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Author: Bennett, Victoria J.

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# Effect of Wind Turbine Proximity on Nesting Success in Shrub-nesting Birds

VICTORIA J. BENNETT<sup>1</sup>

*School of Geology, Energy, and the Environment, Texas Christian University, Fort Worth 76129*

AMANDA M. HALE

*Biology Department, Texas Christian University, Fort Worth 76129*

KRISTOPHER B. KARSTEN

*Department of Biology, California Lutheran University, Thousand Oaks 91360*

CALEB E. GORDON

*Western EcoSystems Technology, Inc., 13001 S.H. 71 West, Ste 102, Austin, Texas 78704*

AND

BRYAN J. SUSON

*680 Kathryn Court, Libertyville, IL 60048*

**ABSTRACT.**—Wind energy development is rapidly expanding globally, as are concerns about the potential threats wind facilities pose to bird and bat populations. To date, many studies have explored the direct impacts of wind turbines on wildlife, such as wildlife-turbine collisions, but few have addressed indirect impacts, such as habitat degradation. These potentially subtle impacts can have far reaching effects on the abundance, distribution, survival, and breeding success of wildlife. We conducted a study to assess whether proximity of wind turbines to shrub-nesting birds influenced rates of nest failure associated mainly with depredation and brood parasitism by Brown-headed Cowbirds (*Molothrus ater*). During the primary nesting period of five passerine species, we monitored 253 active nests. We used a logistic-exposure method to model nest fate as a function of the important variables identified (including distance from turbine and brood parasitism). Our results indicate little relation between nest success and distance to turbine, with one exception, the Blue-gray Gnatcatcher (*Poliophtila caerule*). For this passerine, we found nests closer to wind turbines had a lower probability of being brood parasitized and subsequently had higher nest success rates. We recommend future studies explore the potential implications of wind energy development on brood parasites, such as the Brown-headed Cowbird. As there is regulatory and social pressure to devise management strategies that reduce the impact of brood parasites on species of concern, any opportunities to decrease the risk of brood parasitism could be of benefit.

## INTRODUCTION

The use of wind resources as a source of energy has become a rapidly expanding industry; however, along with its increasing popularity are growing concerns that wind farms may have negative implications for wildlife (Everaert and Stienen, 2007; Kuvlesky *et al.*, 2007; Allison *et al.*, 2008; Bright *et al.*, 2008; Carrete *et al.*, 2009; Inger *et al.*, 2009; Pruett *et al.*, 2009a). To date the majority of studies have focused on the direct impacts of wind turbines on wildlife, as a wide variety of bird and bat species have been killed as a result of collisions with turbine rotor blades (Drewitt and Langston, 2006; Everaert and Stienen, 2007; Kuvlesky *et al.*, 2007).

<sup>1</sup> Corresponding author: e-mail: v.bennett@tcu.edu

In comparison the indirect impacts of wind energy development are more subtle. Time-lagged declines in the distribution, abundance, survival, and reproductive success of wildlife can occur because of changes in land-use (Drewitt and Langston, 2006; Bisson *et al.*, 2011). For instance the development of a wind facility can have immediate implications for local wildlife in terms of habitat loss and fragmentation (Leddy *et al.*, 1999). In contrast the consequences of operating a wind resource facility post-construction may not be as instantaneous or quantifiable.

Birds generally use a set of environmental cues, such as available conditions and resources, to select suitable habitat (Bayard and Elphick, 2010; Chalfoun and Martin, 2010; Greenwood and Dawson, 2011). If the environmental cues used by habitat selectors are well correlated with the factors that impact their fitness, then fitness can be maximized by the habitat selection process. In instances where individual animals recognize a habitat to no longer have appropriate conditions or resources, as a behavioral response, they may avoid that area (Desholm and Kahlert, 2005; Drewitt and Langston, 2006; Pruett *et al.*, 2009a). For example the visual and audible presence of turbines may cause some species to avoid the areas in proximity to turbines (Bayne *et al.*, 2008; Barber *et al.*, 2010; Benítez-López *et al.*, 2010). This phenomenon is known as displacement and recent studies have demonstrated that grassland bird species can be displaced by wind turbines (*e.g.*, Leddy *et al.*, 1999; Dooling, 2002; Stevens *et al.*, 2013).

Alternatively an environmental factor that adversely impacts fitness may not be recognized by habitat selectors, nor correlated with any of the environmental cues to which habitat selectors are responding. In such cases the habitat selection process may result in animals falling into an ecological trap (Schlaepfer *et al.*, 2002; Battin, 2004). In the case of wind energy facilities, shrub-nesting birds may not recognize there could be a loss of fitness caused by the presence of wind turbines. This loss of fitness could manifest in several ways. For example the distance over which male songbirds' vocalizations travel may be limited by the noise generated by operating wind turbines (Swaddle and Page, 2007). This vocal restriction may reduce the ability of males to attract mates and in turn influence breeding success. Similarly if birds do not recognize the presence of turbines has improved habitat for their associated predators, parasites or competitors, this could also influence their survival and breeding success (Francis *et al.*, 2009). For example the presence of tall structures may expose nesting birds to predation by providing vantage points for predators (Liebezeit *et al.*, 2009; Pruett *et al.*, 2009b). These subtle effects of wind farms on fitness have received little attention. Thus there is a clear need not only to understand the potential population-level implications of such effects.

We conducted surveys to explore the nesting success of shrub-nesting birds at an operational wind facility in north-central Texas. More specifically we investigated whether the risk of nest failure among five nesting passerines increased with proximity to wind turbines. We hypothesized if wind facility operation decreased passerine fitness by making wind turbine locations more suitable for associated predators and parasites [such as Brown-headed Cowbirds (*Molothrus ater*)], we would observe: (1) the rate of brood parasitism increasing with decreasing distance from turbines, (2) a decrease in nest success with a decrease in distance to turbines, or (3) both. We discuss how our results shed new light on a key wind-wildlife question, with implications for the conservation, regulatory, scholarly, and commercial communities.

## METHODS

### STUDY SITE

Our study was conducted at Wolf Ridge Wind, LLC in Cooke County within the Cross Timbers and Prairies ecoregion of north-central Texas (33°43'53.538"N, 97°24'18.186"W;

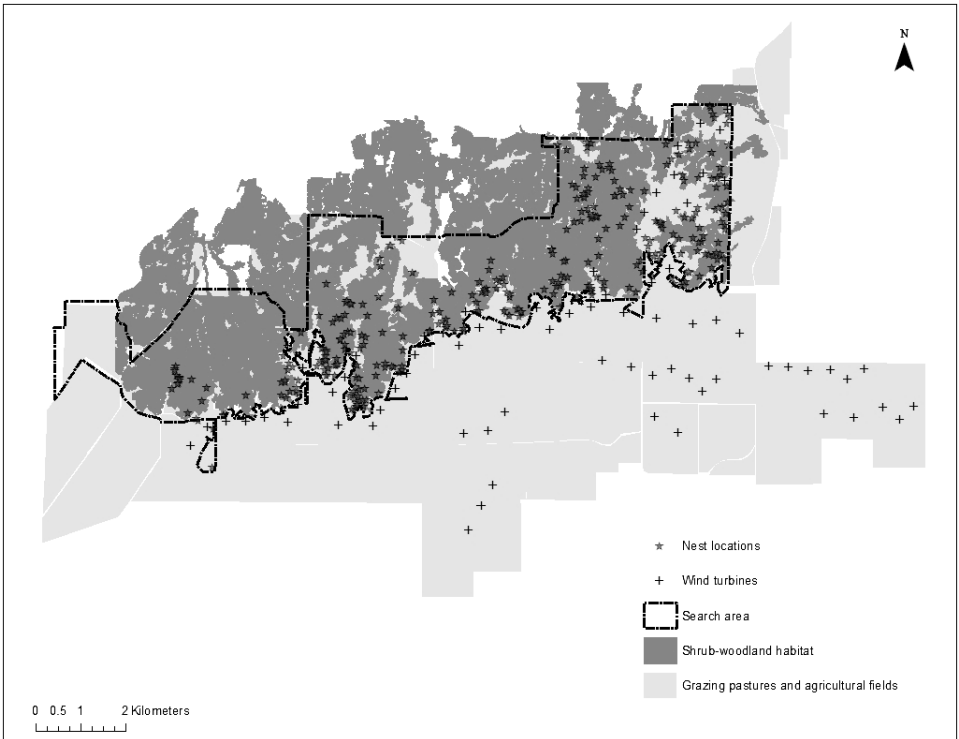


FIG. 1.—Map of study site at Wolf Ridge Wind, LLC in Cooke County, north-central Texas

Griffith *et al.*, 2004). Wolf Ridge is operated by NextEra Energy Resources (Juno Beach, FL) and the land is leased from private landowners. The combined properties comprise 75, 1.5-megawatt General Electric wind turbines extended over ca. 48 km<sup>2</sup> of open agricultural land (mainly cattle grazed) with distinct patches of shrub-woodland located primarily in ravines (Fig. 1). Within Wolf Ridge, we identified ca. 16.4 km<sup>2</sup> of shrub-woodland habitat and conducted surveys across ca. 10.9 km<sup>2</sup> of this habitat (search area shown in Fig. 1). Thus we surveyed all shrub-woodland within the wind resource facility, with the exception of 5.5 km<sup>2</sup> that were landowner restricted or physically hazardous to access (such as scarps). This unsearched area was predominately to the north of the wind resource facility, thus we were able to search all shrub-woodland adjacent to the wind turbines. Within our surveyed area, shrub-woodland was 23–537 m (Mean: 92, SE: 6) from the nearest wind turbine (Fig. 1).

#### FIELD SURVEYS

We conducted surveys during the known nesting season of five local bird species from 5 Apr. to 10 Aug., 2009: White-eyed Vireo (*Vireo griseus*; Hopp *et al.*, 1995), Blue-gray Gnatcatcher (*Poliptila caerulea*; Kershner and Ellison, 2012), Northern Cardinal (*Cardinalis cardinalis*; Halkin and Linville, 1999), Painted Bunting (*Passerina ciris*; Lowther *et al.*, 1999), and Lark Sparrow (*Chondestes grammacus*; Martin *et al.*, 2000). These surveys comprised two activities: (1) searching for nests, and (2) monitoring nests found during searches.

*Nest searching.*—We followed the standard Mayfield methodology for nest searches in the field (Mayfield, 1975; Johnson, 1979). In teams of two to six individuals, we regularly

searched for new nests across the entire survey period. A full search of the survey area was completed every 7–14 d, weather permitting. Eight full searches were conducted over the survey period. In these searches, we walked approximately 10 m apart through the shrub-woodland from the wind turbines to the far side of the survey area (Fig. 1). We used the presence of territorial birds (identified by singing males or alarm calls) and flushed individuals to help identify potential nest locations. Once a nest was found, we recorded nest location using Mio P550 handheld GPS units with ArcPad software (version 7.1.1) and nest status (active or inactive). An active nest was defined as a nest in use (*i.e.*, warm eggs or live nestlings present) or in construction. Adults with nesting material or exhibiting territorial behavior in proximity to the nest were considered an indication of the latter. For active nests, we recorded number of host eggs and nestlings, number of Brown-headed Cowbird eggs and nestlings, evidence of fledging (including the observation of a parent attending newly fledged young in the immediate vicinity of the nest), and any evidence of nest depredation (*e.g.*, broken eggs, chick remains, destroyed or partial destroyed nest, and presence of a predator). For those nests that appeared inactive, we placed a fresh leaf in the nest with the expectation that a nesting adult would remove the leaf from an active nest. The nest was checked on two additional occasions within a 2–4 d interval as part of the monitoring surveys (*see* below). If the leaf remained in place on the third observation, then the nest was deemed inactive and no longer monitored.

In instances where nests could not easily be examined (*e.g.*, above eye level), we used inspection mirrors on extendable poles. Finally we used flagging tape tied around vegetation >3 m from the nest to help us relocate each nest during our monitoring activities. By offsetting the flagging, we tried to ensure that it did not disclose the location of nests to potential predators (Weidinger, 2008; Jacobson *et al.*, 2011).

*Nest monitoring.*—Using the standard Mayfield methodology for nest fate monitoring, we monitored all nests encountered belonging to the five aforementioned passerines (Mayfield, 1975; Johnson, 1979). We checked each nest every 2–4 d, or on rare occasions when constrained by landowner activity, every fifth or sixth day. On each nest visit, we recorded nest status, number of host eggs and nestlings, number of Brown-headed Cowbird eggs and nestlings, evidence of fledging, and any evidence of nest depredation. Evidence of depredation included broken eggs, chick remains, destroyed or partial destroyed nest, and presence of a predator. Evidence of fledging included the observation of a parent attending newly fledged young in the immediate vicinity of the nest. If activity on a prelaying nest ceased and we observed no further progress during three successive visits, we considered the nest abandoned. We also ceased to monitor a nest after all nestlings fledged, the entire nest was depredated, or the nest was destroyed.

#### STATISTICAL ANALYSES

We used a logistic-exposure approach to conduct our nest success analysis (Shaffer, 2004; Grant *et al.*, 2005; Lloyd and Tewksbury, 2007; Shaffer and Thompson, 2007). For this analysis we built a series of models depicting all the various combinations and interactions of the predictor variables recorded (*e.g.*, distance from turbine). Based on our knowledge of the study system, we identified four predictor variables we hypothesized could potentially influence nest success and could be measured effectively. As the main focus of our study was to determine whether the presence of wind turbines impacted nest success, we identified distance (m) to nearest turbine (TURBINE) as our first predictor variable. We postulated this variable was sufficient to capture all the potential impacts associated with wind turbine presence, such as vehicular traffic or maintenance activities, as well as factors caused by the wind turbines themselves, such as flicker (the shadow

created by the passing blades) or noise (IDNR, 2007). The second predictor variable identified was day of the year (1 to 365; DATE). We hypothesized the date on which a nest was discovered could influence nest success. Nests may be more susceptible, for example, to predation, brood parasitism, or stochastic events at certain times during the nesting season (such as storms common in the month of Apr. at the study site). As the third predictor variable, we identified distance (m) from shrub-woodland edge to nests within the shrub-woodland interior (SW\_IN). We hypothesized the further into shrub-woodland the nest, the more sheltered and concealed that nest would be from factors such as wind turbine noise, flicker, and potentially Brown-headed Cowbird parasitism. Finally, we selected Brown-headed Cowbird parasitism (PARA) as the fourth predictor variable, which represented the only categorical variable (*i.e.*, all other variables were continuous), where 0 represented no parasitism and 1 indicated a nest was parasitized at some point during nest monitoring. Studies have shown Brown-headed Cowbird nestlings increase risk of nest predation by vocalizing more frequently and louder than host nestlings (Hannon *et al.*, 2009). Thus, we hypothesized certain species might be more susceptible to brood parasitism and subsequently nest failure than others. TURBINE and SW\_IN were calculated in ArcGIS 9 (ESRI, Inc., Redlands, CA, U.S.A.) using the GPS data. We also hypothesized that the presence of wind turbines may influence each species differently. For example displacement studies have shown that some bird species may avoid areas in proximity to wind turbines while other similar species might not (Stevens *et al.*, 2013). Thus, to determine whether nest success in the presence of wind turbines was species-specific, we analyzed each species separately.

We identified the response variable associated with nest success to be nest fate. Nest fate (primarily incorporating depredation) was a categorical response variable, where 0 indicated complete nest failure and 1 represented production of at least one fledgling. We created a balanced series of candidate models to test all possible combinations of the four selected predictor variables. These models included main effects, additive, and 2-way interactions between all the independent variables. Based on our knowledge of the study system, we hypothesized any of the four selected predictor variables could be interacting with each other to impact nest fate. We also included a constant survival model in which all the independent variables were held constant.

We performed all logistic-exposure analyses in SAS, version 9.1 (SAS Institute, Inc., Cary, North Carolina, U.S.A.). As the logistic-exposure approach establishes nest success by modeling the time-specific effects of nest age and date, we divided the data for each nest monitored into exposure periods and applied the appropriate predictor and response variables to each interval. We performed the PROC GENMOD statement using the EVENTS/TRIALS model. The Akaike Information Criterion ( $AIC_C$ ) provided the best measure of relative model fit as adjusted for finite small sample sizes (Burnham and Anderson, 2002); the model with the lowest  $AIC_C$  was deemed the most informative subset of predictor variables. For each model we also defined the number of estimable parameters (K), the difference in  $AIC_C$  between the model of interest and the  $AIC_C$  of the best model ( $\Delta AIC_C$ ), and the model's Akaike weight ( $\omega$ ). The  $\Delta AIC_C$  allowed for direct comparison of models relative to the optimum; all models with  $\Delta AIC_C < 2$  were considered to have strong support. We used the Akaike weight ( $\omega$ ) to assess the relative weight that each model carried in the overall explanation for the response variable. Where the TURBINE predictor variable had strong support, we analyzed the relative influence of TURBINE on the response variable by calculating relative importance weight,  $w + (i)$  (Burnham and Anderson, 2002). Relative importance weights were calculated by summing Akaike weights of each model in which

TABLE 1.—Nest success characteristics of five bird species inhabiting Wolf Ridge wind facility in north-central Texas

Species	Latin name	No. of nests	No. parasitized	No. nests failed	Distance from Turbine (m)	
					Mean $\pm$ 1 SE	Range
White-eyed Vireo	<i>Vireo griseus</i>	50	26	49	429 $\pm$ 29	126–1096
Blue-gray Gnatcatcher	<i>Poliophtila caerulea</i>	22	10	17	430 $\pm$ 67	95–1360
Northern Cardinal	<i>Cardinalis cardinalis</i>	124	11	113	400 $\pm$ 27	70–1549
Painted Bunting	<i>Passerina ciris</i>	37	22	32	330 $\pm$ 35	90–1204
Lark Sparrow	<i>Chondestes grammacus</i>	20	1	16	296 $\pm$ 58	85–1253

TURBINE occurred, thus allowing the assessment of its relative influence (Burnham and Anderson, 2002). These weights provided additional insights as to whether TURBINE contributed to the outcome, especially where several models gave overall support.

### RESULTS

We monitored 298 nests, of which 253 were deemed active (see Fig. 1 for nest locations). Table 1 provides a list of the number of nests found for each of the five species included in the study. During nest monitoring surveys, we were able to effectively identify Brown-headed Cowbird eggs and nestlings in the nests of all passerines, except for Northern Cardinals. While we did record brood parasitism in this species (11 out of 124 nests), confidence in our abilities to successfully identify all parasitized cardinal nests was low as cowbird and cardinal eggs were very similar in appearance. Therefore we did not include the predictor variable PARA (brood parasitism) in our analyses for Northern Cardinals. Nevertheless among the remaining four passerines, we recorded over 45% of nests parasitized in Blue-gray Gnatcatchers, Painted Buntings, and White-eyed Vireos and <5% in the Lark Sparrow (Table 1). Overall nests were found 70–1549 m from the nearest wind turbine (Mean: 373 m; SE: 14 m). We found the mean distance of nests and their standard errors fell consistently between 200 and 500 m from the wind turbines (Table 1).

For each species excluding Northern Cardinals, we created a total of 22 candidate models for analysis. As we were unable to assess brood parasitism in Northern Cardinals, we only developed 12 candidate models that included three of the four predictor variables (*i.e.*, TURBINE, DATE, and SW\_IN). For the full results of the log exposure analysis refer to Table 2. From the log exposure analysis, we found that nest fate of Lark Sparrows was not influenced by the presence of wind turbines, as the models that included TURBINE as a predictor variable were either not informative or not supported by the data ( $\Delta\text{AIC}_C < 2$ ; Table 2). For Painted Bunting distance from turbine as an interaction with the day nests were discovered ( $\Delta\text{AIC}_C$  of 0.25) was the fifth of five models that supported the data (Table 2). However, TURBINE as a predictor variable only accounted for a total Akaike weight of 0.32 [ $w + (i)$ ] and represented the variable with the least overall strength (Table 3). Similarly the second and third most informative models for White-eyed Vireo nest fate was DATE + TURBINE and PARA + DAY + TURBINE ( $\Delta\text{AIC}_C = 0.76$  and 0.81 respectively; Table 2). However, again TURBINE as a predictor variable only accounted for a total Akaike weight of 0.39 [ $w + (i)$ ] and had the least overall strength (Table 3). For Northern Cardinals, after the constant survival model ( $w = 0.31$ ) the main effect of distance from turbine ( $\Delta\text{AIC}_C = 1.25$ ) was the second of three models that best-supported the data (Table 2). While TURBINE as a predictor variable accounted for a total Akaike weight of 0.39 [ $w + (i)$ ] and represented the variable with the greatest strength, there was little

TABLE 2.—Selection results for the logistic exposure analysis to determine which combination of predictor variables best explained nest fate in shrub-nesting birds at the Wolf Ridge wind facility in north-central Texas in 2009. Either the top five models or all models with an  $\Delta AIC_C < 2$  are provided. An \* in the Obs column identifies those models that are informative and best-supported by the data

Obs	Model	Log L	Deviance	n	K	AIC	AIC <sub>C</sub>	$\Delta AIC_C$	$\omega_{\text{Akaike}}$
<b>White-eyed Vireo</b>									
1*	DATE	-97.1512	194.302	417	2	198.302	198.331	0.00000	0.11336
2	PARA + DATE	-96.1545	192.309	417	3	198.309	198.367	0.03561	0.11136
3	DATE + TURBINE	-96.5180	193.036	417	3	199.036	199.094	0.76258	0.07742
4	PARA + TURBINE + DATE	-95.5215	191.043	417	4	199.043	199.140	0.80855	0.07566
5	Constant survival	-98.7172	197.434	417	1	199.434	199.444	1.11260	0.06499
6	PARA + SW_IN	-96.8458	193.692	417	3	199.692	199.750	1.41827	0.05578
7	PARA + DATE + SW_IN	-95.9024	191.805	417	4	199.805	199.902	1.57043	0.05169
8	Global model additive effects	-97.9666	195.933	417	5	199.933	199.962	1.63070	0.05016
<b>Blue-gray Gnatcatcher</b>									
1*	TURBINE + PARA + TURBINE*PARA	-30.6864	61.3729	197	4	69.3729	69.5812	0.0000	0.86577
2	PARA + TURBINE	-34.6792	69.3583	197	3	75.3583	75.4827	5.9015	0.04528
3	PARA + TURBINE + SW_IN	-34.0168	68.0335	197	4	76.0335	76.2418	6.6606	0.03098
4	PARA + TURBINE + DATE	-34.5986	69.1971	197	4	77.1971	77.4055	7.8242	0.01731
5	PARA + SW_IN	-35.7364	71.4729	197	3	77.4729	77.5972	8.0160	0.01573
<b>Northern Cardinal</b>									
1*	Constant survival	-242.120	484.240	1025	1	486.240	486.243	0.00000	0.30914
2*	TURBINE	-241.739	483.479	1025	2	487.479	487.490	1.24685	0.16573
3*	SW_IN	-242.014	484.028	1025	2	488.028	488.040	1.79618	0.12593
4*	DATE	-242.113	484.225	1025	2	488.225	488.237	1.99333	0.11410
5*	SW_IN + TURBINE	-241.607	483.214	1025	3	489.214	489.238	2.99409	0.06918
<b>Painted Bunting</b>									
1*	SW_IN + PARA + SW_IN*PARA	-70.2187	140.437	363	4	144.437	144.471	0.00000	0.12594
2	PARA + SW_IN	-70.2187	140.437	363	3	144.437	144.471	0.00000	0.12594
3	PARA + DATE + SW_IN	-69.2544	138.509	363	4	144.509	144.576	0.10493	0.11950
4	PARA + DATE	-69.2544	138.509	363	3	144.509	144.576	0.10493	0.11950
5	TURBINE + DATE + TURBINE*DATE	-68.3046	136.609	363	4	144.609	144.721	0.25030	0.11112
<b>Lark Sparrow</b>									
1*	Global model additive effects	-31.5863	63.1727	141	1	65.1727	65.2014	0.00000	0.098563
2	Constant survival	-31.5863	63.1727	141	2	65.1727	65.2014	0.00000	0.098563
3	SW_IN	-31.5863	63.1727	141	2	65.1727	65.2014	0.00000	0.098563
4	PARA	-31.5863	63.1727	141	5	65.1727	65.2014	0.00000	0.098563
5	SW_IN + PARA + SW_IN*PARA	-31.1083	62.2167	141	4	66.2167	66.3036	1.10220	0.056803

Results show the Log-Likelihood function (Log L), number of estimated parameters (K), selection criterion (AIC<sub>C</sub>), simple differences ( $\Delta AIC_C$ ), and Akaike weights ( $\omega$ ). DATE represented the Julian day on which a nest was discovered, TURBINE represented the distance of a nest from a wind turbine, PARA represented a categorical variable indicating whether a nest was brood parasitized or not, and SW\_IN represented the distance of the nest within shrub-woodland from that habitat edge



TABLE 3.—Total Akaike weight of each predictor variable across the candidate models used in a logistic-exposure to determine which combination of predictor variables best explained nest fate in five shrub-nesting birds at the Wolf Ridge wind facility in north-central Texas in 2009. DATE represented the Julian day on which a nest was discovered, TURBINE represented the distance of a nest from a wind turbine, PARA represented a categorical variable indicating whether a nest was brood parasitized or not, and SW\_IN represented the distance of the nest within shrub-woodland from that habitat edge

Species	Predictor variable total Akaike weight [ $w + (i)$ ]			
	DATE	TURBINE	PARA	SW_IN
White-eyed Vireo	0.615	0.394	0.502	0.399
Blue-gray Gnatcatcher	0.034	0.961	1.000	0.061
Northern Cardinal	0.285	0.387	NA	0.328
Painted Bunting	0.585	0.325	0.674	0.563
Lark Sparrow	0.361099	0.334	0.493	0.553

difference in strength between the three variables (Table 3). Finally only one model was found to best-support nest fate in Blue-gray Gnatcatchers and that was an interaction between distance from turbine and brood parasitism ( $\Delta AIC_C = 0$ ; Table 2). This model accounted for 0.87 of the Akaike weight alone and TURBINE as a predictor variable had a total Akaike weight of 0.96 [ $w + (i)$ ; Table 3], indicating that distance from turbine was strongly associated with nest fate in Blue-gray Gnatcatchers.

#### DISCUSSION

Our results indicate proximity of nests to wind turbines at the Wolf Ridge wind facility had no influence on the overall nest success of the species of shrub-nesting birds investigated, with the exception of the Blue-gray Gnatcatcher. The logistic-exposure analysis revealed the model with the strongest support for predicting nest fate for this species was the interaction between distance from turbine and brood parasitism. Our findings suggest the presence of wind turbines may reduce the probability of brood parasitism, which in turn reduces nest failure among Blue-Gray Gnatcatchers. We note we were limited by the single year scope of this study and inter-annual variation is likely to have a substantial effect on brood parasitism specifically, and nest success more broadly, in the study system. However, our study uncovers an interesting pattern in brood parasitism and distance to wind turbine that cannot necessarily be explained by naturally fluctuating variables and therefore warrants further investigation.

As an important determinant of nest fate, it is reasonable to assume the variables that dictate brood parasitism rates will also be important in nest fate (Goguen *et al.*, 2009). In general studies have found that brood parasitism increases with proximity to anthropogenic influences such as urban development (Rodewald, 2009; Borgmann and Morrison, 2010). These increases have been associated with the provision of additional resources (*i.e.*, bird feeders, exotic shrubs, etc.). In contrast wind turbines do not appear to offer any resources that would be beneficial to Brown-headed Cowbirds, and the turbines may have detrimental implications. For example the wind turbines themselves may provide potential vantage points for aerial predators (Pruett *et al.*, 2009b; Liebezeit *et al.*, 2009). There is also growing concern among wildlife managers that the flicker range (the shadow created by the passing blades) may affect wildlife (IDNR, 2007). While no study to date has been conducted into the effects of flicker range, shadows are used by many prey species as visual indicators of approaching aerial predators (Cooper, 2009; Lohrey *et al.*, 2009; McCoy *et al.*, 2009). It is

therefore plausible, as an environmental cue, that Brown-headed Cowbirds are associating wind turbines with an increased risk of predation and are thus actively avoiding nests close to turbines. Nevertheless during our surveys, we observed flocks of Brown-headed Cowbirds foraging within 100 m of wind turbines, suggesting that they are not sensitive to the presence of turbines, at least during these activities.

It is also possible the noise created by the wind turbines and/or moving shadows within the flicker range may simply be restricting the Brown-headed Cowbird's ability to detect nests. As both predators and parasites tend to be visually orientated, activities of parents may provide important visual cues as to the location of a nest (Banks and Martin, 2001; Remes, 2005). Thus if the flickering shadows created by the moving wind turbine blades obscured the Brown-headed Cowbirds' ability to effectively see the activities of adults and/or increased noise levels prevented Cowbirds from audibly locating adults, we would expect a decrease in brood parasitism rates closer to wind turbines (Pietz *et al.*, 2009; Svagelj *et al.*, 2009). This hypothesis supports our findings at Wolf Ridge and therefore warrants further research.

#### FUTURE RESEARCH

The results of our study at Wolf Ridge indicate that wind turbines may have positive implications for particular passerine species, such as the Blue-gray Gnatcatcher, that are susceptible to brood parasitism by Brown-headed Cowbirds. For species of concern, brood parasitism can potentially have negative population-wide effects on reproductive success (Curson *et al.*, 2010; Farrell *et al.*, 2010). Property and wildlife managers are therefore under regulatory and social pressure to devise management strategies that reduce the impact of brood parasites (Kosciuch and Sandercock, 2008; Rasmussen *et al.*, 2009; Farrell *et al.*, 2010). If proximity of wind turbines does decrease the risk of brood parasitism in some shrub-nesting bird species, thereby increasing their nest survival, and does not impact the nesting success of other species, there may be a beneficial outcome of wind energy development. We recommend that further studies determine whether the presence of wind turbines, particularly the flicker range, influence brood parasites, such as the Brown-headed Cowbird.

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