HABITAT CHARATERISTICS THAT INFLUENCE SCISSOR-TAILED FLYCATCHER NEST SUCCESS AT A UTILITY-SCALE WIND FARM IN NORTH-CENTRAL TEXAS

by

TREVOR GEORGE RUBENSTAHL

Bachelor of Science, 2008
University of Texas at Austin
Austin, Texas

Submitted to the Graduate Faculty of the
College of Science and Engineering
Texas Christian University
in partial fulfillment of the requirements for the degree of

Master of Science

May 2010

ACKNOWLEDGEMENTS

Thanks to everyone who helped me write this dang thing. A special thanks to my major professor, Dr. Amanda Hale; Dr. Kris Karsten, who introduced me to the wonderful world of univariate and multivariate Mayfield logistic regression analysis; and to the rest of my committee, Dr. Mike Slattery and Dr. Dean Williams. I'd also like to thank the members of the field crew: Ryan Perry, Angela Medina, Jennifer Bull, Meredith Jantzen, Will Martin, Shannon Lee, Bryan Suson, Alysa Lapine, Jennifer Ellis and Tom Stevens who assisted me in the field ---those birds don't monitor themselves. Thanks to Stephanie Eady, and Kim Ozenick for editing help and to Jerry Bags, and Roy Purcell, the owners of the control sites. Thanks also to NextEra Energy for funding and permission to work on their property and to Tom Trowbridge and Chris Page of Wolf Ridge Wind, LLC. Additional funding and support was provided by the Institute for Environmental Science and the Biology Department at Texas Christian University. And last but not least, thanks to my family and friends for giving me much needed moral support.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Habitat loss, fragmentation, and deterioration of native grasslands are directly implicated in the decline in grassland birds of North America (Brennan and Kuvlesky 2005, Faaborg 2002, Peterjohn and Sauer 1999, Samson and Knopf 1994). This deterioration of pristine habitat decreases grassland bird populations by increasing the chances of nest failure due to snake and mammal predation (Klug et al. 2010, Winter et al. 2000), or Brown-headed Cowbird (*Molothrus ater*) brood parasitism (Rahmig et al. 2009). Native grassland has been replaced and fragmented by farms, ranches, and expanding urban areas for quite some time; however, the increasing numbers of utility-scale wind farms that are being constructed across the Great Plains are contributing to this habitat loss and fragmentation. Wind facility development has more than doubled in the last five years (Tollefson 2008). For example, Texas had an installed wind capacity of 1,290 MW in 2004, but now has 9,410 MW as of May 2009 (American Wind Energy Association 2009). The first wind facilities in Texas were built in areas with the highest average wind speeds, but new wind facilities are being built further east and north utilizing newer technologies to exploit the lower, but economically viable, average wind speeds in north-central Texas (Combs 2008). Not only does this development potentially decrease the amount of habitat available for already declining grassland species, but these areas also coincide with a major migratory pathway, the Central Flyway (Brown et al. 2001). Thus, wind turbine operations represent a potential new source of pressure on bird populations.

Habitat loss associated with wind facilities is less than what occurs in other energy extraction industries such as oil and gas drilling and coal mining (Kuvlesky et al. 2007). The typical modern wind turbine has a footprint (land impacted directly) between 0.08 ha and 0.20 ha and collectively, the footprint from wind turbines comprises only 2-5% of the total impact of the wind facility (Fox et al. 2006). In addition to the wind turbines themselves, new transmission lines, roads, and buildings contribute to habitat loss and fragmentation. The additional roads are of greatest concern because they further fragment habitat and create a network of disturbed areas which facilitates colonization by invasive plant species which can then outcompete native vegetation (Gelbard and Belnap 2003, Rentch et al. 2005). Most wind-wildlife studies to date have focused on quantifying direct mortality of birds that have collided with the towers, rotating blades, or other infrastructure associated with wind farms (e.g., Johnson et al. 2002, Erickson et al. 2005, Drewitt and Langston 2006, de Lucas et al. 2008). Recent research efforts have also been focused on the indirect impacts of wind turbines on wildlife (e.g., loss of habitat, displacement, and behavioral changes in response to wind turbines (Drewitt and Langston 2006, Kuvlesky et al. 2007).

Displacement can magnify the amount of lost habitat if birds avoid areas near wind turbines or facilities that are otherwise located in suitable breeding or foraging habitat. Displacement can occur due to visual, auditory, or vibration impacts from the wind turbines themselves or from vehicle or personnel movements related to wind facility maintenance (Drewitt and Langston 2006). For example, Leddy et al. (1999) found that densities of grassland passerines within 180 m of wind turbines were less than densities surveyed in comparable habitat that lacked turbines. A recent study of the Lesser Prairie Chicken (*Tympanuchus pallidicinctus*) and Greater Prairie-Chicken (*T. cupido*) found that both species avoided powerlines and that the Lesser Prairie-Chicken avoided one highway located within otherwise suitable habitat (Pruett et al. 2009b). How these wind turbines might indirectly affect other grassland species is unknown.

Wind turbines can also displace birds during migration (e.g., Desholm and Kahlert 2005). Radar tracking of migratory European birds (Christensen et al. 2004, Kahlert et al. 2004) has revealed that migrants adjust their course to avoid off shore wind facilities. Most migrants can avoid one wind facility easily, but multiple wind facilities on the migration path could cause an increase in failed migrations (Masden et al. 2009). It is also possible that migrants could attempt to use off-shore turbines as a rest stop which would increase the chances of rotor collision (Desholm and Kahlert 2005).

The purpose of my study was to investigate the indirect effects of wind turbines on a charismatic and abundant grassland bird, the Scissor-tailed Flycatcher (*Tyrannus forficatus*), at Wolf Ridge Wind, LLC in north-central Texas. Specifically, I asked the following questions: 1) Does the presence of wind turbines influence nest placement by Scissor-tailed Flycatchers? 2) Does proximity to wind turbines affect the probability of nest survival in Scissor-tailed Flycatchers? 3) Does the presence of wind turbines affect the patterns of incubation in nesting Scissor-tailed Flycatchers?

METHODS

Study Sites and Species

The Scissor-tailed Flycatcher is a Tyrannid flycatcher that over-winters in Central America and migrates north to breed, mostly in Texas and Oklahoma (Regosin 1998). During the breeding season, density ranges from 1.6 to 3.3 breeding pairs/10 ha and male territories are roughly 0.2-0.4 ha (Fitch 1950, Regosin and Pruett-Jones 1995). Scissor-tailed Flycatchers construct their nests 1.5 to 12.2 m above the ground in isolated trees or along the edges of woodland patches (Nolte and Fulbright 1996). The Scissor-tailed Flycatcher population has not shown any signs of decline and is listed as a species of Least Concern by the IUCN (2009).

I conducted my study at Wolf Ridge Wind, LLC, located north of Muenster, Texas in Cooke and Montague Counties, ca. 20 km south of the Texas-Oklahoma border (Fig. 1). This wind facility, owned and operated by NextEra Energy, began operations in October 2008 and is the most easterly located wind facility in Texas. Wolf Ridge Wind was built in the Crosstimbers ecoregion of north-central Texas (Engle et al. 2006), and this area consists of some woodlands and many open grass fields used primarily for cattle grazing and farming. This patchwork habitat provides suitable breeding areas for the Scissor-tailed Flycatcher, which prefers to nest in savannah-like habitat as well as in agricultural fields and pastures (Regosin 1998). These types of habitat provide plenty of perching spots overlooking open grassy areas which are used for foraging on flying insects (Regosin 1998). The control sites consisted of two privately owned ranches located 16 km and 29 km south of Wolf Ridge. The control sites were also comprised of Crosstimbers woodlands with open fields used for cattle and sheep grazing.

The most common tree at my study sites was hackberry (*Celtis occidentalis*), but Ashe juniper (*Juniperus ashei*) and mesquite (*Prosopis glandulosa*) were also abundant. The agricultural fields were either lying fallow or contained winter wheat. Little bluestem (*Schizachyrium scoparium*) and Indian grass (*Sorghastrum nutans*) were common in the hay fields and some livestock grazing pastures.

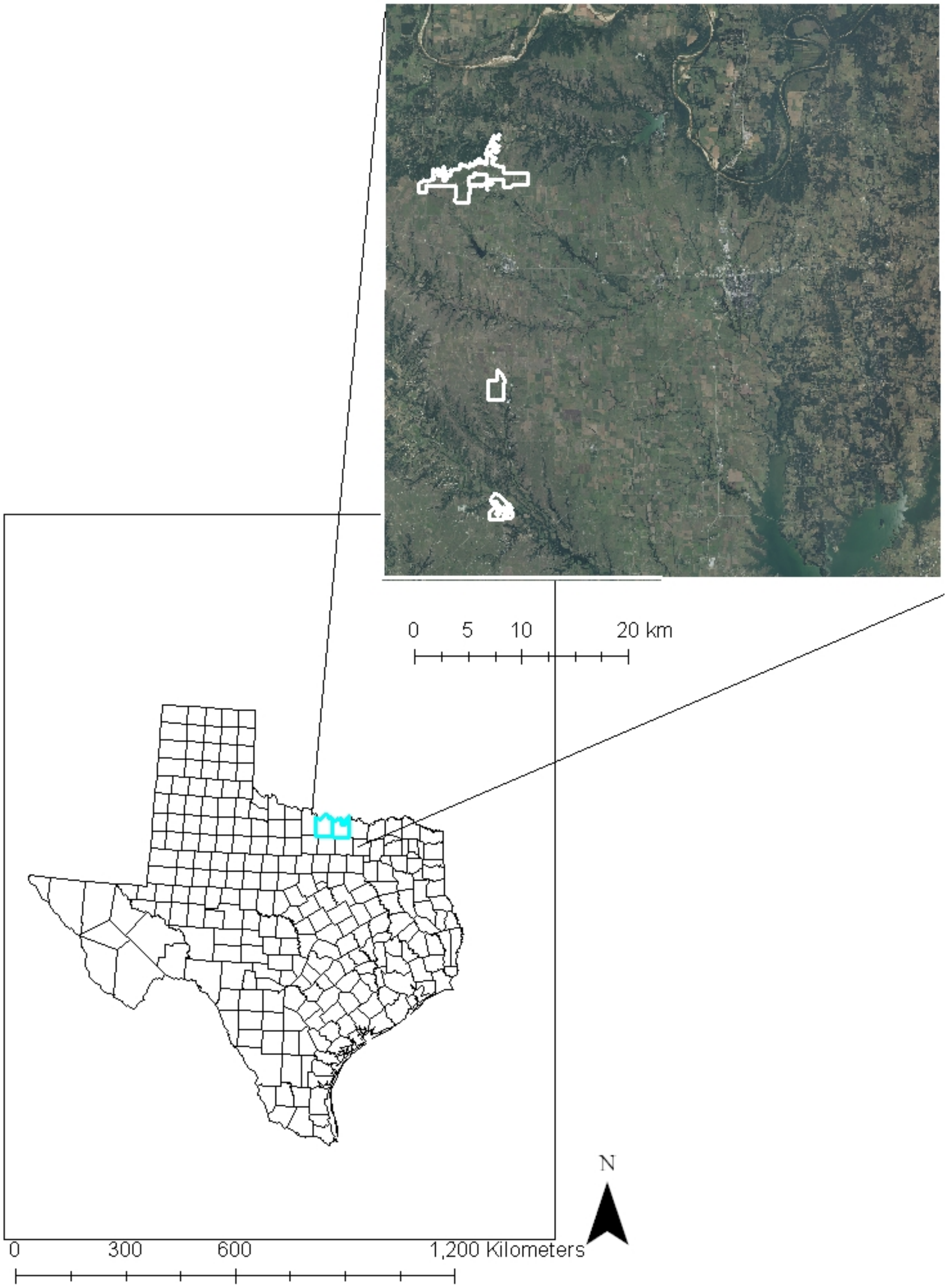

Figure 1. Wolf Ridge Wind and the control sites were located in Montague and Cooke Counties in north-central Texas. The study sites are outlined in white and Wolf Ridge Wind is the most northern site.

Nest Search Strategy

I observed Scissor-tailed Flycatcher nesting biology from 25 May - 2 August 2009 (Fig. 2). At Wolf Ridge, I searched for nests within 1,592 ha of open fields intersected by 46.7 km of fence lines. At the control sites, I searched 605 ha of open fields intersected by 33.8 km of fence lines. I began nest searches at sunrise, checking trees for nests and finding individuals or pairs of Scissor-tailed Flycatchers. Once I located a Scissor-tailed Flycatcher, I recorded evidence of breeding behavior and followed the bird to its nest. Although Scissor-tailed Flycatchers are most active in nest building, territory defense, and foraging during the morning hours (Regosin and Pruett-Jones 1995), afternoon nest searches were still productive. I was alerted to the presence of breeding pairs because close approach to an active nest tree often elicited an alarm call from the breeding Scissor-tailed Flycatchers.

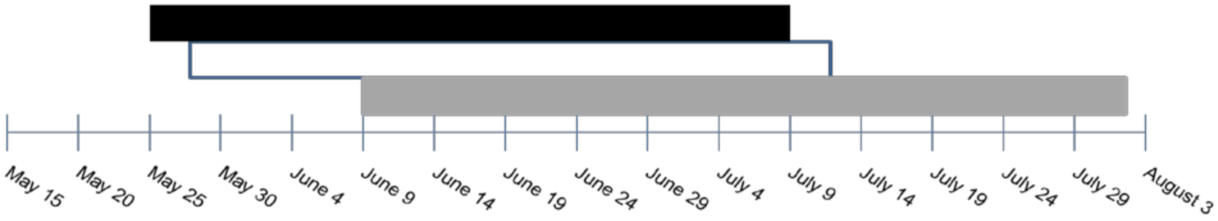

Figure 2. Nesting timeline (nests construction - black bar; incubation - white bar; feeding nestlings - gray bar) for Scissor-tailed Flycatchers at Wolf Ridge Wind and the control sites in north-central Texas in 2009.

Although my focus was on locating and monitoring Scissor-tailed Flycatcher nests, I also monitored nests of all other species opportunistically discovered. Because the searched area at

Wolf Ridge was approximately two times the searched area of the control sites, I searched for new nests at Wolf Ridge for two days for every one day of searching at the control sites.

Once I found a nest, I recorded its location using a Trimble® GeoXH™ handheld GPS unit. I also recorded the nesting stage (under construction, egg laying, incubation, or nestling) and any observed parent activity. I used an extendable pole with an attached mirror to look into nests constructed above head height. I was able to use the mirrored pole to survey the nest contents of every nest found with the exception of just two nests. One of these exceptions was a nest more than 13 m high in a tree and the other was built directly adjacent to high-powered electrical lines. I revisited each monitored nest at least every 3 days to record the nest status until nest failure or fledging.

Estimating Nest Success

I calculated the daily survival rate (DSR) of nests using the Mayfield method (Mayfield 1975). Because not every nest was observed from initiation of nest construction to fledgling, the observed mortality rate will be lower than the true mortality rate. To reduce this underestimation, the Mayfield method uses nest-days to calculate daily mortality and survival rates. For example, if over an observation period of 3 days I found 5 nests, this would result in 15 nest days. If 3 out of 5 nests failed, the mortality rate would be calculated by dividing the total number of losses (3) by nest days (15), resulting in a daily mortality rate of 0.2/day. Daily survival rate is the reciprocal proportion of daily mortality rate, or 0.8/day in this example.

Habitat Characteristics

I collected data on habitat characteristics associated with Scissor-tailed Flycatcher nests at Wolf Ridge and the control sites. I recorded nest height, nest distance from trunk, nest tree height, diameter of the nest tree at breast height (DBH), and percentage of canopy coverage after the nest had failed or the nestlings had fledged the nest. Nest height was measured from the ground to the bottom of the nest to the nearest 0.1 m. Distance from trunk was the distance from the trunk to the nearest edge of the nest to the nearest 0.1 m. Nest tree height was the height of the tree in which the nest was built to the nearest 0.1 m. Diameter at breast height (DBH) measured the diameter of the nest tree 142 cm from the ground to the nearest 0.1 m. I measured canopy coverage (the percent of the sky obscured by foliage) using a sighting tube from underneath the nest. I also determined the number of woody plants, percentage ground cover, and canopy tree height within a circular 0.05 ha plot centered on the nest tree using methods described by James (1992). Inside the plot, I counted the number of woody plants (other than the nest tree) over 30 cm tall and recorded the species and height of the tallest tree in the plot, hereafter referred to as the "canopy tree." I recorded the percentage of vegetation ground cover using a randomly placed 0.5 × 0.5 m quadrat (Bibby et al. 2000).

Incubation Behavior

To quantify incubation behavior, I placed temperature data loggers in two nests at Wolf Ridge and two nests at the control sites to record the timing and duration of incubation bouts. I used HOBO® U23-004 data loggers (Onset Computer Corp., Pocasset, MA) with an external probe (1.8 m). The probe was passed through the nest wall and placed so that it was horizontal at the bottom of the nest cup and partly embedded in the nest lining (Weidinger 2006). These data loggers recorded the temperature inside and outside the nest every minute for 6 days starting at 0000 h on 18 June 2009 and ending at 0000 h on 24 June 2009. Excluding the overnight period (2100-0430 h), I divided the remaining 16.5 hour day into 4 parts: early morning (0430 - 0859 h), late-morning (0900 - 1259 h), early afternoon (1300 - 1659 h), and evening (1700 - 2059 h). When a bird was incubating the eggs, the temperature inside the nest was higher than the ambient temperature. A sudden drop in temperature inside the nest indicated when the bird left the nest (Weidinger 2006). I compared the number and length of these off-bouts (parent off the nest) in two nests at the control sites to two nests at Wolf Ridge. I marked the beginning of an off-bout when there was a marked drop of at least 1°C in temperature inside the nest and marked the end of the off-bout when the inside temperature rebounded. All nests were actively attended by the breeding pair and contained eggs until 24 June.

Statistical Methods

To determine if there was a relationship between distance to turbine and nest fate (success or failure), I used a univariate Mayfield logistic regression (Hazler 2004) testing for significance at the $p = 0.05$ level. Additionally, I was interested in identifying those habitat variable(s) that could best explain the pattern of nest success and failure. For these analyses, I used an information-theoretic approach (Burnham and Anderson 2002). This approach uses a multivariate Mayfield logistic regression (Hazler 2004) in which a series of models were constructed from different combinations of habitat variables. Rather than testing against an alpha level, this information-theoretic approach tests multiple alternative hypotheses simultaneously, where each model is an alternative hypothesis (Hazler 2004, Burnham and Anderson 2002), to give each model/hypothesis a relative measure of support in explaining nest success/failure. Model support is measured using the Akaike Information Criterion (AIC) , which is an information-theoretic derivative of the log-likelihood function that provides the best measure of model fit in the case of observational data (Burnham and Anderson 2002, Burnham and Anderson 2004). The model with the lowest AIC is the model best supported by the observational data. I also calculated the number of parameters (K), the difference between that model and the best fit model (ΔAIC), and the model's Akaike weight (ω). The Akaike weight (ω) indicates the relative strength of each model in explaining the overall relationship between the habitat variable(s) and nest failure and the ΔAIC was used to directly compare and rank the models by fit. Models with the lowest AIC are the more informative hypotheses. The relative Akaike weight ($\omega_{+}(i)$) provides the relative strength of each individual variable in the overall explanation of patterns of nest failure. These analyses were done using the software SAS, version 9.1 (SAS Institute, Inc., Cary, North Carolina, USA).

All other statistical analyses were implemented in Minitab version 15.1.0.0. I used parametric tests when the data met the assumptions of normality and equal variance. When the data did not meet the assumptions of the parametric tests, I first transformed the data and if that failed to meet parametric assumptions, I then used non-parametric alternatives. Unless otherwise noted, all means are presented with ± 1 standard error. Spatial analyses were done with ArcMap Version 9.3.1.

RESULTS

Patterns of Nest Success

On 26 May 2009 I found the first Scissor-tailed Flycatcher nest, which was under construction. I found the first eggs on 29 May 2009. The last active nest under observation was predated on 2 August 2009. All successful nests were first observed between 26 May 2009 and 8 June 2009.

In total, I found 32 Scissor-tailed Flycatcher nests at Wolf Ridge, resulting in a nest density of 0.19 nests/10 ha (Fig. 3). Five of those nests (16%) fledged at least one chick. I discovered 13 nests before the female started laying eggs, 6 nests when the female was in the process of laying her clutch, and 8 nests that already had full clutches when discovered. The mean number of chicks fledged from successful nests was 3.8 ± 0.20. The nests at Wolf Ridge had a mean clutch size of 4.2 ± 0.26 eggs. All of the unsuccessful nests failed due to predation except one, which failed due to abandonment of the 2 intact eggs. Overall DSR for nests at Wolf Ridge was 0.935 ± 0.133 over a period of 413 nest days, raising the DSR to the power equal to the number of days of the incubation and nestling stages results in the percentage chance for a nest to survive. Nests are Wolf Ridge have a 13.3% chance of surviving to produce fledglings.

At the control sites, I found the first of the 6 Scissor-tailed Flycatcher nests on 3 June 2009 and the last on 19 June 2009. Scissor-tailed Flycatcher nest density was 0.10 nests/10 ha (Fig. 4). I found 3 of the nests during the egg laying phase and I found the remaining 3 nests after incubation had started. Two nests (33%) produced at least 1 fledgling and the mean number of fledglings per successful nest was 3.5 ± 0.50 from a mean clutch size of 3.8 ± 0.31. DSR for nests at the control sites was 0.947 ± 0.195 over a period of 75 nest days, resulting in a 19.5% chance for success. I tested for a significant difference in DSR between Wolf Ridge and the control sites using the method outlined in Johnson (1979); DSR of Scissor-tailed Flycatcher nests over the entire nesting period did not differ between Wolf Ridge and the control sites ($Z = 0.420$, $P = 0.67$; Fig. 5).

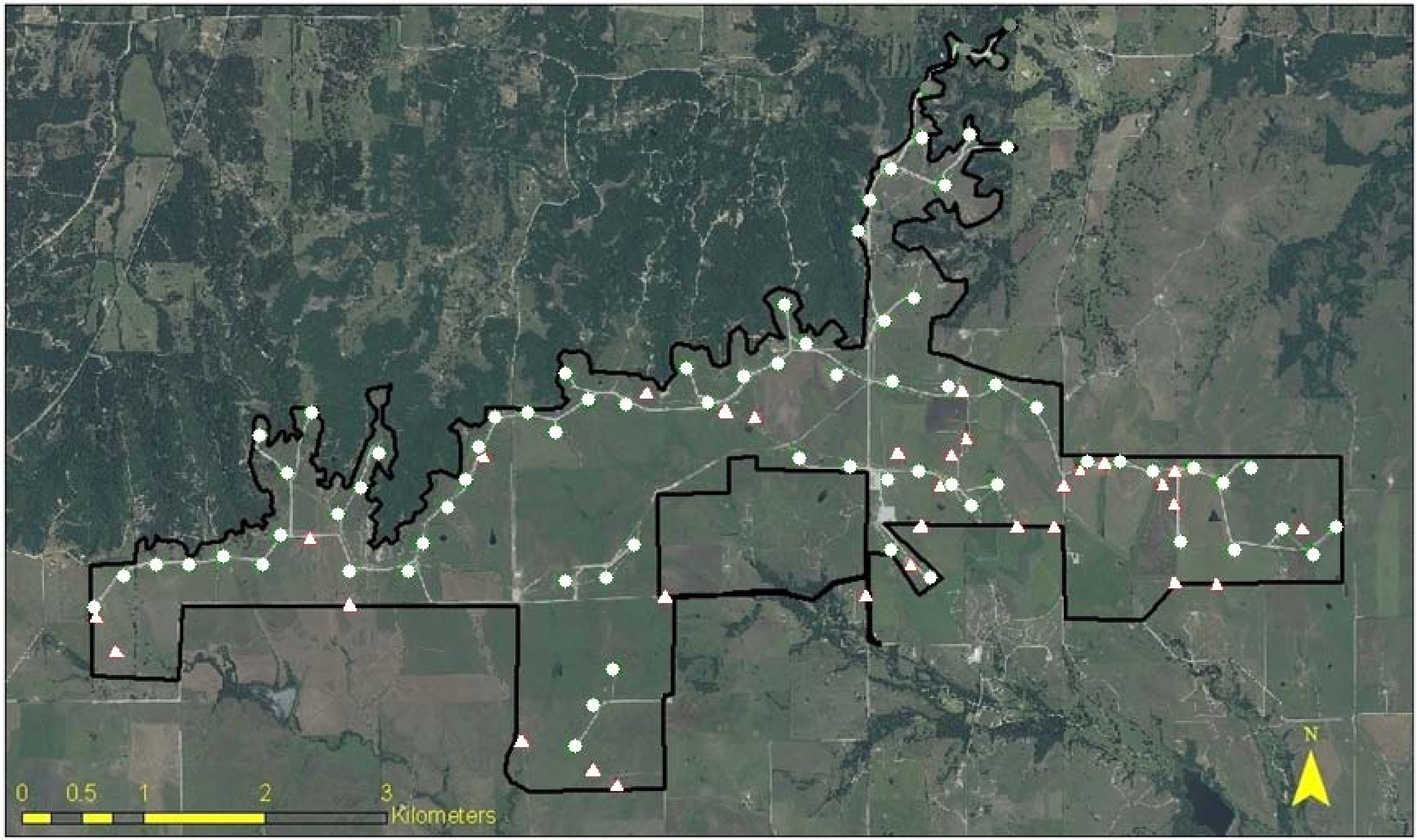

Figure 3. Aerial view of Wolf Ridge Wind located in north-central Texas. The black lines represent the boundary of the searched area. The white circles represent the locations of wind turbines and the white triangles represent Scissor-tailed Flycatcher nests.

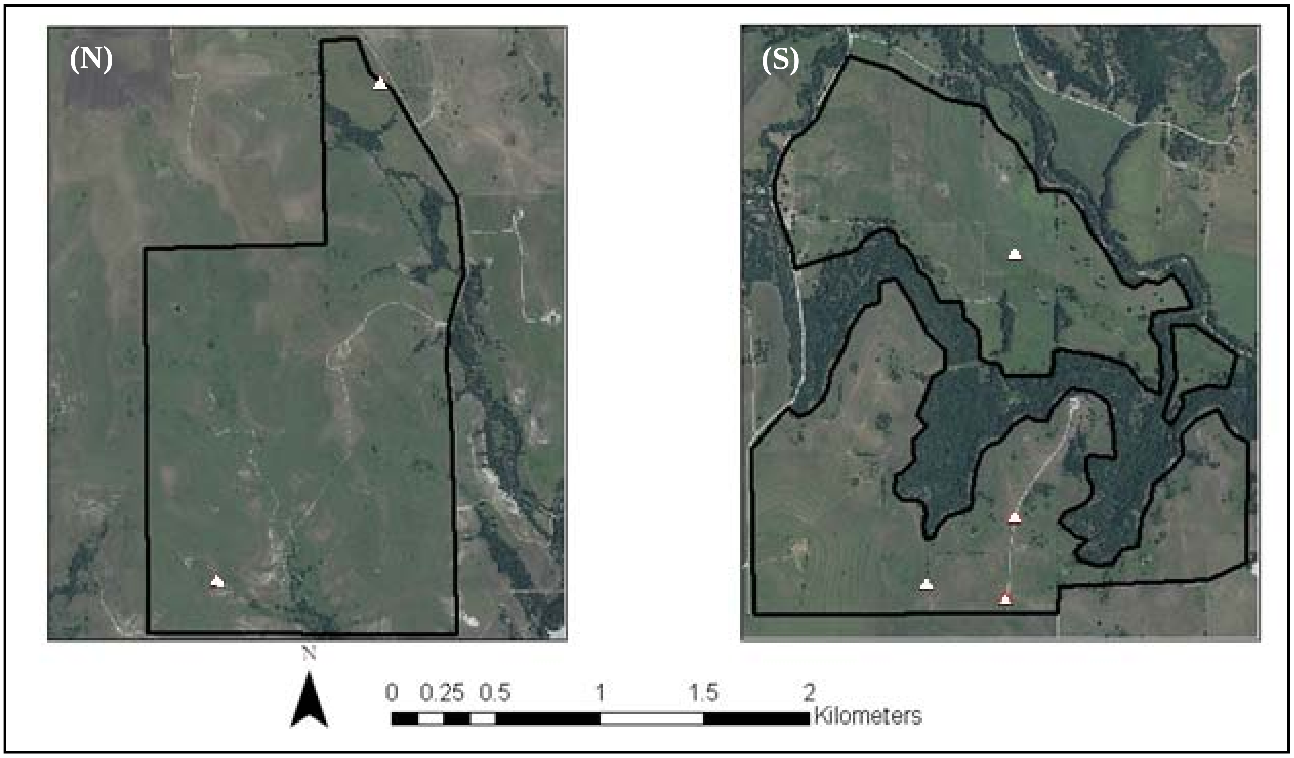

Figure 4. Aerial view of the northern (N) and southern (S) control sites in north-central Texas in 2009. The black lines indicate the boundaries of the searched areas. The white triangles are the locations of Scissor-tailed Flycatcher nests.

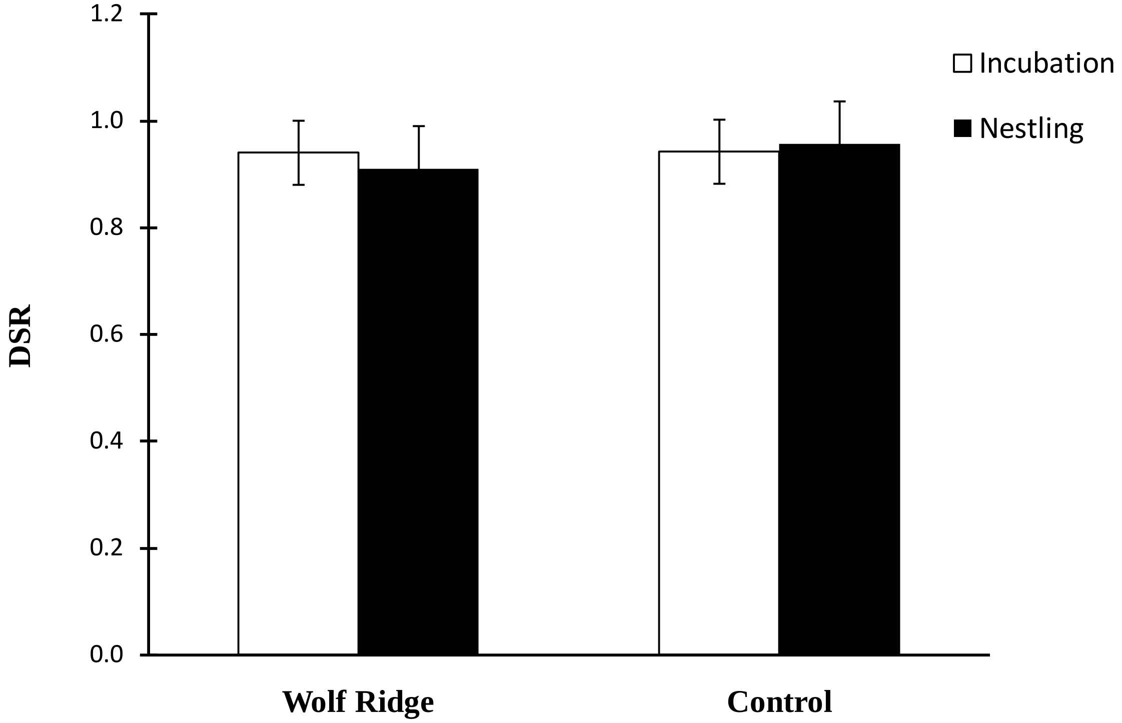

Figure 5. Daily survival rates (DSR) during incubation and the nestling stage for Scissor-tailed Flycatchers at Wolf Ridge Wind and the control sites. DSR did not differ between the nesting stages or study sites.

I also found and monitored nests of seven other species of birds at Wolf Ridge and nests of two other species at the control sites, for a total of 39 non-Scissor-tailed Flycatcher nests at Wolf Ridge and six other nests at the control sites (Appendix A).

Scissor-tailed Flycatcher Incubation Patterns

In the two nests that were monitored at Wolf Ridge, the median off-bout duration was 8 min in the early morning (n = 78, inter quartile range, IQR = 7.3), 8 min during late morning (n = 110, IQR = 7), 8 min in the afternoon (n = 110, IQR = 10.2) and 11 min in the evening (n = 77, IQR = 13; Fig. 6A, Table 1). In the two nests that were monitored at the control sites, the median off-bout was 19 min in early morning (n = 23, IQR = 61), 12 min in late morning (n = 22, IQR = 14.5), 11 min in the afternoon (n = 45, IQR = 16.5), and 37 min in the evening (n = 23, IQR = 80; Fig. 6B, Table 1). Scissor-tailed Flycatchers at Wolf Ridge had more off-bouts than did Scissor-tailed Flycatchers at the control sites (two sample t-test: t = 6.48, df = 6, $P = 0.001$, Wolf Ridge $\bar{x} = 93 \pm 9.4$ (SE) off-bouts, control sites $\bar{x} = 25 \pm 4.9$ (SE) off-bouts). Although the result was not significant, Scissor-tailed Flycatcher off-bouts tended to be shorter at Wolf Ridge than at the control sites (Mann-Whitney U test: $W = 13131$, $P = 0.07$; Wolf Ridge n = 155 off-bouts, median length = 10 min; control sites n = 18 off-bouts, median length = 17 min; Table 1; Fig. 6).

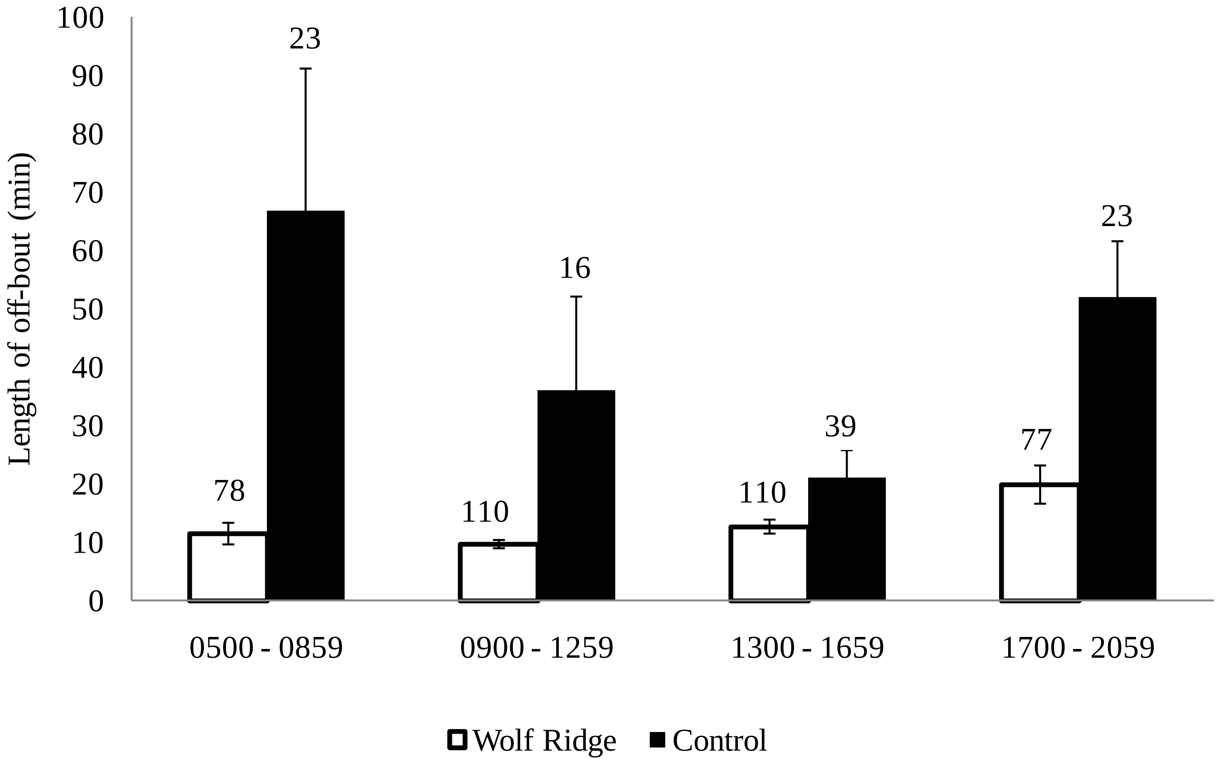

Figure 6. The length and number of incubation off-bouts (min) by Scissor-tailed Flycatchers at Wolf Ridge Wind and the control sites from 18 to 24 June, 2009.

Table 1. Mean ± 1 SE duration (min) and frequency of incubation off-bout lengths by Scissor-tailed Flycatchers in the early morning, late morning, mid-day to afternoon, and early evening time periods from June 18 to 24, 2009 at Wolf Ridge Wind and the control sites.

	Nest ID	Early morning	Late Morning	Mid-Day to Afternoon	Early Evening
	number	0430-0859	0900-1259	1300-1659	1700-2059
Wolf Ridge	1	16 ± 2.2 min (n = 28)	11 ± 0.9 min (n = 46)	12 ± 1.2 min (n = 56)	27 ± 7.7 min (n = 29)
	2	9 ± 2.6 min (n = 50)	9 ± 1.0 min (n = 64)	14 ± 2.1 min (n = 54)	16 ± 2.4 min (n = 48)
Control Sites	3	31 ± 8.2 (n = 9)	40 ± 19.7 min (n = 13)	9 ± 1.4 min (n = 20)	65 ± 25.9 min (n = 5)
	4	90 ± 38.8 (n = 14)	38 ± 24.5 (n = 9)	37 ± 7.7 (n = 25)	48 ± 10.2 (n = 18)

Distance to Turbine and Scissor-tailed Flycatcher Nest Success at Wolf Ridge

Scissor-tailed Flycatcher nests were located over a wide range of distances from wind turbines at Wolf Ridge (Fig. 7). Approximately two-thirds of the nests were built within 125 and 407 m of the nearest wind turbine (n = 32, $\bar{x}$ = 266 ± 25 m). There was a significant relationship between distance to turbine and DSR (univariate Mayfield logistic regression; n = 512.5 nest days, slope coefficient = 0.003, p = 0.04), but in the opposite direction than what was predicted. Failed nests were farther away from turbines (269 ± 28 m) than successful nests (210 ± 48 m). The odds ratio for the logistic regression was 1.003 (95% CI = 1.000-1.006); in other words, for every 10 m closer a nest is built to a turbine, there is a 0.3% increase in the probability it would successfully fledge young.

Habitat Analysis

For both study sites combined, 34 of the 38 nests were built in the canopy tree in each 0.05 ha plot. Artificial structures (e.g., electrical poles) were considered a canopy or nest tree if they contained a Scissor-tailed Flycatcher nest. I found 4 nests behind the transformer on electrical poles and all of these successfully-fledged young. Twenty-five of the Scissor-tailed Flycatcher nest trees were located in trees along a fence line, whereas 13 were located in isolated trees in the middle of open fields (Table 2). The majority of nests were built on the north (315-45 degrees; n = 12) or west (315- 225 degrees; n = 13) side of the tree. Only 6 nests were built on the east side (45-135 degrees) and 7 on the south (225 – 135 degrees).

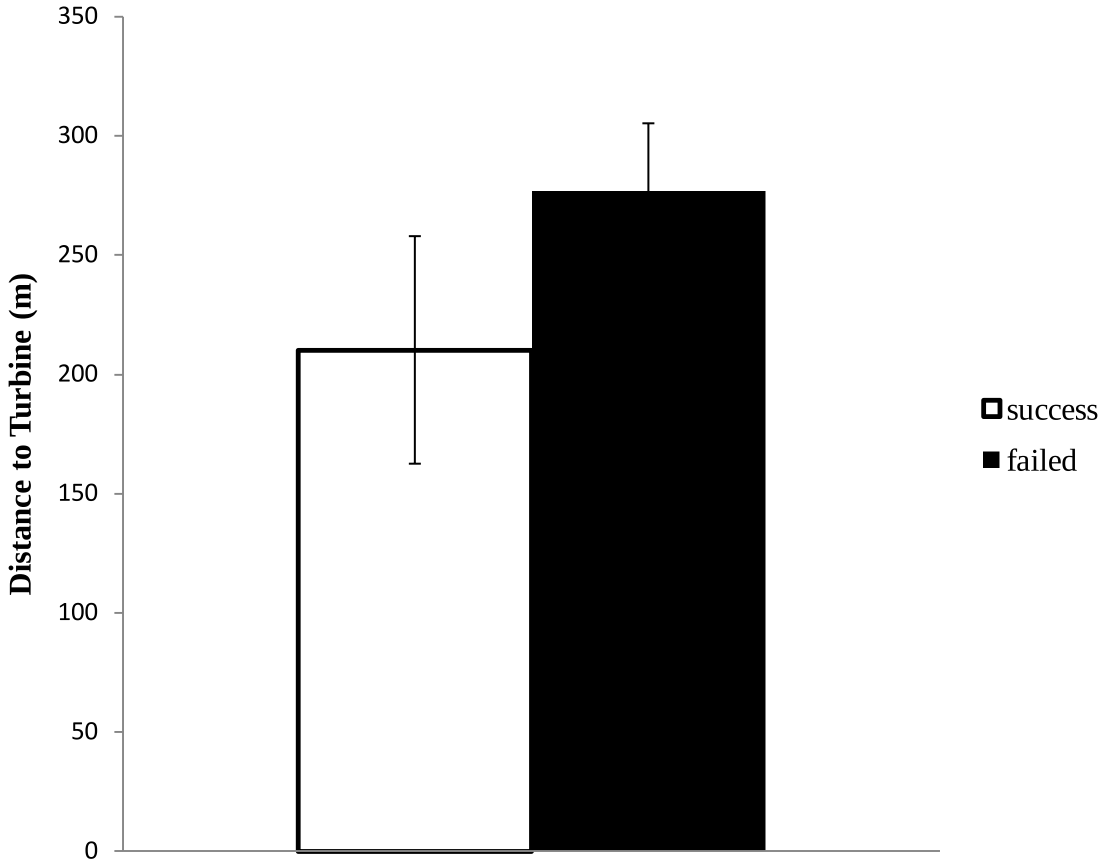

Figure 7. Graph showing distance to nearest wind turbine for successful (n = 5) and failed (n = 27) Scissor-tailed Flycatcher nests at Wolf Ridge in 2009.

The six nests that were predated by fire ants were constructed closer to the ground than the other unsuccessful nests (mean height of ant predated nests = 2.0 ± 0.17 m, n = 6; mean height of non-ant predated nests = 3.3 ± 0.32 m, n = 25; two sample t-test after a natural log transformation: t = -2.45, df = 29, *P* = 0.02). Fire ants will consume eggs by chewing a small hole in the shell to reach the edible contents, effectively leaving the eggshells intact. Fire ants will also consume nestlings and their presence was confirmed by seeing ants and the remains of nestlings together in the nest.

Table 2. Nest site characteristics of successful (n = 7) and unsuccessful (n = 31) Scissor-tailed Flycatcher nests found at Wolf Ridge and control sites during the 2009 breeding season. Data are the proportion of nests within each category (successful and failed) that exhibited the specific nest placement characteristic.

Characteristic	Successful Nests	Unsuccessful Nests
Nest in canopy tree	1.00	0.87
Nest not in canopy tree	0.00	0.13
Fence line	0.57	0.68
Open Field	0.43	0.32
Nest built in a tree	0.43	1.00
Nest built in an artificial structure	0.57	0.00

The multivariate, information-theoretic approach yielded the hypothesis of canopy tree height, DBH, and percentage canopy coverage combined as the habitat model that explained the most variation in Scissor-tailed Flycatcher nest success at Wolf Ridge (AIC = 206.91, $\omega = 0.163$; Table 3). The variable that was most associated with nest success was the percentage of canopy cover ($\omega_+(i) = 0.91$, Table 4). The successful nests had an average canopy cover of 18.5% (n = 7, SE = 9.86) versus 66.1% (n = 31, SE = 4.45) in failed nests. The second strongest variable was DBH ($\omega_+(i) = 0.64$).

Table 3. Mayfield logistic regression analysis of habitat variables on nest success of Scissor-tailed Flycatchers at Wolf Ridge in 2009. CANOPYHT = Canopy height, CANOPYCV = Canopy cover percentage. DISTANCE = Distance from trunk, NESTHT = Nest height, DBH = diameter at breast height. For brevity, only the top ten models are shown.

Model	**AIC**	**ΔAIC**	**ω**
DBH + CANOPYHT + CANOPYCV	206.91	0.00	0.163
DISTANCE + DBH + CANOPYHT + CANOPYCV	207.74	0.83	0.108
DBH + CANOPYCV	208.13	1.22	0.088
NESTHT + DBH + CANOPYHT + CANOPYCV	208.44	1.53	0.076
CANOPYCV	208.62	1.71	0.069
NESTHT + CANOPYCV	208.77	1.86	0.064
DISTANCE + DBH + CANOPYCV	209.25	2.35	0.050
DISTANCE + CANOPYCV	209.30	2.39	0.049
NESTHT + DISTANCE + DBH + CANOPYHT + CANOPYCV	209.42	2.51	0.046

Table 4. Relative weight of each variable used in the information-theoretic Mayfield logistic regression analysis of habitat variables on nest success of Scissor-tailed Flycatchers at Wolf Ridge in 2009.

Variable	$\omega_+(i)$
Canopy cover %	0.91
DBH	0.64
Canopy height	0.54
Distance from trunk	0.38
Nest height	0.37

DISCUSSION

Scissor-tailed Flycatcher Reproductive Success

Scissor-tailed Flycatcher reproductive success was very low at the Wolf Ridge wind farm (DSR = 0.935) and nearby control sites (DSR = 0.947) in 2009. This is much lower than the estimated DSR of 0.994 for Scissor-tailed Flycatchers in Brazos County, central Texas (Fitch 1950). Assuming a 26.5-day period from the start of incubation to fledgling (12.5 d incubation, 14 d nestling stage; Baicich and Harrison 2005), each nest in Fitch's study would have had an 85.3% chance of fledging young. This is much higher than the 23.6% chance of fledging young that I observed at the control sites or the 16.8% chance of fledging young at Wolf Ridge. Although Fitch's study site was located in a different region of Texas, both studies (his and this one) observed Scissor-tailed Flycatchers breeding in habitat influenced by anthropogenic activities.

Other Scissor-tailed Flycatcher studies have also reported higher nest success, even with substantial inter-annual variation. For example, 76.7% of nests in 1991 and 38.7% of nests in 1992 successfully fledged young at Fort Sill Military Reservation in Comanche County in southwestern Oklahoma (Regosin and Pruett-Jones 1995). This Oklahoma study site was much smaller (800 ha) than my study site and was a mesquite (*Prosopis juliflora*) savannah with 100 ha of mowed grass with planted trees. Regosin and Pruett-Jones also reported a greater percentage of nests that successfully fledged young than I found in my study, which was only 18%. Additional research should be conducted at Wolf Ridge to determine if 2009 was an unfavorable year or if habitat variables (both natural and anthropogenic) contribute to consistently low Scissor-tailed Flycatcher nest success at this location.

Nesting habitat is an important determinant of nesting success and as such, sink populations are often located in areas with low quality breeding habitat (Bader and Bednarz 2009). Individuals who cannot compete with established breeders in a high quality source population may immigrate to sink populations if their expected reproductive success in the sink population is greater than foregoing reproduction altogether (Pulliam 1988). It is possible that Wolf Ridge and the surrounding areas represent a sink population of Scissor-tailed Flycatchers supported by individuals immigrating from source populations in the region. A similar situation occurs in some populations of Mississippi Kites (*Ictinia mississippiensis*) in eastern Arkansas (Bader and Bednarz 2009). In this sink population, low reproductive success was largely influenced by nest placement; Mississippi Kites nest along the edge of woodlands overlooking waterways and the movements of nest predators may be concentrated in these same woodland edges. This configuration of habitat produces a high degree of contact between predators and prey, a situation that could be comparable to Scissor-tailed Flycatchers nesting along fence lines and in predator corridors in this study. Perhaps Scissor-tailed Flycatchers would experience greater reproductive success nesting in isolated trees in savannahs rather than in fence rows.

Most Scissor-tailed Flycatchers nested in trees along fence lines at Wolf Ridge and the control sites. In contrast to the permanent fence lines at Wolf Ridge, most of the fences at the control sites were temporary electrical fences that were not associated with trees and as a result, the control sites had less suitable nesting habitat for Scissor-tailed Flycatchers. The grazing and agriculture fields contained few isolated nest trees and Scissor-tailed Flycatchers rarely nested along the edge of large woodland areas. It is likely that the Scissor-tailed Flycatchers avoided the wooded areas because the canopies were too crowded. Similar to my results, Nolte and Fulbright (1996) found that successful nests tended to have less cover around them than failed nests. While the fence lines provided trees with sufficently open canopies to attract Scissor-tailed Flycatchers, they could also be corridors for mammalian and reptilean predators (Winter et al. 2000, Klug et al. 2010) such as raccoons (*Procyon lotor*), Virginia opossums (*Didelphis virginiana*), striped skunks (*Mephitis mephitis)*, and western rat snakes (*Elaphe obsoleta*). Each of these types of predators was observed during nest searches and monitoring in this study. It is likely that the habitat structure at my study sites, would channel both prey and predators to the same relatively small area (Donovan et al. 1997, Bader and Bednarz 2009).

Wind Turbines and Nesting Behavior

Most Scissor-tailed Flycatchers built their nests at least 125 m from the nearest wind turbine. Using recent aerial images in GIS, I estimated the area containing visible tree canopy within 125 meters of all the turbines at Wolf Ridge. Only ca. 0.9% of the land within 125 m of the turbines contained a tree canopy. However, I know of at least a few trees that were not detectable on the overhead satellite image, and therefore 0.9% may be an underestimate. Nevertheless, there were very few isolated trees in close proximity to wind turbines at Wolf Ridge and so the small numbers of Scissor-tailed Flycatcher nests in these areas may simply be due to a lack of nest trees. In fact, one breeding pair initiated a nest directly above the access door to one turbine (KBK, pers. obs.). Although the pair abandoned the nest during construction, their presence suggests that Scissor-tailed Flycatchers do not always avoid areas near turbines.

I found no adverse effect of distance to turbine on nest success in Scissor-tailed Flycatchers. Rather, the timing of nest initiation and nest placement explained much of the variation in nesting success. All successful nests were discovered early in the breeding season, suggesting that either early nesters have an advantage over later arrivals because they can claim the better nest sites (Sedgwick 1993, Brown and Roland 2002) or the nests discovered later in the season were re-nesters and their success is lower (Kershner et al. 2001). Because Scissor-tailed Flycatchers do not nest in colonies nor do they build very cryptic nests, a good nest site might be one that limits predator access to the nest (Nolte and Fulbright 1996). Although nests built away from the fence corridors may be more exposed to aerial predators, the overall predation pressure exerted by terrestrial predators may be greater. Four of the six successful nests at Wolf Ridge had no canopy cover and breeding adults aggressively defended their nests by scolding loudly and harassing black vultures and passing aerial predators (e.g., hawks; TGR and KBK, pers. obs.). These four nests were located on telephone poles. It is probable that at least some, if not most, nest predators were unable to climb the relatively smooth and vertical surface. Mullin and Cooper (2002) tested climbing abilities in rat snakes (*Elaphe obsoleta*) and found that failure rate was greatest in snakes climbing Nuttall Oak trees which have a smoother bark compared to Overcup Oak and Sugarberry trees, which have large irregular plates or ridges with fissures in between and corky warts or ridges punctuating the otherwise smooth bark, respectively. In six of the 31 failed nests in my study, the entire clutch disappeared without any signs of broken eggs nearby, suggesting snake predation (Best 1978). The other 25 nests had signs that they were depredated by other predators: either the nest was damaged and the eggs were broken inside the nest or on the ground below, or discarded egg shells and dead nestlings remained inside the nest.

DSR of Scissor-tailed Flycatcher nests decreased with increasing distance from turbine. One possible explanation for this surprising result could be that potential nest predators avoid areas near turbines; building nests closer to turbines could reduce the chances of nest predation by vertebrates. Another possible explanation is that habitat variables associated with nest placement are correlated with distance to turbine. I found that nests in large trees and structures, both in terms of height and DBH, with little canopy coverage had the greatest probability of success. The first two variables are intuitive; both describe bigger, older trees in which Scissor-tailed Flycatchers could build their nests higher but retain stability in windy conditions (but see Nolte and Fulbright 1996). Although low canopy coverage could be indicative of nests located at the edge of the tree's canopy, where Scissor-tailed Flycatchers often build their nests, distance from trunk had relatively little explanatory power on nest success ($\omega_{+}(i) = 0.38$, Table 4). Alternatively, this pattern is more likely related to the placement locations of the relatively few successful nests: four of the six nests that ultimately fledged young were located on telephone poles, resulting in a canopy coverage percentage and distance from trunk of zero, a combination that did not occur when the nest was placed in a tree. The data gathered from nests on telephone poles should not be excluded, however, because it seems that nesting on anthropogenic structures plays an important role in nesting success of the Scissor-tailed Flycatcher.

Although I only monitored incubation patterns in four Scissor-tailed Flycatcher nests, the results are intriguing. Incubation off-bouts were more frequent and tended to be shorter (although this result was not significant) at Wolf Ridge compared to the control sites. These differences in incubation patterns could potentially impact egg development and subsequent survivorship of the nests and should be studied in more detail in the future. For example, increased activity to and from the nest is more likely to attract predator attention to the nest and could lead to decreases in DSR (Conway and Martin 2000, Mullin and Cooper 1998).

Conclusions

I found no significant adverse effect of wind turbines on nest fate in Scissor-tailed Flycatchers. Instead, habitat variables associated with possible reductions in nest predation appear to better explain patterns of nest success. Successful nests were built in locations that were taller, had greater DBH, and had less canopy coverage than nesting sites of failed nests. Because snake predation was common, less canopy coverage might inhibit arboreal snakes' ability to readily access Scissor-tailed Flycatcher nests. Reduced canopy coverage could also reduce predation by other terrestrial vertebrates. For invertebrate nest predators, such as fire ants, nest height could be important. Nests that were infested by fire ants were all lower to the ground than those that were not infested by ants, and successful nests were higher than failed nests. Although close proximity to wind turbines is not associated with lower reproductive success, there may be an impact of wind turbines on the frequency and duration of parental departures from the nest during incubation. More robust analyses and larger samples sizes of nests are needed before drawing any definitive conclusions.

APPENDIX A.

The number of nests of non-target bird species and their outcomes at Wolf Ridge Wind and the control sites during the 2009 breeding season.

Wolf Ridge

Common Name	Scientific Name	N	Proportion of nests that were successful
Northern Cardinal	*Cardinalis cardinalis*	1	0.00
Northern Mockingbird	*Mimus polyglottos*	10	0.20
Lark Sparrow	*Chondestes grammacus*	8	0.00
Loggerhead Shrike	*Lanius ludovicianus*	2	1.00
Mourning Dove	*Zenaida macroura*	15	0.33
Eastern Kingbird	*Tyrannus tyrannus*	1	0.00
Greater Roadrunner	*Geococcyx californianus*	2	1.00
Total		39	0.28

Control Sites

Common Name	Scientific Name	N	Proportion of nests that were successful
Northern Cardinal	*Cardinalis cardinalis*	2	0.00
Northern Mockingbird	*Mimus polyglottos*	4	0.00
Total		6	0.00

REFERENCES

American Wind Energy Association. 2009. 4th quarter 2009 market report.

Bader, T. J., and J. C. Bednarz. 2009. Reproductive Success and Causes of Nest Failures for Mississippi Kites: A Sink Population in Eastern Arkansas? Wetlands 29: 598-606.

Baicich, P. J., and C. J. O. Harrison. 2005. Nests, Eggs, and Nestlings of North American Birds. Second Edition. Princeton: Princeton University Press.

Best, L. B. 1978. Field Sparrow reproductive success and nesting ecology. Auk 95: 9-22.

Bibby, C. J., N. D. Burgess, D. A. Hill, and S. H. Mustoe. 2000. Bird Census Techniques. Second Edition. San Diego: Academic Press.

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

Brown, S., C. Hickey, B. Harrington, and R. Gill. 2001. The U.S. Shorebird Conservation Plan. Second Edition. Manomet: Manomet Center for Conservation Sciences.

Brown, W. P., and R. R. Roland. 2002. Temporal patterns of fitness and survival in the wood thrush. Ecology 83: 958–969.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. New York: Springer Science.

Burnham K. P., and D. R. Anderson. 2004. Multimodel inference - understanding AIC and BIC in model selection. Sociological Methods & Research 33: 261-304.

Christensen, T.K., J. P. Hounisen, I. Clausager, and I. K. Petersen. 2004. Visual and Radar Observations of Birds in Relation to Collision Risk at the Horns Rev. Offshore Wind Farm. Annual status report 2003.

Churchwell, R. T., C. A. Davis, S. D. Fuhlendorf, and D. M. Engle. 2008. Effects of patch-burn management on dickcissel nest success in a tallgrass prairie. Journal of Wildlife Management 72: 1596-1604.

Combs, S. 2008. The Energy Report. Austin: Texas Comptroller of Public Accounts.

Conway, C. J., and T. E. Martin. 2000. Evolution of avian incubation behavior: Influence of food, climate and nest predation. Evolution 54: 670-685.

de Lucas, M., G. F. E. Janss, D. P. Whitfield, and M. Ferrer. 2008. Collision fatality of raptors in wind farms does not depend on raptor abundance. Journal of Applied Ecology 45: 1695-1703.

Desholm, M., and J. Kahlert. 2005. Avian collision risk at an offshore wind farm. Biology Letters 1: 296-298.

Donovan, T. M., P. W. Jones, E. M. Annand, and F. R. Thompson. 1997. Variation in local-scale edge effects: Mechanisms and landscape context. Ecology 78: 2064-2075.

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

Engle, D. M., T. N. Bodine, and J. F. Stritzke. 2006. Woody plant community in the cross timbers over two decades of brush treatments. Rangeland Ecology & Management 59: 153-162.

Erickson, W. P., G. D. Johnson, and D. P. Young, Jr. 2005. A Summary and Comparison of Bird Mortality from Anthropogenic Causes with an Emphasis on Collisions. Retrieved April 2, 2009, from U.S. Forest Service: http://www.fs.fed.us/psw/publications/documents/psw_gtr191/Asilomar/pdfs/1029-1042.pdf

Faaborg, J. 2002. Saving migrant birds—developing strategies for the future. Austin: University of Texas Press.

Fitch, F. W. 1950. Life history and ecology of the Scissor-tailed Flycatcher, *Muscivora forficata*. Auk 67: 145-168.

Fox, A. D., M. Desholm, J. Kahlert, T. K. Christensen, and I. K. Petersen. 2006. Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. Ibis 148: 129–144.

Gelbard, J. L. and J. Belnap. 2003. Roads as conduits for exotic plant invasions in a semiarid landscape. Conservation Biology 17: 420–432.

Hazler, K. R. 2004. Mayfield logistic regression: A practical approach for analysis of nest survival. Auk 121: 707-716.

IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. http://www.iucnredlist.org Retrieved 02 March 2010.

James, D. A. 1992. Measure shrubland vegetational structure using avian habitats as an example. Proceedings of the Arkansas Academy of Science 46: 46-48.

Johnson, G. D., W. P. Erickson, M. D. Strickland, M. F. Shepherd, D. A Shepherd, and S. A. Sarappo. 2002. Collision mortality of local and migrant birds at a large-scale wind-power development on Buffalo Ridge, Minnesota. Wildlife Society Bulletin 30: 879-887.

Kahlert, J., I. K. Petersen, M. Desholm, and I. Clausager. 2004. Investigations of migratory birds during operation of Nysted offshore wind farm at Rødsand: Preliminary Analysis of Data from Spring 2004.

Kershner, E. L., E. K. Bollinger, M. N. Helton. 2001. Nest-site selection and renesting in the Blue-grey Gnatcatcher (*Potioptila caerula)*. American Midland Journalist 146: 404-413.

Klug, P. E., S. L. Jackrel, K. A. With. 2010. Linking snake habitat use to nest predation risk in grassland birds: the dangers of shrub cover. Oecologia 162: 803-813.

Kuvlesky, W. P., Jr., 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. The Journal of Wildlife Management 71: 2487–2498.

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.

Masden, E. A., D. T. Haydon, A. D. Fox, R. W. Furness, R. Bullman, and M. Desholm. 2009. Barriers to movement: impacts of wind farms on migrating birds. Ices Journal of Marine Science 66: 746-753.

Mayfield, H. F. 1975. Suggestions for Calculating Nest Success. Willson Bulletin 87: 456-466.

Mullin, Stephen J. and R. J. Cooper. 2002. Barking up the wrong tree: climbing performance of rat snakes and its implications for depredation of avian nests. Canadian Journal of Zoology 80: 591-595.

Mullin, Stephen J. and R. J. Cooper. 1998. The Foraging Ecology of the Gray Rat Snake (*Elaphe obsoleta spiloides*)-Visual Stimuli Facilitate Location of Arboreal Prey. American Midland Naturalist 140: 397-401.

Nolte, K. R., and T. E. Fulbright. 1996. Nesting ecology of scissor-tailed flycatchers in south Texas. Wilson Bulletin 108: 302-316.

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

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. 1988. Sources, Sinks, and Population Regulation. American Naturalist 132: 652-661.

Rahmig, C. J., W. E. Jensen, and K. A. With. 2009. Grassland Bird Responses to Land Management in the Largest Remaining Tallgrass Prairie. Conservation Biology 23: 420-432.

Rentch, J. S., R. H. Fortney, S. L. Stephenson, H. S. Adams, W. N. Grafton, and J. T. Anderson. 2005. Vegetation–site relationships of roadside plant communities in West Virginia, USA. Journal of Applied Ecology 42: 129–138.

Regosin, J. V. 1998. Scissor-tailed Flycatcher *(Tyrannus forficatus)*. http://bna.birds.cornell.edu/bna/species/342 Retrieved April 2, 2009

Regosin, J. V. and S. Pruett-Jones. 1995. Aspects of Breeding Biology and Social-Organization in the Scissor-Tailed Flycatcher. Condor 97: 154-164.

Samson, F. and F. Knopf. 1994. Prairie Conservation in North-America. Bioscience 44: 418-421.

Sedgwick, J. A. 1993. Dusky flycatcher: the birds of North America 78. Philadelphia: The Academy of Natural Sciences.

Texas State Energy Conservation Office, Texas Wind Energy Resources. http://www.infinitepower.org/reswind.htm.

Tollefson, J. 2008. Credit crunch threatens US wind-energy projects. Nature 455: 572-573.

Weidinger, K. 2006. Validating the use of temperature data loggers to measure survival of songbird nests. Journal of Field Ornithology 77: 357-364.

Winter, M., D. H. Johnson, and J. Faaborg. 2000. Evidence for edge effects on multiple levels in tallgrass prairie. Condor 102: 256-266.

VITA

Trevor George Rubenstahl was born April 28, 1986, in Houston, Texas. He is the son of George and Beverly Rubenstahl. A 2004 graduate of St. Thomas High School, Houston, Texas, he received a Bachelor of Science degree with a major in Biology from the University of Texas, Austin, in 2008.

In August, 2008, he enrolled in graduate study at Texas Christian University, where he will receive his MS in Environmental Science in 2010. While working on his masters in Environmental Science, he held a Teaching Assistantship in 2008-2009 and a Research Assistantship during 2009-2010.

ABSTRACT

HABITAT CHARATERISTICS THAT INFLUENCE SCISSOR-TAILED FLYCATCHER NEST SUCCESS AT A UTILITY-SCALE WIND FARM IN NORTH-CENTRAL TEXAS

by Trevor George Rubenstahl, Masters, 2010
Department of Environmental Science
Texas Christian University

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

I investigated the indirect effects of wind turbines on the nesting behavior of the Scissor-tailed Flycatcher (*Tyrannus forficatus*) in north-central Texas. I tracked the fate of 38 nests at Wolf Ridge Wind, LLC and control sites during breeding season in 2009. Overall nest predation rates were high and reproductive success was low, with only 18% of nests fledging at least one offspring. Daily nest survival rates did not differ between Wolf Ridge (94.3%) and the control sites (94.4%). A univariate Mayfield logistic regression analysis suggested that proximity to wind turbines is associated with increased nesting success. AIC Mayfield logistic regression analysis indicated, however, that variation in nesting success was best explained by canopy cover, DBH, and canopy height, three habitat variables most closely associated with nest predation risk.