than 25 presence location using the default parameters for Maxent. To create probability of presence values for species with more than 25 occupied plots, I had Maxent run five replicates, and then cross-validate each with a different randomly selected 20% of occupied plots used for model testing. I had Maxent generate response curves for the effect of each variable on species distributions, and preform a jackknife analysis to measure the importance of each ecological variable to the creation of the models.

Habitat suitability models created with Maxent are most often validated using area under the ROC curve (AUC), a threshold independent statistic that represents the probability that a randomly chosen presence site will be more suitable than a randomly chosen pseudo-absence (e.g. Hu and Jiang

2010, Rebelo and Jones 2010, Lahoz-Monfort *et al*. 2010, Gromley *et al*. 2011). This requires separating presence locations into training samples and testing samples, as it is improper to test a model with the data used to generate it. I used AUC validation for species with more than 25 occupied plots.

In cases where the sample size of presence locations is limited (n < 25), separating presence locations can be inappropriate, as training and testing samples become very small (Pearson *et al*. 2007). For this reason I did not use AUC validation for some study species. Instead, I used a jackknife technique developed by Pearson *et al*. (2007) specifically for validating models with small sample sizes. In this method, each presence location is removed once from the dataset and the remaining n -1 locations are used to build the model. Species with n presence locations will have n separate models built for testing. Thus each occupied plot with have a probability of presence value based on training of the other n – 1 occupied plots. The models predictive performance is assessed based on the ability of each model to classify the single presence location excluded in that data set as suitable habitat. Model performance was assessed at two thresholds for suitable habitat; minimum training presence (MTP) and a fixed cumulative value of 1 (FCV1). MTP provides a conservative threshold to estimate habitat suitability, only plots with a probability of presence greater than or equal to the lowest probability of presence for an occupied plot used to calibrate the model were considered suitable habitat. In contrast, FCV1 provides a more relaxed threshold to estimate habitat suitability, allowing plots marginally below probability of presence levels for occupied plots to be considered suitable habitat.

For species in which I found significant habitat associations, I repeated the binary logistic regression analysis for an effect of wind turbine on plot occupancy using just those plots that were determined to be suitable habitat under the MTP and FCV1 thresholds. For the species in which the binary logistic regression found evidence for displacement, I performed a Mann-Whitney U test to compare the distribution of probability of presence values from suitable plots (MTP) in which I did not detect the species with the distribution of "left out" probability of presence values from occupied plots. I used "left out" probability of presence values from the jackknife analysis for presence locations to avoid independence issues surrounding the use of probability of presence values from plots used to train the model for comparison. I also ran a Spearman rank correlation test of "left out" probability of presence and density of individuals per plot for occupied plots. These tests were performed to assess the effect of the magnitude of probability of presence on plot occupancy and density of birds per plot.

RESULTS

Plot Characteristics and Occupancy

I searched 93 plots in the winter of 2009-2010 and 117 in the winter of 2010-2011. Plots were located from 17 to 1423 m from the nearest turbine. Of the 210 plots, 135 were in pasture, 46 were in hay fields, and 29 were in winter wheat fields. The most common plant species in the plots were meadow dropseed (n = 51 plots), winter wheat (n = 27 plots), and Bermuda grass (n = 26 plots).

I recorded 26 species of birds in 75% of the plots over the two field seasons. In total, we observed 2,115 individuals in 484 independent observations (Appendix A). Three hundred and ten observations were of solitary birds, whereas the remaining observations were of flocks ranging in size from 2 to 250 birds. Savannah Sparrows and meadowlarks constituted approximately 71% of the individuals and 78% of the observations within plots (Table 1).

Table 1. The number of individual birds, observations (a single bird or flock), and percent of occupied plots for the five most common species or groups during the winters of 2009/2010 and 2010/2011 at Wolf Ridge. A high ratio of individuals to observations indicates a greater tendency for flocking behavior.

Species	Individuals	Observations	Percent of plots occupied
Savannah Sparrow	750	314	59%
Meadowlarks	763	64	27%
Flyers	384	25	10%
Le Conte's Sparrow	31	28	9%
Sprague's Pipit	20	19	8%

We observed the highest mean density of birds per hectare (b/ha) 10.99 ± 2.58 (SE) in plots in pastures, followed by plots in hay fields (9.85 b/ha ± 2.50), and in plots in agricultural fields (7.56 b/ha ± 2.15). Plots in hay fields had the highest percent occupancy for all bird species combined (89%), followed by plots in pastures (75%) and plots agricultural fields (64%). Pasture plots in which Bermuda grass was the most common plant species (n = 26) had an average of 3.08 b/ha (± 1.03), while all other grazed plots (n = 109) had an average of 12.8 b/ha (± 3.15).

The 2009/2010 field season was colder (mean temperature during searches 6.42 ± 0.69°C) than the 2010/2011 field season (mean temperature during searches 12.52 ± 0.67°C). The 2009/2010 field season had an average of 13.24 (± 3.80) b/ha and 1.57 (± 0.17) observations per ha. The 2010/2010 field season an average of 7.5 (± 1.13) b/ha and 2.74 (± 0.22) observations per ha. This indicates that flocking was more common during the colder winter of 2009/2010.

Habitat Associations

Savannah Sparrows, meadowlarks, Le Conte's Sparrow, flyers, and Sprague's Pipits had sufficient sample sizes (see Table 1) to test habitat associations. Savannah Sparrows were not randomly distributed at Wolf Ridge (field use: χ^2 = 34.34, df = 2, p < 0.001; Plant species: χ^2 = 36.79, df = 6, P<0.001). Savannah Sparrows avoided plots used for winter wheat and plots in which Bermuda grass was the most common plant species. Meadow dropseed and tall forbs were the most common plant species or plant grouping within 1 m^2 of the Savannah Sparrow sightings. Meadowlarks were found in all field types (field use: χ^2 = 1.46, df = 2, p > 0.05; plant species: χ^2 = 10.36, df = 6, p > 0.05) and microhabitat data were similar to the distribution of available habitat at Wolf Ridge (Table 2). Sprague's Pipits were found in all field types (field use: χ^2 = 1.33, df = 2, p > 0.05; plant species: χ^2 = 2.33, df = 6, p > 0.05), and were the only species that commonly used (32% of observations) monoculture grasses (Bermuda grass, King ranch bluestem, winter wheat) as microhabitat. Le Conte's Sparrows were not distributed randomly at Wolf Ridge (field use: χ^2 = 26.90, df = 2, p < 0.001; plant species: χ^2 = 24.82, df = 6, P<0.001). Le Conte's Sparrows were found exclusively in hay fields that had not recently been plowed (61% of observations) and pastures with low grazing pressure (39% of observations). Tall warm season grasses, especially switchgrass, and meadow dropseed were the most common plant species within 1 m^2 of the Le Conte's Sparrow sightings. Flyers were found in all field types (field use: χ^2 = 2.50, df = 2, p > 0.05; plant species: χ^2 = 5.00, df = 6, p > 0.05). We found that different species categorized as flyers also used different types of habitat. Horned Larks (n = 7), American Pipits (n = 5), and McCown's Longspurs (n = 1) were found exclusively in agricultural fields, overgrazed pastures, or other disturbed areas. Chestnut-collared Longspurs (n = 5) were found exclusively in hay fields. Finally, Smith's Longspurs (n = 7) were found in heavily grazed pastures and recently plowed hay fields.

Flocking Behavior

Sixty-eight percent of Savannah Sparrow observations were of solitary birds, 27% were of small flocks (2 - 5 individuals), and 5% were of large flocks (n > 5) (mean group size 2.4 ± 0.3, range = 1 - 50). Meadowlarks were solitary in 48% of observations, in small flocks in 23% of observation, and in large flocks in 29% of observations (mean group size 11.9 ± 4.6, range = 1 - 250). Ninety-five percent Sprague's Pipit observations were solitary birds, 1 observation was of 2 birds. Eighty-nine percent of Le Conte's Sparrow observations were of solitary birds, the remaining 3 observations were of two birds. Different species within the group flyers had different flocking tendencies. American Pipits (n = 5, mean groups size 22.6 ± 6.6, range = 13 - 50) and McCown's Longspurs (n = 1, group size 100) were always in large flocks. Horned Larks were in small flocks in 43% of observations and in large flocks in 57% of observations (mean group size 17.7 ± 6.4, range = 2 - 40). Chestnut-collared Longspurs were always in small to moderately sized flocks (avg. group size 4 ± 0.8, range = 2 - 6). Smith's Longspurs were solitary in 86% of observations, 1 observation was of two birds.

Table 2. Mean microhabitat characteristics for the 210 randomly located 1-m^2 quadrats within each plot during the winters of 2009/2010 and 2010/2011 at Wolf Ridge.

Field use	Max veg height (cm)	Plant Species Richness	% Cover	% Grass	% Forb	% BG	% KRB	% LBS	% MDS	% SBG	% TF	% TWSG	% WW
Grazed	45	3.7	92	67	13	17	6	2	12	5	8	3	0
Hay	71	4.9	95	79	5	0	6	22	19	1	1	18	0
Agriculture	9	2.1	69	55	4	0	0	0	1	0	1	0	53
All Plots	45	3.7	89	68	10	11	5	6	12	4	5	6	7

BG = Bermuda grass, KRB = King Ranch bluestem, LBS = proportion little bluestem, MDS = meadow dropseed, SBG = silverbeard grass, TF = tall forb (common broomweed and western ragweed), TWSG = tall warm season grass (big bluestem, Indian grass, switchgrass), WW = winter wheat.

Effect Turbine on Plot Occupancy

Distance to nearest turbine did not predict plot occupancy for Savannah Sparrows, meadowlarks, flyers, or Sprague's Pipet (Table 3). Nevertheless, I did find a significant relationship between distance to nearest turbine and plot occupancy for Le Conte's Sparrow (Hosmer-Lemeshow p = 0.46, odds ratio = 1.003601, 95% CI 1.000168 – 1.005773, p = 0.0002); Le Conte's Sparrows occupancy increased with distance to turbine. Because Savannah Sparrows and Le Conte's Sparrows were not randomly distributed among habitat types at Wolf Ridge, I used ecological niche modeling to identify plots with suitable habitat for these species. Average AUC for the five Savannah Sparrow replicates was 0.444 ± 0.026. This shows that the model was no better than random (AUC = 0.5) in predicting occurrences compared to a random selection of background points. In general, models with AUC values below 0.7 are poor (Araujo and Guisan 2006). Therefore we did not use Maxent to eliminate unsuitable plots for the Savannah Sparrow.

In contrast, the jackknife validation test found that the Maxent model had high predictive performance for excluded plots occupied by Le Conte's Sparrow, 72% at MTP and 100% at FCV1 (p = 0.005, 0.0002, respectively).

Le Conte's Sparrows were most likely to occur in plots with one or more of the following characteristics: tall vegetation, hay fields, and fields in which little bluestem or meadow dropseed was the most common plant species (Fig. 3). Le Conte's Sparrows were least likely to be found in plots with a high portion of Bermuda grass or winter wheat in the randomly sample $1m^2$ qudrat (Fig. 3-5). Using a relaxed threshold for suitable habitat (FCV1), Maxent modeled 127 plots (60%) as suitable habitat for Le Conte's Sparrows. Using a conservative threshold for suitable habitat (MTP), Maxent modeled 86 plots (41%) as suitable habitat for Le Conte's Sparrows. The mean distance to turbine for plots categorized as Le Conte's Sparrow habitat was 321 m ± 19.5 at FCV1 and 338 m ± 25.7 at MTP. The median distance to turbine for plots categorized as Le Conte's Sparrow habitat was 292.5 m at FCV1 and 306 m at MTP (Figures 6a, 6b). The mean distance to turbine for plots where Le Conte's Sparrows were present was 497 m ± 80.2. The median distance to turbine for plots where Le Conte's Sparrows were present was 411 m. The closest presence location to turbine was at 182 m (Table 4).

Table 3. Binary logistic regression results for plot occupancy of grassland birds as a function of distance to nearest turbine in the winters of 2009/2010 and2010/2011 at Wolf ridge.

Species	P-Value (Test that all slopes are zero)	P-Value (Hosmer-Lemeshow)	Odds Ratio (1m increments)	Odds Ratio Lower 95% CI	Odds Ratio Upper 95% CI
SASP	0.739	0.097	1.000228	0.998903	1.001617
ME	0.729	0.728	1.002570	0.998753	1.001665
Flyers	0.929	0.885	1.000099	0.997695	1.002033
SPPI	0.892	0.288	1.000168	0.997433	1.002281
LCSP FCV1	0.001	0.217	1.003246	1.001292	1.005592
LCSP MTP	0.002	0.159	1.003503	1.001211	1.006418

SASP = Savannah Sparrows; ME = Eastern and Western Meadowlarks; SPPI = Sprague's Pipits; LSCP FCV1 = Le Conte's Sparrows within suitable habitat at a fixed cumulative value of 1; LCSP MTP = Le Conte's Sparrows within suitable habitat at minimum training presence.

We repeated the logistic regression analysis for the Le Conte's Sparrow using just those plots that Maxent identified as suitable habitat at two thresholds. With each of these data sets, we found that Le Conte's Sparrows occupancy increased with distance to turbine (Table 3). Two occupied plots were more than 1400 m from the nearest wind turbine (Fig. 6a, 6b), but even with these data points excluded from the analyses, the displacement effect was still significant (results not shown, $p < 0.05$ for each threshold). There was no difference in the probability of presence for plots in which we observed Le Conte's Sparrows compared to those plots that were identified as suitable habitat at MTP ($U = 816$, $n_1 = 19$, $n_2 = 67$, $p = 0.92$). Probability of presence was not correlated with the number of individual Le Conte's Sparrows observed in a plot ($r = -0.16$, $p = 0.49$).

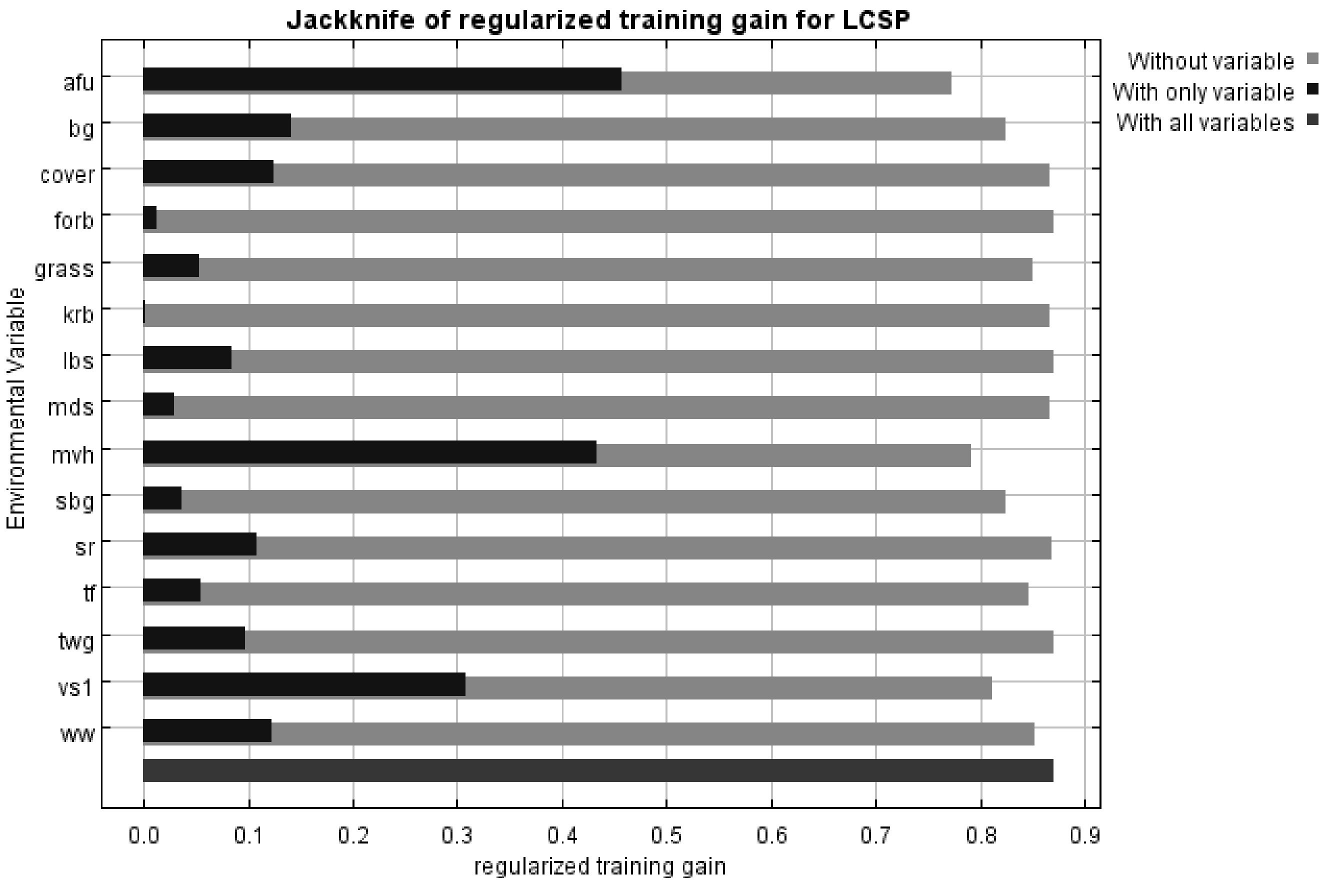


Figure 3. Results of a jackknife test showing the relative importance of 14 environmental variables for the Le Conte's Sparrow Maxent model. "Without variable" is the predictive ability lost by the model with only that variable missing compared to "With all variables". "With only variable" is the amount of predictive ability a model with only that one variable. Environmental variables: field use (afu), most common plant species in plot (vs1), maximum vegetation height in quadrat (mvh), plant species richness in quadrat (vs), % ground cover in quadrat: for Bermuda grass (bg), total ground cover (cover), total forb cover (forb), total grass cover (grass), King Ranch bluestem (krb), little bluestem (lbs), meadow dropseed (mds), silverbeard grass (sbg), tall forbs (tf), tall warm season grasses (twg), and winter wheat (ww).

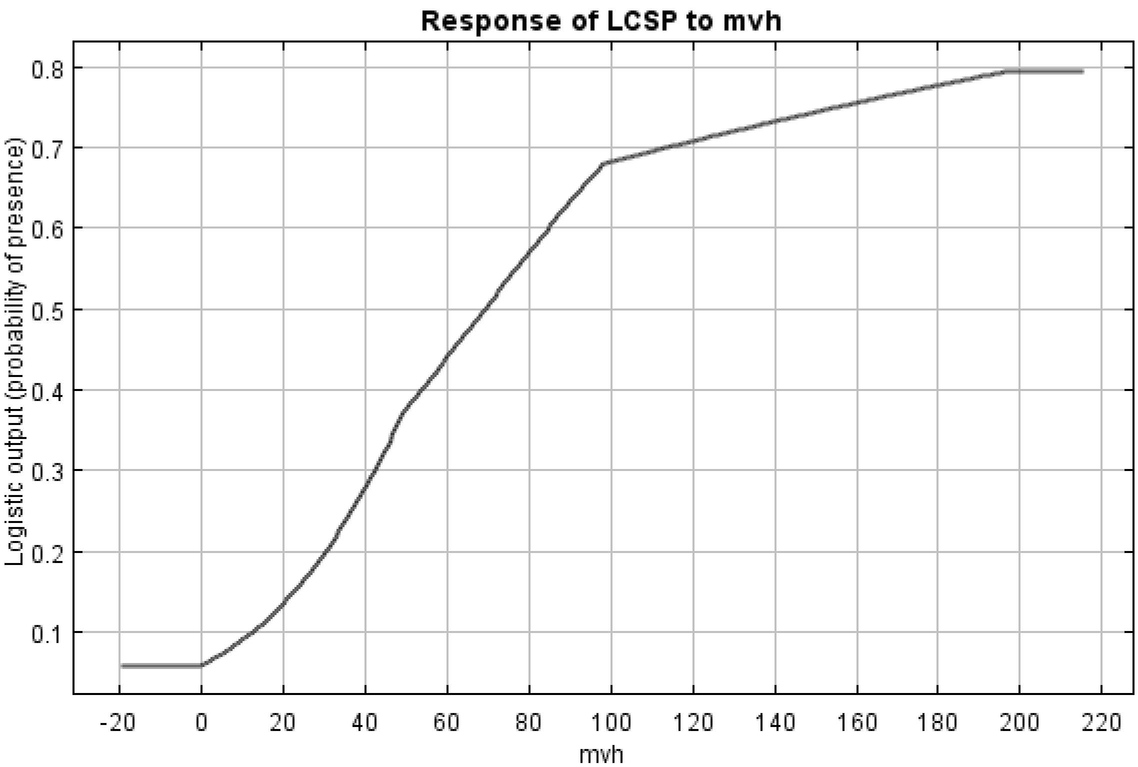
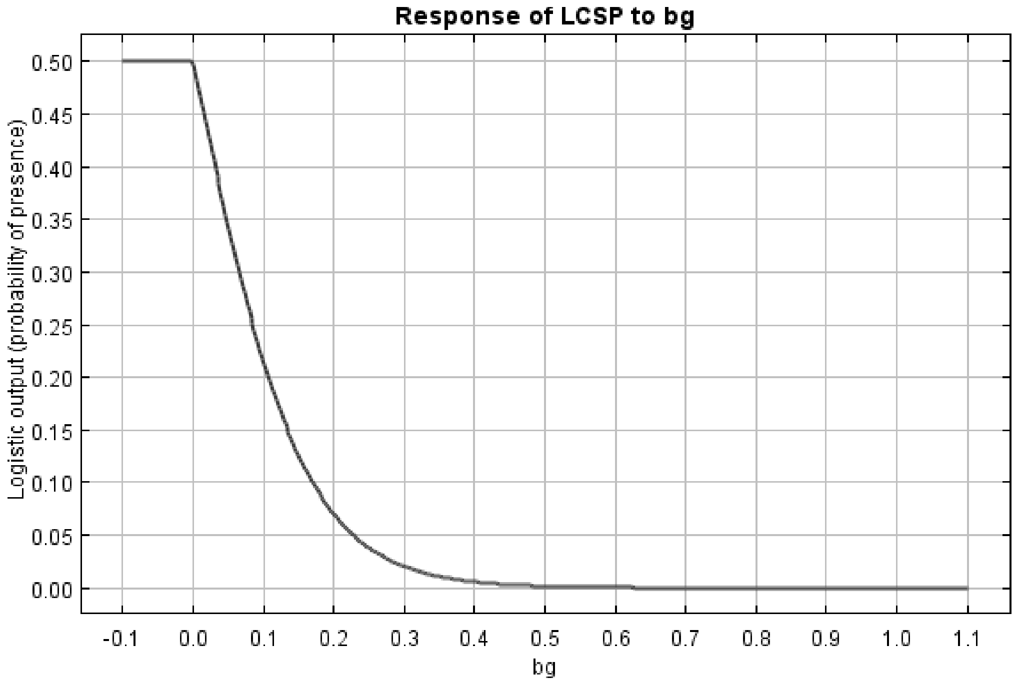
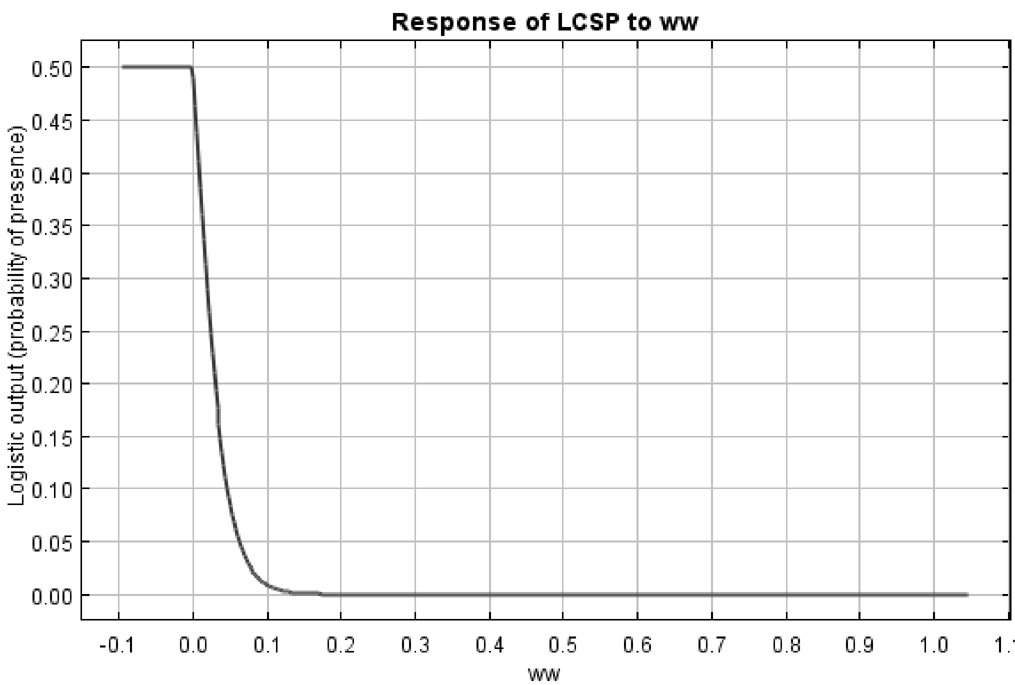


Figure 4. Probability of presence for Le Conte's Sparrow (LCSP) increased with maximum vegetation height (cm) in plots at Wolf Ridge in the winters of 2009/2010 and 2010/2011.

A)

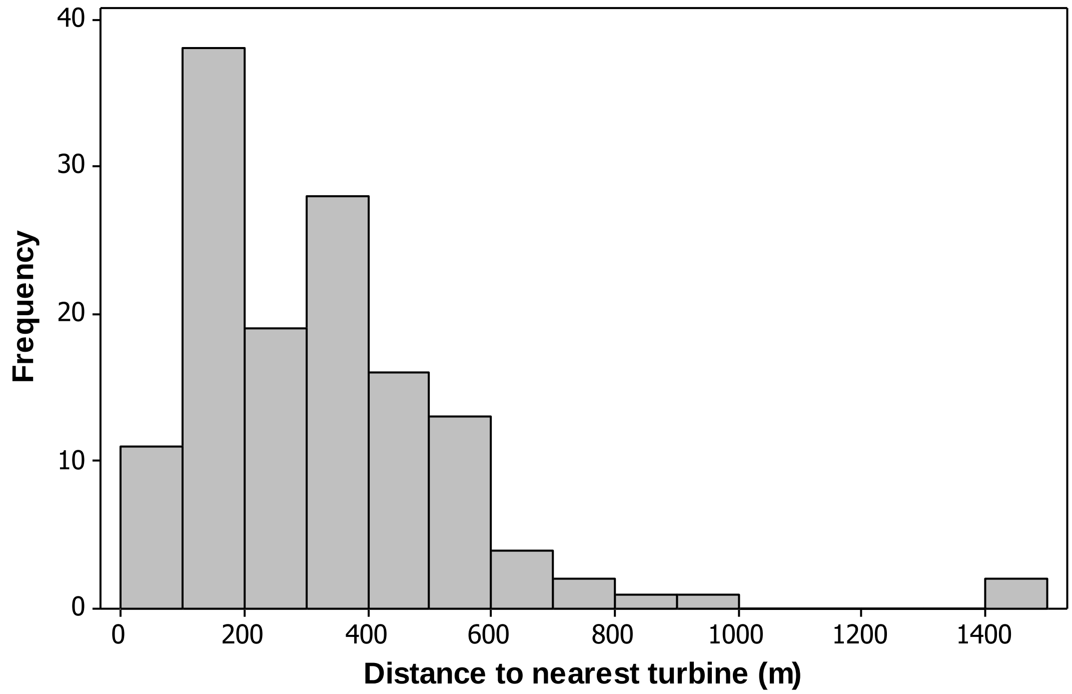


B)



Figures 5. Probability of presence for Le Conte's Sparrow (LCSP) decreased rapidly as the percentage of (**A**) Bermuda grass (bg) or (**B**) winter wheat (ww) in the plots increased in the winters of 2009/2010 and 2010/2011 at Wolf Ridge.

A)



B)

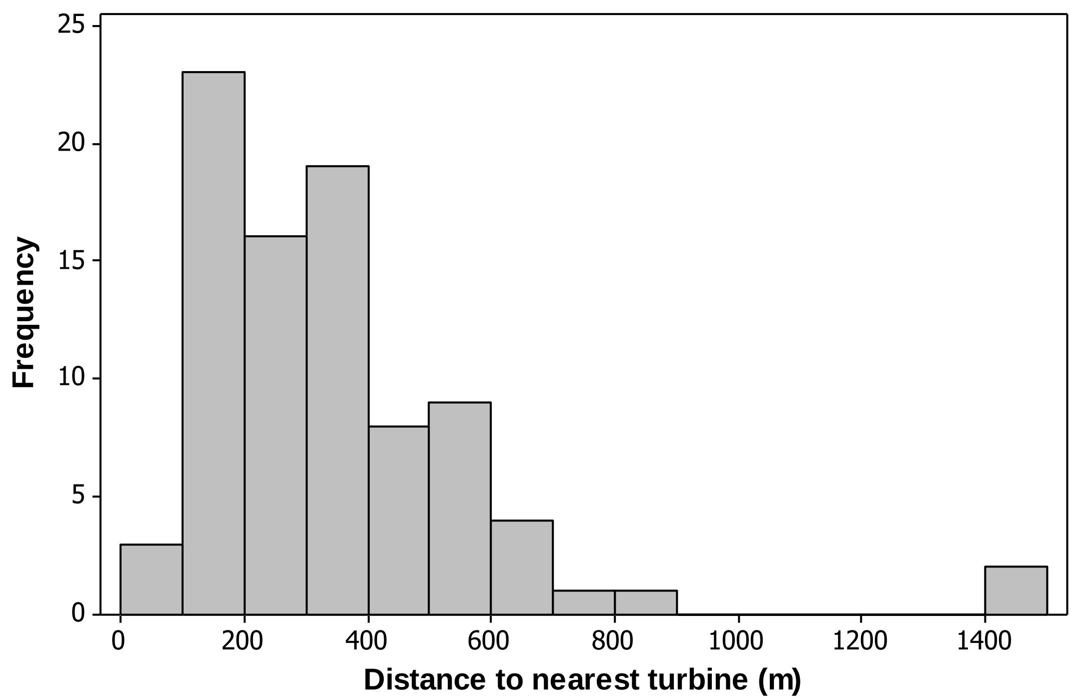


Figure 6. Distribution of distance to nearest turbine for search plots included in the ecological niche modeling for Le Conte's Sparrow at (**A**) FCV1 and (**B**) MTP.

Table 4. Distance to nearest turbine, probability of presence when used in model training, and probability of presence when "left out" of model training for all 19 plots in which we observed Le Conte's Sparrows in the winters of 2009/2010 and 2010/2011 at Wolf Ridge.

Plot Number	Distance to turbine	Training POP	Test POP
33	182	0.233	0.123
190	186	0.647	0.425
214	216	0.630	0.492
186	220	0.198	0.074
44	305	0.697	0.560
77	317	0.440	0.184
184	333	0.552	0.102
141	390	0.519	0.253
20	408	0.442	0.477
15	414	0.518	0.350
166	429	0.677	0.368
98	470	0.749	0.463
3	478	0.676	0.413
71	521	0.260	0.166
37	535	0.708	0.380
161	563	0.786	0.665
187	636	0.526	0.293
135	1413	0.766	0.675
192	1423	0.697	0.541
	$\bar{X}$ 497	$\bar{X}$ 0.565	$\bar{X}$ 0.369

DISCUSSION

Winter Bird Community

The Wolf Ridge winter bird community is diverse; we observed 26 species in a diversity of habitat types within this disturbed grassland. Controlled burns have not been practiced at Wolf Ridge, allowing trees and shrubs to spread into surrounding grasslands, and the high avian diversity is likely due to the high diversity of habitat types. Some species were found in only one habitat type: Chestnut-collared Longspur (hay fields), Le Conte's Sparrow (recently undisturbed fields), and Horned Larks (overgrazed/disturbed fields). A large number of species that made up a small portion of the total individuals and observations were strictly associated with tree and shrubs (e.g. Fox Sparrow, *Passerella iliaca*; Harris's Sparrow, *Zonotrichia querula*; Northern Cardinal, *Cardinalis cardinalis*; Northern Flicker, *Colaptes auratus*; and Northern Mockingbird, *Mimus polyglottos*). The most common birds at Wolf Ridge, Savannah Sparrows and meadowlarks, were found in all habitat types. In contrast, Sprague's Pipits, a globally threatened species (IUCN 2011), was also found in all habitat types although it was not frequently observed. Wolf Ridge had similar overwintering bird diversity to pastures and undisturbed grasslands in southern Oklahoma (26 species; Roberts and Schnell 2006) and Texas costal prairie (25 species; Igl and Ballard 1999). Wolf Ridge had greater overwintering bird diversity than CRP grasslands in west Texas (12 species; Thompson *et al*. 2009).

Winter Bird Behavior

Birds that forage far from cover (e.g. grassland birds) can avoid predators using one of two strategies (Pulliam and Mills 1977, Grzybowski 1983a). Social evasion is adopted in areas with little cover where an increase in numbers can assist in the initial detection of predators, whereas cryptic evasion is adopted most often in areas of thick grass, where a single bird can stay hidden from predators. When occupying open sparse habitat at Wolf Ridge, Savannah Sparrows, meadowlarks, and flyers all exhibited social evasion strategies. All species in the group flyers but one, the Smith's Longspur, were strictly social evaders. Savannah Sparrows and meadowlarks moved between social and cryptic strategies in response to cover availability. Sprague's Pipits were often found alone in extremely sparse habitat (e.g. recently plowed agricultural fields), which contradicts previous expectations and observations of non-breeding grassland bird behavior (Pulliam and Mills 1977, Grzybowski 1983b).

The Le Conte's Sparrow was the only species at Wolf Ridge that strictly adhered to a solitary, cryptic evasion strategy. Like many species that employ cryptic evasion, Le Conte's Sparrows have a low flight initiation distance, as it pays to only fly as a last resort after detection (Pulliam and Mills 1977). Roberts and Schnell (2006) found that the probability of detecting an individual bird 10 m from a transect line remained high for all species at their study site except for Le Conte's Sparrow (*Ammodramus leconteii*), in which the probability of detection or flushing decreased rapidly at distances greater than 4 m. As a result, estimates of Le Conte's Sparrows in this study could be downwardly biased; however, the extent of the bias is not expected to vary with distance to turbine. Le Conte's Sparrows are sedentary on their overwintering grounds and inhabit small home ranges (Baldwin *et al*. 2010). I observed Le Conte's Sparrows running away from searches on the ground rather than flushing from cover. This behavior may have resulted in two Le Conte's Sparrows being recorded as one observation; one individual was pushed by searchers toward another causing them to flush in close proximity to one another.

Ecological Niche Modeling

Although a χ^2 test showed that Savannah Sparrows were not randomly distributed among habitat types at Wolf Ridge, Maxent could not accurately model suitable habitat for this species. Avoidance of plots dominated by winter wheat or Bermuda grass was the strongest contributors to the chi-squared statistic. In plots that were not dominated by winter wheat or Bermuda grass (157 plots, 104 occupied), Maxent could not predict presence locations for Savannah Sparrows. This may have occurred because I did not measure a variable that is important to Savannah Sparrow distribution. Sparrow density has been shown to be significantly correlated with seed density in Texas and Oklahoma grasslands (Grzybowski 1983a). Savannah Sparrows did not appear to be territorial at Wolf Ridge. The largest groups of Savannah Sparrows we observed were loosely organized flocks congregating at stands of large forbs in recently disturbed areas (roadside ditches, grazed drainages, and areas disturbed during turbine construction). Weed seeds are a primary energy source for many wintering sparrows (Smith *et al*. 2005). In contrast, previous studies have associated Le Conte's Sparrows with seed poor habitat (Grzybowski 1983a), which likely contributed to Maxent's ability to successfully predict Le Conte's Sparrow presence and absence locations.

As the probability of presence values generated by Maxent represented a continuous variable, I wanted to ensure that occupied plots were not simply plots with the highest probability of presence, and by chance far away from turbines. Probability of presence (when "left out") for plots occupied by Le Conte's Sparrows was not different from probability of presence at unoccupied suitable plots. This result may have been caused by poor detection in highly suitable plots (Roberts and Schnell 2006) and displacement from highly suitable plots near turbines. I was more likely to successfully detect a Le Conte's Sparrow in a plot containing multiple individuals. Nevertheless, Maxent modeled probability of presence values based on occupancy only. I confirmed that there was no correlation between the number of Le Conte's Sparrows in a plot and probability of presence. Therefore, between any two suitable plots, we were not more likely to detect a Le Conte's Sparrow in the plot with the higher probability of presence. Probability of presence values should not be used to rank habitat quality. Our finding that Le Conte's Sparrows were displaced by turbines is dependent on the assumption that detectability did not change with distance to turbine.

Birds and Wind Turbines

Savannah Sparrows, meadowlarks, flyers, and Sprague's Pipits showed no evidence of displacement by wind turbines at Wolf Ridge. In contrast, Le Conte's Sparrows were displaced from suitable habitat near wind turbines at Wolf Ridge. This is the first study to show displacement of a species in an overwintering bird community. Binary logistic regression showed that the probability of Le Conte's Sparrow occupancy in suitable habitat increased with distance to turbine. At FCV1, for each 100 m in distance from the nearest turbine, the odds of detect a Le Conte's Sparrow increased by 32%. At MTP, for every 100 m in distance from the nearest turbine, the odds of detecting a Le Conte's Sparrow increased by 35%. Logistic regression it is robust to outliers, and we reached the same conclusion regarding displacement with two distant plots (> 1400 m) removed from the analysis.

Why are some birds displaced and not others? Grassland birds may hard-wired to associate tall structures with predation (i.e. raptor perches; Pruett *et al*. 2009). If birds perceive wind turbines as some type of threat or predation risk, social and cryptic species may respond differently to them. The Le Conte's Sparrow was the only species at our study site that exclusively used a cryptic predator evasion strategy. Because social species move in groups and are strong fliers, they can afford to move through area in which they are exposed to predation threats. In contrast, cryptic species like the Le Conte's Sparrow are often weak fliers that travel alone, and therefore would be unlikely to forage or move through high risk areas.

When comparing their results with those of Devereux *et al*. (2008), Pearce-Higgins *et al*. (2009) hypothesized that species occupying remote, semi-natural habitats are more sensitive to wind energy development than species occupying intensive production landscapes. Wolf Ridge WRA provided a microcosm for this hypothesis, as both intensely produced landscapes (agricultural fields producing winter wheat) and semi-natural landscapes (hay fields and lightly grazed fields) were present. Savannah Sparrows, meadowlarks, flyers, and Sprague's Pipits were all adaptable to a variety of altered habitats, including agricultural fields and heavily overgrazed fields. None of these species showed evidence of displacement by turbines. In contrast, the Le Conte's Sparrow was limited to hay fields and lightly grazed fields, and showed evidence for displacement by turbines. Chestnut-collared Longspurs were also limited hay fields at Wolf Ridge; although they were not analyzed individually due to a small sample size (3 plots occupied), we found no Chestnut-collared Longspurs near turbines (distance to nearest turbine = 359, 460, and 519 m, respectively). These results support the hypothesis of Pearce-Higgins *et al*. (2009).

Recommendations

Cryptic predator evasion and dependence on natural or semi-natural landscapes are two possible indicators of susceptibility to displacement by wind turbines for grassland birds. I recommend that future wind energy development be primarily located in heavily produced or altered landscapes. Habitat loss and fragmentation due to displacement by wind turbines could compound already rapid rates of habitat loss for susceptible grassland birds such as *Ammodramus* sparrows (Roth *et al*. 2004). Other species from the genus *Ammodramus* use cryptic strategies to evade predators (Pulliam and Mills 1977, Gordon 2000, Dunning 2001). Baird's Sparrows (*A. bairdii*), Henslow's Sparrows (*A. henslowii*), Nelson's Sharp-tailed Sparrows (*A. nelsoni*), Saltmarsh Sharp-tailed Sparrows (*A. caudacutus*), and Seaside

Sparrows (*A. maritimus*) are all species of conservation concern (Rich *et al*. 2004). The possible displacement of these species by wind turbines should be studied, and if possible in areas of continuous habitat where rope dragging or active flushing strip transects can be used to increase detectability in these cryptic species (Fletcher *et al*. 2000, Twedt *et al*. 2008). Recent, large scale wind energy development on Texas's Gulf Coast overlaps with wintering and breeding ranges for multiple *Ammodramus* species (Sibley 2000, Kuvlesky *et al*. 2007).

This studies results show very different responses to wind turbines within one family, and should caution others to not group species for analysis when it is not necessary. Grouping all species (Leddy *et al*. 1999), or using an ecological group like granivores (Devereux *et al*. 2008) would have given our study a result of non-significance, as higher sample sizes of Savannah Sparrows would have drowned out any effect of turbine on Le Conte's Sparrow distribution. If grouping species is necessary, we recommend grouping birds based on social behavior/predator evasion strategies and habitat use.

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Appendix A

Appendix A. Bird species observed during winter surveys in 210 1-ha plots in 2009/2010 and 2010/2011 at the Wolf Ridge wind farm in north-central Texas.

Common Name	**Scientific Name**	**Individuals**	**Observations**	**Plots occupied**
American Kestral	*Falco sparverius*	1	1	1%
Northern Flicker	*Colaptes auratus*	1	1	1%
Loggerhead Shrike	*Lanius ludovicianus*	4	3	1%
Horned Lark	*Eremophila alpestris*	124	7	2%
Eastern Bluebird	*Sialia sialis*	45	2	1%
Northern Mockingbird	*Mimus gundlachii*	2	2	1%
Sprague's Pipit	*Anthus spragueii*	20	19	8%
American Pipit	*Anthus rubescens*	133	5	2%
Northern Cardinal	*Cardinalis cardinalis*	6	4	1%
Field Sparrow	*Spizella pusilla*	8	1	1%
Le Conte's Sparrow	*Ammodramus leconteii*	31	28	9%
Savannah Sparrow	*Passerculus sandwichensis*	750	314	59%

Vesper's Sparrow	*Pooecetes gramineus*	8	4	1%
Harris's Sparrow	*Zonotrichia querula*	6	3	1%
White-crowned Sparrow	*Zonotrichia leucophrys*	18	6	12%
Fox Sparrow	*Passerella iliaca*	1	1	1%
Lincoln's Sparrow	*Melospiza lincolnii*	1	1	1%
Dark-eyed Junco	*Junco hyemalis*	3	1	1%
McCown's Longspur	*Calcarius mccownii*	100	1	1%
Chestnut-collared Longspur	*Calcarius ornatus*	19	5	1%
Smith's Longspur	*Calcarius pictus*	8	7	3%
Meadowlark	*Sturnella*	763	64	27%
Brown-headed Cowbird	*Molothrus ater*	7	1	1%
Red-winged Blackbird	*Agelaius phoeniceus*	38	1	1%
House Finch	*Carpodacus mexicanus*	1	1	1%
American Goldfinch	*Carduelis tristis*	20	1	1%

REFERENCES

Arey, S. D., E. Erfling, R. K. Jones, and T. A. Rosingol. 1998. A team approach to coastal prairie conservation. Endangered Species Bulletin **23**:12-13.

Araujo, M. D. and A. Guisan. 2006 Five (or so) challenges for species distribution modeling. Journal of Biogeography **33**:1677-1688.

Askins, R. A., F. Chavez-Ramirez, B. C. Dale, C. A. Haas, J. R. Herkert, F. L. Knope, and P. D. Vickery. 2007. Conservation of grassland birds in North America: understanding ecological processes in different regions. Ornithological Monographs **64**:1-46.

Baldwin, H. Q., J. B. Grace, W. C. Barrow Jr., and F. C. Rohwer. 2007. Habitat relationships of birds overwintering in a managed coastal prairie. Wilson Journal of Ornithology **199**:189-197.

Baldwin, H. Q., C. W. Jeske, M. A. Powell, P. C. Chadwick, and W. C. Barrow Jr. 2010.Home-range size and site tenacity of overwintering Le Conte's Sparrows in a firemanaged prairie. Wilson Journal of Ornithology **122**:139-145.

Barrios, L. and A. Rodriguez. 2004. Behavioural and environmental correlates of soaring-bird mortality at on-shore wind turbines. Journal of Applied Ecology **41**:72-81.

Basili, G. D. and S. A. Temple. 1999. Dickcissels and crop damage in Venezuela: defining the problem with ecological models. Ecological Applications **9**:732-739.

Brooks, B. L. and S. A. Temple. 1990. Dynamics of a Loggerhead Shrike population inMinnesota. Wilson Bulletin **102**:441-450.

Brennan, L. A. and W. P. Kuvlesky. 2005. North American grassland birds: an unfolding conservation crisis? Journal of Wildlife Management **69**:1-13.

Butler, A. B., J. A. Martin, W. E. Palmer, and J. P. Carroll. Winter use of south Florida dry prairie by two declining grassland passerines. Condor **111**:511-522.

Conover, R. R., L. W. Burger, and E. T. Linder. Winter avian community and sparrowResponse to field border width. Journal of Wildlife Management **71**:1917-1923.

De Lucas, M., G. F. E. Janss, and M. Ferrer. 2004. The effects of a wind farm on birds in a migration point: the Strait of Gibraltar. Biodiversity and Conservation **13**:395-407.

Devereux, C. L., M. J. H. Denny, and M. J. Whittingham. 2008. Minimal effects of wind turbines on the distribution of wintering farmland birds. Journal of Applied Ecology **45**:1689-1694.

Diamond, D. D. and F. E. Smeins. 1984. Remnant grassland vegetation and ecological affinities of the upper coastal prairie of Texas. Southwestern Naturalist **29**:321-334.

Drewitt, A. L. and R. H. W. Langston. 2006. Assessing the impacts of wind farms on birds. Ibis **148**:29-42.

Dunning, J. 2001. New World Sparrows. In C. Elphick, J. Dunning, D. Sibley, editors. The Sibley Guide to Bird Life and Behavior. Alfred A. Knopf, New York.

Elith, J., C. H. Graham, R. P. Anderson, M. Dudík, S. Ferrier, A. Guisan, R. J. Hijmans, F. Huettmann, J. R. Leathwick, A. Lehmann, J. Li, L. G. Lohmann, B. A. Loiselle, G. Manion, C. Moritz, M. Nakamura, Y. Nakazawa, J. M. Overton, A. T. Peterson, S. J. Phillips, K. Richardson, R. Scachetti-Pereira, R. E. Schapire, J. Soberón, S. Williams, M. S. Wisz, and N. E. Zimmermann. 2006. Novel methods improve prediction of species' distributions from occurrence data. Ecography **29**:129-151.

Fletcher, R. J., J. A. Dhundale, and T. F. Dean. 2000. Estimating non-breeding season bird abundance in prairies: A comparison of two survey techniques. Journal of Field Ornithology **71**:321-329.

Fretwell, S. 1980. Evolution of migration in relation to factors regulating bird numbers.In A. Keast and E. S. Morton, editors. Migrant Birds in the Neotropics: Ecology, Behavior, Distribution, and Conservation. Smithsonian Institution Press,Washington, DC.

Gordon, C. E. 2000. Movement patterns of wintering grassland sparrows in Arizona. Auk **117**:748-759.

Griffith, G.E., S.B. Bryce, J.M. Omernik, and A. Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality. Austin, Texas.

Gromley, A. M., D. M. Forsyth, P. Griffioen, M. Lindeman, D. S. L. Ramsey, M. P.Scroggie, and L. Woodford. Using presence-only and presence-absence datato estimate the current and potential distributions of established invasive species. Journal of Applied Ecology **48**:25-34.

Grzybowski, J. A. 1982. Population structure in grassland bird communities during winter. Condor **84**:137-152.

Grzybowski, J. A. 1983a. Sociality of grassland birds during winter. Behavioral Ecology and Sociobiology **13**:211-219.

Grzybowksi, J. A. 1983b. Patterns of space use in grassland bird communities duringwinter. Wilson Bulletin **95**:591-602.

Hernandez, P. A., C. H. Graham, L. L. Master, and D. L. Albert. 2006. The effect of sample size and species characteristics on performance of different species distribution modeling methods. Ecography **29**: 773-785.

Hu, J. and Z. Jiang. 2010. Predicting the potentional distribution of the endangered Przewalski's gazelle. Journal of Zoology **282**:54-63.

Igl, L. D. and B. M. Ballard. 1999. Habitat associations of migrating and overwintering grassland birds in southern Texas. Condor **101**:771-782.

BirdLife International 2008. *Anthus spragueii*. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. www.iucnredlist.org. Downloaded on 31 October 2011.

Knight, D. H. 1994. Methods for Sampling Vegetation: An Instruction Manual for Botany 4700. University of Wyoming, Laramie.

Knopf, F. L. 1994. Avian assemblages on altered grasslands. Studies in Avian Biology**15**:247-257.

Knopf, F. L. and F. B. Samson, editors. 1997. Ecology and Conservation of Great Plains Vertebrates. Springer, New York.

Klob, H. 1965. The Audubon winter bird-population study. Audubon Field Notes **19**:432-434.

Kuvlesky, W. P., L. A. Brennan, M. L. Morrison, K. K. Boydston, B. M. Ballard, and F. C. Bryant. 2007. Wind energy development and wildlife conservation: Challenges and opportunities. Journal of Wildlife Management **71**:2487-2498.

Lahoz-Monfort, J. J., G. Guillera-Arroita, E. J. Milner-Gulland, R. P. Young, and E. Nicholson. 2010. Satellite imagery as a single source of predictor variables for habitat suitability modeling: how Landsat can inform the conservation of a critically endangered lemur. Journal of Applied Ecology **47**:1094-1102.

Leddy, K. L., K. F. Higgins, and D. E. Naugle. 1999. Effects of wind turbines on upland nesting birds in conservation reserve program grasslands. Wilson Bulletin **111**:100-104.

Macias-Duarte, A., A. B. Montoya, C. E. Mendez-Gonzalez, J. R. Rodriguez-Salazar, W. G. Hunt, and P. G. Krannitz. 2009. Factors influencing habitat use by migratory grassland birds in the state of Chihuahua, Mexico. Auk **126**:896-905.

Marra, P. P., K. A. Hobson, and R. T. Holmes. 1998. Linking winter and summer events in a migratory bird using stable carbon isotopes. Science **282**:1884-1886.

Pearce-Higgins, J. W., L. Stephen, R. H. W. Langston, I. P. Bainbridge, and R. Bullman. 2009. The distribution of breeding birds around upland wind farms. Journal of Applied Ecology **46**:1323-1331.

Pearson, R. G., C. J. Raxworthy, M. Nakamura, and A. T. Peterson. 2007. Predicting species distributions from small numbers of occurrence records: a test case using cryptic geckos in Madagascar. Journal of Biogeography **34**:102-117.

Peterjohn, B. G. and J. R. Sauer. 1999. Population status of North American grassland birds from the North American breeding bird survey, 1966-1996. Studies in Avian Biology **19**:27-44.

Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modeling **190**:231-259.

Pruett, C. L., M. A. Patten, and D. H. Wolfe. 2009. Avoidance behavior by prairie grouse: implications for development of wind energy. Conservation Biology **23**:1253-1259.

Pulliam, H. R. and G. S. Mills. The use of space by wintering sparrows. Ecology **58**:1393-1399.

Rappole, J. H., D. I. King, and J. Diez. 2003. Winter- vs. breeding-habitat limitation foran endangered avian migrant. Ecological Applications **13**:735-742.

Rebelo, H., G. Jones. 2010. Ground validation of presence-only modeling with rare species: a case study on barbastelles *Barbastella barbastellus* (Chiroptera: Vespertilionidae). Journal of Applied Ecology **47**:410-420.

Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D. W. Demarest, E. H. Dunn, W. C. Hunter, E. E. Iñigo-Elias, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J. S. Wendt, and T. C. Will. 2004. Partners in Flight North American Landbird Conservation Plan. Cornell Lab of Ornithology. Ithaca, NY.

Robbins, C. S. 1981. Reappraisal of the winter bird-population study technique. Studies in Avian Biology **6**:52-57.

Roberts, J. P. and G. D. Schnell. 2006. Comparison of survey methods for wintering grassland birds. Journal of Field Ornithology **77**:46-60.

Sibley, D. A. 2000. The Sibley Guide to Birds. Alfred A. Knopf, New York.

Smith, M. D., P. J. Barbour, L. W. Burger Jr., and S. J. Dinsmore. 2005. Density and diversity of overwintering birds in managed field borders in Mississippi. WilsonBulletin **117**:258-269.

Thompson, T. R., C. W. Boal, and D. Lucia. 2009. Grassland bird associations in introduced and native grass conservation reserve program fields in the southernhigh plains. Western North American Naturalist **69**:481-490.

Twedt, D. J., P. B. Hamel, and M. S. Wodrey. 2008. Winter bird population studies and project prairie birds for surveying grassland birds. Southeastern Naturalist **7**:11-18.

Vickery, P. D. and J. R. Herkert. 2001. Recent advances in grassland bird research: where do we go from here? Auk **118**:11-15.

Wise, M. S., R. J. Hijmans, J. Li, A. T. Peterson, C. H. Graham, A. Guisan, and NCEAS Predicting Species Distributions Working Group. 2008. Effects of sample size on the performance of species distribution models. Diversity and Distributions **14**:763-773.

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ABSTRACT

THE EFFECTS OF WIND ENERGY ON OVERWINTERING GRASSLAND BIRDS

by Thomas King Stevens, M.S. 2011
Department of Geology, Energy, and the Environment
Texas Christian University

Thesis Advisor: Amanda M. Hale, Assistant Professor of Biology

Wind energy represents a potential threat to grassland birds. We used an area search methodology to survey winter grassland birds Wolf Ridge Wind, LLC. To investigate the displacement of birds by wind turbines, I used logistic regression to test for patterns in plot occupancy. Plot occupancy for Savannah Sparrows, meadowlarks, Sprague's Pipits, and 'flyers' (longspurs, Horned Larks, and American Pipits) did not change with distance to turbine. As distance to turbine increased, plot occupancy for the Le Conte's Sparrow increased. To ensure that variation in suitable habitat across distance to turbine did not bias logistic regression results, I used an ecological niche modeling method that determined which plots were suitable Le Conte's Sparrow habitat. Logistic regression using only suitable plots for Le Conte's Sparrows confirmed that plot occupancy increased with distance to turbine. Predator evasion strategy and tolerance for disturbance may be two indicators for susceptibility to displacement by turbines.