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Original Research Article

Ultrasonic acoustic deterrents significantly reduce bat fatalities at wind turbines

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ABSTRACT

Wind turbines are known to cause bat fatalities worldwide. Ultrasonic acoustic deterrents are a potential solution to reduce impacts on bats, but few experimental field studies have been conducted at utility scale wind energy facilities. Our objective was to assess effectiveness of a recently developed deterrent for reducing bat fatalities at wind turbines in southern Texas, USA. We quantified fatalities at control (deterrents off) and treatment (deterrents on) wind turbines from 31 July through 30 October in 2017 and 2018, and assessed deterrent effectiveness using generalized linear mixed models. Our results indicate deterrents significantly reduced bat fatalities for *Lasiurus cinereus* and *Tadarida brasiliensis* by 78% and 54%, respectively. We observed no significant reduction in fatalities for other species in the genus *Lasiurius*. Thus, deterrents represent a potential impact reduction strategy for some bat species, but research is still warranted to improve species-specific effectiveness.

1. Introduction

For some species of bats, wind energy development is considered one of the largest sources of direct mortality in the world (O'Shea et al., 2016). Bats are long-lived, slow reproducing mammals, and thus may be unable to recover from large-scale sustained mortality events, such as those resulting from wind turbines (hereafter turbine; Frick et al., 2017). As global wind energy development expands to meet energy demands (Bernstein et al., 2006) and mitigate climate change (Intergovernmental Panel on Climate Change, 2011), these impacts need to be managed, especially since bats provide crucial ecosystem services (i.e., pest control, pollination; Boyles et al., 2011; Ghanem and Voigt, 2012). Despite this need, few practicable solutions for reducing these impacts exist (Arnett et al., 2016).

Currently, the only proven method of reducing turbine-caused bat fatalities is curtailment (i.e., feathering turbines and raising nighttime cut-in speeds above the manufacturer's cut-in speed during the higher risk periods of late summer and early autumn). Although effective, curtailment is cost-prohibitive in many circumstances and limits low carbon renewable

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energy generation (Baerwald et al., 2009; Arnett et al., 2011). As a result, where laws and regulations do not require fatality reduction strategies, few companies implement curtailment at wind speeds above manufacturer cut-in speeds (Arnett et al., 2016). Moreover, in regions of lower wind speed, curtailment may not be practicable (Arnett et al., 2013; Hayes et al., 2019). New technologies that reduce the risk to bats without impacting turbine operations would represent a mutually beneficial solution for conservationists and wind energy producers.

Insectivorous bat species emit ultrasonic (>20 kHz) vocalizations to echolocate. Returning echoes of these vocalizations reflected from nearby objects is used as a means of sensory perception (Jones and Teeling, 2006). Some insect prey have coevolved mechanisms to deter bat predation by emitting their own ultrasound; effectively "jamming" or masking an approaching bat's ability to receive and/or decipher its own echolocation, thereby reducing capture success (Corcoran et al., 2009; Corcoran and Conner, 2012). If bats are unable to effectively forage near competing ultrasound emissions, then using ultrasound to dissuade bats from approaching turbines may provide a practicable impact reduction strategy for the wind energy industry.

Between 2009 and 2010, the first experimental test of ultrasonic acoustic deterrents (hereafter deterrents) was conducted at an operational wind energy facility in Pennsylvania (Arnett et al., 2013). Despite operational challenges with the devices (e.g., water entry and overheating), there was an 18–62% reduction in overall fatalities, with statistically significant reductions for low-frequency calling species. Nevertheless, results from large experimental studies at other wind energy facilities have shown mixed results, with significant reduction for some species but not for others (C. Hein, unpublished data), as well as interannual variation in effectiveness (Romano et al., 2019). Moreover, at the time of this study no commercial ready systems existed.

Our objectives were to (1) assess overall and species-specific effectiveness of a deterrent technology for reducing bat fatalities at an operational wind energy facility, and (2) determine functionality of deterrents to meet mechanical expectations in a variety of weather conditions. We report one of the first successful studies of a mechanically viable deterrent capable of significantly reducing bat fatalities at wind turbines for specific species.

2. Methods

This research was conducted in accordance with the Texas State University Institutional Animal Care and Use Committee (IACUC) permit number 20171185494, and Texas Parks and Wildlife Department (TPWD) permit number SPR-0213-023. In addition, we followed guidelines of the American Society of Mammalogists (Sikes and Gannon, 2011).

2.1. Study area

We tested a newly developed deterrent technology at the Los Vientos III, IV, and V wind energy facilities (hereafter Los Vientos) near Rio Grande City, Starr County, Texas, USA. The three facilities were treated as a single facility for this study because they are adjacent to one another and are equipped with a total of 255 identical Vestas V-110, 2-MW turbines. All turbines had a nacelle height of 95 m, a rotor diameter of 110 m, and were feathered up to the manufacturer's cut-in speed of 3.0 m/s. The southernmost boundary and turbine of Los Vientos are approximately 3.8 km and 10.1 km north from the U.S.–Mexico border, respectively (Fig. 1).

2.2. Turbine selection, deterrent installation, and treatment schedule

We conducted our study from 31 July to 30 October 2017 and 2018. We randomly selected 16 turbines for testing and reviewed turbine selection to ensure they were distributed across the study site and were a representative sample of the different habitat types (crops, grasslands, and thornscrub) encompassed at the facility.

Deterrents were manufactured by NRG Systems (Hinesburg, VT). Each deterrent consisted of a waterproof box with 6 subarrays. Each subarray emitted a continuous high frequency sound at one of the following predetermined frequencies (kHz): 20, 26, 32, 38, 44, and 50. Therefore, deterrents emitted a frequency range from 20 to 50 kHz. This frequency range overlaps with the characteristic frequency of most bat species in the U.S. The sound pressure level, measured at 1 m, averages 120 dB (dB).

In 2017, we equipped all 16 turbines with 6 deterrents, each mounted on the nacelle (4 on the top and 2 on the bottom). We selected this configuration based on prior behavioral research indicating most bats approach turbines from the leeward (downwind) side and investigate the nacelle region behind the rotor-swept area (Cryan et al., 2014). We, therefore, positioned deterrents so sound was projected leeward of the turbines, assuming that encountering deterrent sound upon first approach would cause bats to change course and leave the airspace around a turbine. However, a concurrent study using the same model of deterrents at a different facility suggested bats may alter activity away from the nacelle and toward the rotor-swept area, instead of avoiding turbines altogether (NRG Systems, personal communication, March 28, 2018). In 2018, we changed the configuration on all 16 turbines and removed a unit positioned on the back of the nacelle such that there were only 5 deterrents per turbine (3 on top and 2 on bottom). We also reoriented three deterrents to face toward the rotor-swept area (see Figs. S1–S5, Supporting Information). To account for potential spatial and temporal variability in bat fatalities, we used a randomized block design with turbine as the blocking factor. Each night, we randomly assigned 8 turbines to the control (i.e., deterrents off) and 8 to the treatment (i.e., deterrents on) groups; each turbine was both a control and treatment turbine

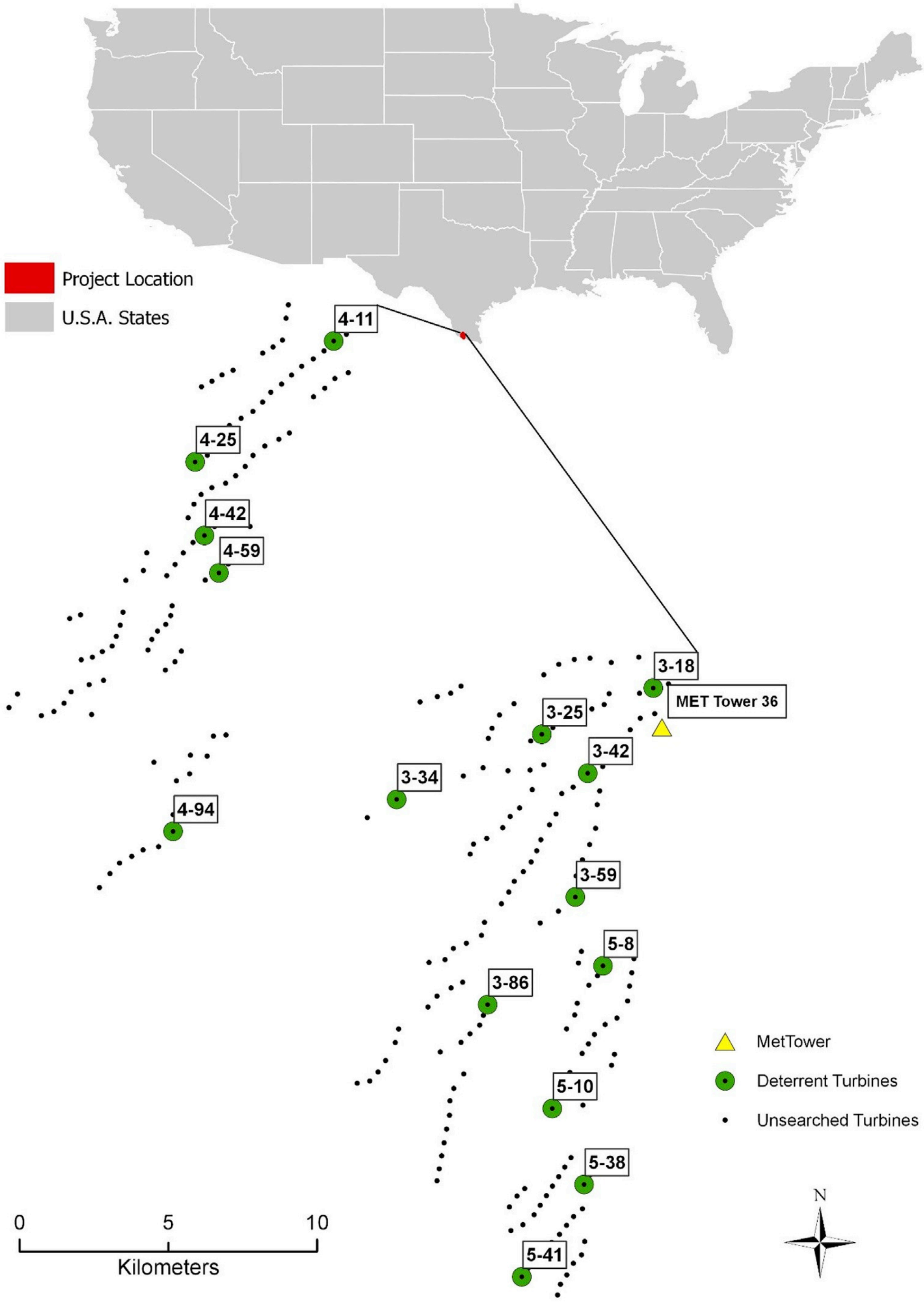

Fig. 1. Study area map. Each study wind turbine was retrofitted with 6 deterrents, manufactured by NRG systems, in 2017, and 5 deterrents in 2018, at Duke Energy Renewable's Los Vientos wind energy facility in Starr County, Texas, USA. Weather data for this study were taken from meteorlogical (MET) tower 36, with its location displayed in the map.

during the study. The assignment schedule was originally balanced every 16 nights to ensure each turbine received treatment and control conditions equally during the study period. However, in 2017 we experienced several technical difficulties with scheduling the deterrents resulting in incorrectly assigned treatments during seven nights of the study and an unbalanced design. Although we did not experience these issues in 2018, during both years conditions that caused turbines to go unsearched (described below) also contributed to an unbalanced design. In addition, there was a delay in updating the deterrent configuration for one turbine in 2018 that resulted in a reduced search effort for that particular turbine.

2.3. Bat fatality surveys

We established circular search plots measuring 100 m in radius surrounding each of the 16 turbines, with linear transects within the plot spaced 5 m apart and oriented north-south. We conducted daily carcass searches at all 16 turbines when possible. Reasons for abandoned searches included unsafe weather (e.g., lightning) and site conditions (e.g., flooded roads). Searches began 15 min after sunrise, and technicians walked each transect at a rate of approximately 60 m/min, searching 2.5 m on each side of the transect line for 100% plot coverage. We cleared search plots of vegetation biweekly to increase visibility and carcass detection. We identified species either via morphological traits or using species barcoding to genetically confirm identification of all yellow bat and red bat carcasses, because of morphological similarities, and for any carcasses we were unable to identify morphologically.

2.4. Data analysis

We used only fresh carcasses (i.e., those determined to be killed the previous night) found in search plots during scheduled searches. These carcasses could confidently be assigned to a treatment or control group. The identification of fresh carcasses was based on several factors, including insect load, pliability of wings, presence of fluid in the eyes, and odor. We randomly assigned and blocked on the turbine the search schedule for each day. Therefore, adjustments for detectability between turbines were not necessary. Field technicians were unaware of nightly turbine assignments to eliminate any potential searching bias. To assess the effectiveness of deterrents at reducing bat fatalities, we used a randomized block design with turbine as the blocking factor and night-within-turbine as sampling unit. The total number of carcasses attributed to each treatment at each turbine per night was the response variable. To quantify effectiveness of the deterrent, we used a generalized linear mixed model (GLMM), with turbine as random effect and treatment as fixed effect, using the package "glmmTMB" version 0.2.3 (Brooks et al., 2017) in R version 3.5.3 (R Development Core Team, 2019). We tested Poisson, type 1 negative binomial (NB1), and type 2 negative binomial (NB2) error distributions with and without zero inflation and selected the lowest Akaike information criterion (AIC) value to determine the best-fit model. We did this for all bats and by species when sample size was large enough. We conducted an additional GLMM to test if configuration influenced effectiveness, again testing for best-fit family distribution, but only included carcasses discovered at treatment turbines as the response variable, year as a fixed effect, and turbine as a random effect. We calculated percent reduction and 95% confidence intervals for all bats and by species, when sample size was sufficient. We also compared carcass-fall distribution from turbines for each group to determine if deterrents caused a shift in bat activity toward the blade tips, known as the "push" effect, which could result in carcasses falling farther from treatment turbines than control turbines.

3. Results

Based on combined data from both years, we conducted a total of 2560 searches, 1282 at control turbines and 1278 at treatment turbines. We found 627 fresh bat carcasses comprising 8 species and 1 species group during standardized searches for carcasses identified as killed the previous night. We were unable to identify to species one carcass due to scavenging and did not obtain tissue from which to perform genetic analysis. Of the 627 carcasses, 78% (n = 486) were *Tadarida brasiliensis* (Table 1). We found approximately 33% of carcasses at treatment turbines, and 67% at control turbines.

The total number of carcasses discovered at individual turbines, irrespective of treatment schedule, ranged from 23 at turbine 3−86, to 40 at turbine 3−34. The total number of carcasses discovered by day ranged from 0 to 35, with the latter occurring on October 19, 2018. No differences exist in the fall distribution of carcasses between controls and treatments (Fig. 2).

Results indicate deterrents significantly reduced fatalities for all bats, and for *L. cinereus* and *T. brasiliensis*; however, they did not have a statistically significant effect on *L. intermedius* fatalities (Table 2). The mean number of bat carcasses per night

Table 1
Total number of fresh bat carcasses and species composition of carcasses discovered at control (deterrents off) and treatment (deterrents on) turbines during scheduled carcass searches at Los Vientos wind energy facility, Starr County, Texas, from 1 August −31 October 2017 and 2018.

Species	Total at Treatments	Total at Controls	Total	Reduction (%)
Tadarida brasiliensis	152	334	486	54.5
Lasiurus intermedius	25	20	45	−25.0
Lasiurus cinereus	8	37	45	78.4
Lasiurus ega	15	9	24	−66.7
Nycticeius humeralis	6	10	16	40.0
Lasiurus xanthinus	1	4	5	75.0
Lasiurus spp.	0	2	2	100.0
Lasiurus blossevillii	2	0	2	–
Unidentified spp.	0	1	1	100.0
Myotis velifer	0	1	1	100.0
Total Bats	**209**	**418**	**627**	**50.0**

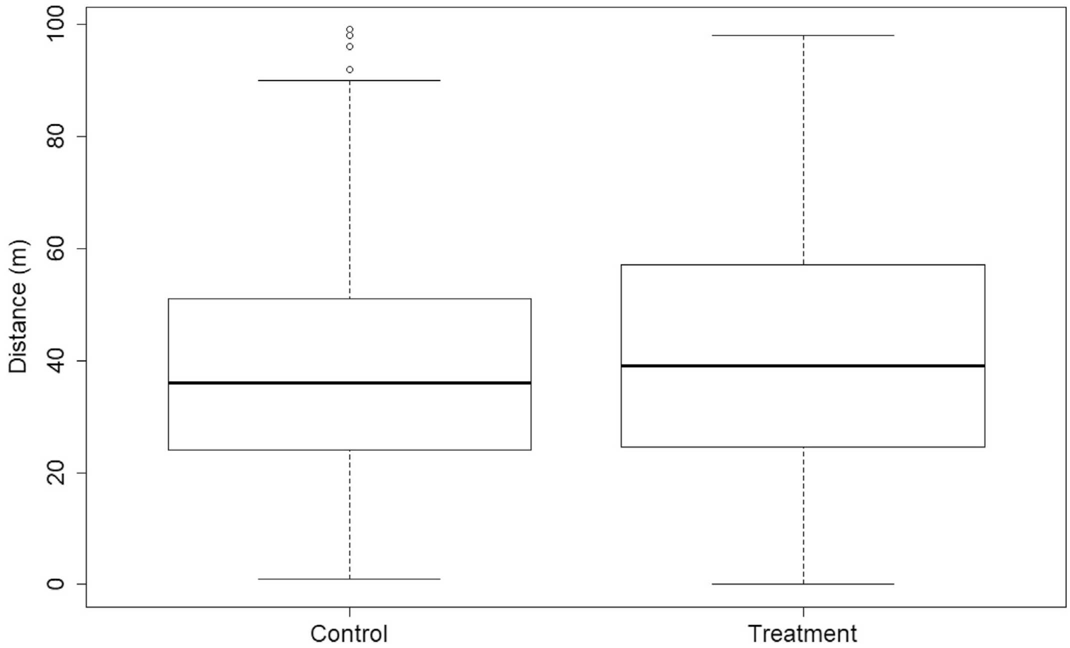

Fig. 2. Box plots of distance from turbine of bat carcasses at control (deterrents off) and treatment (deterrents on) turbines discovered during fatality monitoring at the Los Vientos wind energy facility in Starr County, Texas, USA from 1 August 2017 through 31 October 2017 and 2018.

Table 2
Top-ranked generalized linear mixed models of deterrent effect on bat fatalities at Los Vientos wind energy facility, Starr County, Texas, from 1 August −31 October 2017 and 2018.

Species	Distribution	Predictor	Coefficient	*SE*	z	Pr(>|z|)
All Bats	NB2	Intercept	−1.139	0.088	−12.976	<2e −16
		Treatment	−0.688	0.111	−6.214	5.17e −10
L. cinereus	NB1	Intercept	−3.547	0.198	−17.920	<2e −16
		Treatment	−1.555	0.416	−3.738	0.000185
T. brasiliensis	NB2	Intercept	−1.368	0.101	−13.498	<2e −16
		Treatment	−0.782	0.132	−5.909	3.44e −09
L. intermedius	Poisson	Intercept	−4.161	0.223	−18.606	<2e −16
		Treatment	0.226	0.300	0.754	0.451
	NB2	Intercept	−4.160	0.226	−18.386	<2e −16
		Treatment	0.226	0.304	0.744	0.457
	NB1	Intercept	−4.148	0.225	−18.455	<2e −16
		Treatment	0.203	0.3028	0.671	0.502

found at control turbines was 0.326 (95% *CI*: 0.280−0.372), which was 2.0 times higher than at treatment turbines 0.164 (95% *CI*: 0.127−0.200; Fig. 3a). Overall, there was a 50.0% (95% *CI*: 38.5−61.2%) reduction in fatalities at treatment relative to control turbines for all bats, independent of species. The mean number of *L. cinereus* carcasses per night found at control turbines was 0.029 (95% *CI*: 0.019−0.039), which was 3.91 times higher than those found at treatment turbines 0.006 (95% *CI*: 0.001−0.011; Fig. 3b). The average number of *T. brasiliensis* carcasses per night found at control turbines was 0.261 (95% *CI*: 0.219−0.302), which was 2.19 times higher than those at treatment turbines 0.119 (95% *CI*: 0.086−0.152; Fig. 3c). Overall, there was a 78.4% (95% *CI*: 61.5−95.1%) reduction in fatalities for *L. cinereus*, and a 54.5% (95% *CI*: 41.5−67.1%) reduction in *T. brasiliensis* fatalities. The average number of *L. intermedius* carcasses found at control turbines per night was 0.016 (95% *CI*: 0.009−0.022; Fig. 3d), which was 1.3 times lower than those found at treatment turbines 0.020 (95% *CI*: 0.012−0.028).

Results of GLMMs on treatment-only data indicated two competing models, NB1 and NB2, with AIC weights of 1177.9 and 1178.1, respectively. While the NB1 model returned a significant result ($\beta = 0.331$, SE $= 0.161$, $Z = 2.06$, $p = 0.039$), it was indistinguishable from the NB2 model, which showed deterrent configuration did not influence number of carcasses found between 2017 and 2018 ($\beta = 0.194$, SE $= 0.179$, $Z = 1.08$, $p = 0.279$). The overall fatality reduction was 45.9% in 2017 and 53.6% in 2018.

When we assessed the mechanical performance of deterrent units, we found a single subarray on one deterrent needed replacing during testing in 2017. No mechanical or functional issues occurred for any units during testing in 2018. Between 2017 and 2018 when testing was not occurring, an additional 4 subarrays failed and were replaced before the 2018 testing

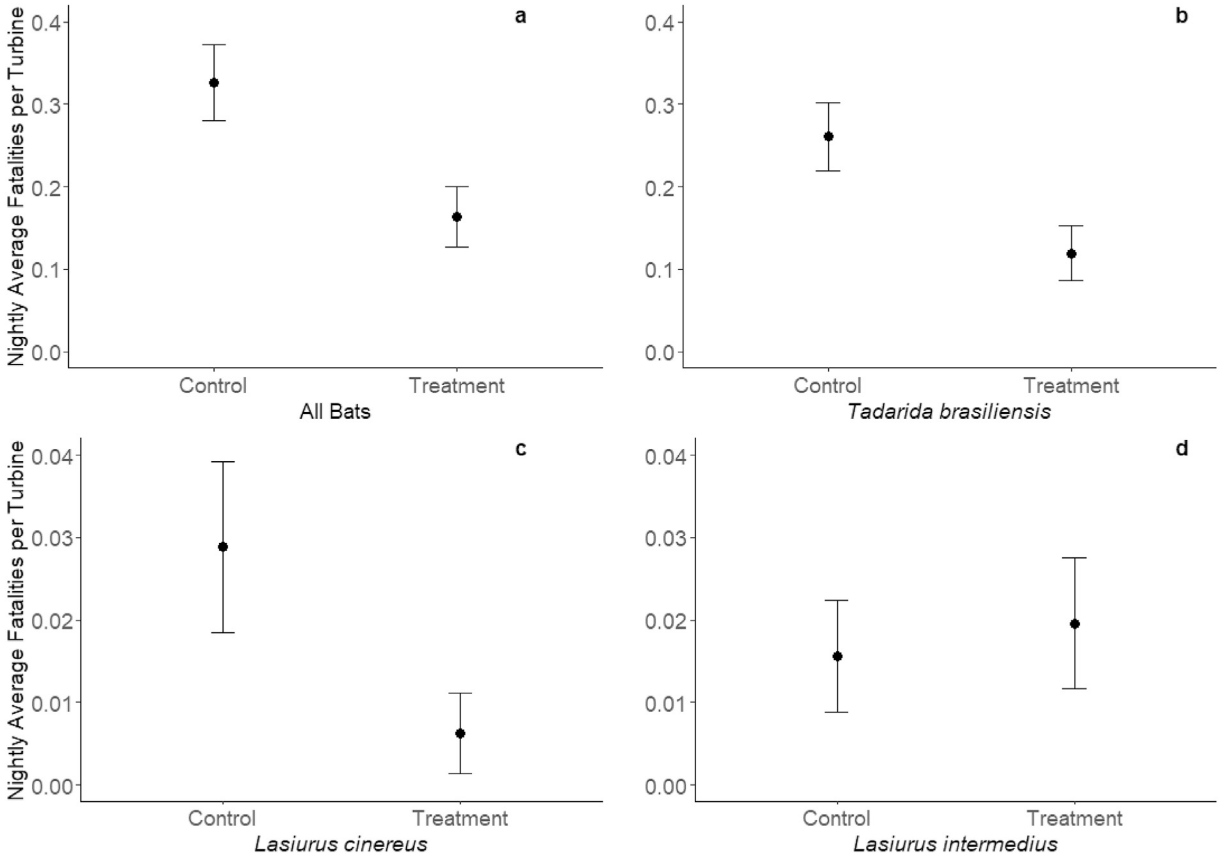

Fig. 3. Point estimates and 95%-confidence intervals of nightly bat fatalities per turbine at control (deterrents on) and treatment (deterrents off) turbines for all bats combined (a), *Tadarida brasiliensis* (b), *Lasiurus cinereus* (c), and *Lasiurus intermedius* (d) at Los Vientos wind energy facility in Starr County, Texas, USA. Note y-axis scales vary for discernibility.

season. No whole unit failures were detected at any point during or after testing both years, and deterrents functioned as expected for 99.5% of the study period.

4. Discussion

Overall, we observed a significant reduction in bat fatalities at deterrent turbines. Where possible, we documented species-specific responses, but for 6 species/species groups data were insufficient to model independently, thus we report results for all species combined. Based on our results, deterrents can be an effective impact reduction strategy for *L. cinereus* and *T. brasiliensis*, which can incur high fatalities at wind energy facilities (Piorkowski and O'Connell, 2010; Weaver, 2019). Although other natural and anthropogenic stressors can influence bat population dynamics, impacts from wind energy appear to be the primary stressor for migratory tree-roosting bats in North America, particularly for *L. cinereus;* fatalities for this species constitute nearly one third of all wind turbine-related bat fatalities reported (Arnett and Baerwald, 2013; Allison and Butryn, 2018) and assuming a similar growth rate to other bat species ($\lambda = 1.01$; see Frick et al., 2017), it is considered a species at risk of population-level declines from wind energy impacts (Frick et al., 2017). However, Frick et al. (2017) did not account for the effect of implementing impact-reduction strategies in population models. A recent study expanding on their effort was conducted to determine reduction levels at wind energy facilities necessary to lower probability of extinction to <1% by 2050. This study found a reduction of 78% would be sufficient to manage extinction risk in a population of at least 1.9 million *L. cinereus* bats (N. Friedenberg, personal communication, September 28, 2019). According to Frick et al. (2017), the most likely population size of *L. cinereus* is 2.25 million. This indicates that if deterrents are widely implemented within their range, and effectiveness remains similar, population-level declines from wind energy impacts may be greatly reduced.

Deterrents might also be effective for the subspecies, *L. cinereus semotus*, which is a federally endangered species found only on the Hawaiian Islands, USA (U.S. Fish and Wildlife Service, 2011), and have been recently deployed at a commercial wind energy facility for this purpose. The success of deterrents is also important for *T. brasiliensis*, a species that concentrates in the tens of millions during summer in Oklahoma, Texas, and northern Mexico, and annually migrates through these regions (Wilkins, 1989; Ammerman et al., 2012; Schmidly and Bradley, 2016), which are becoming areas of expanding wind energy development (American Wind Energy Association, 2019; Mexican Association of Wind Energy [Spanish translation—Associación Mexicana de Energía Eólica; AMDEE], 2019).

Tadarida brasiliensis and *L. cinereus* are considered two of the most widespread mammals in the Americas (Shump and Shump, 1982; Wilkins, 1989). In addition to fatalities in North America, *T. brasiliensis* have incurred fatalities at wind energy facilities in Puerto Rico (Rodríguez-Durán and Feliciano-Robles, 2015), and fatalities of both species have been documented at wind energy facilities in South America (Escobar et al., 2015). Moreover, when considering the number of commercially operating wind turbines within the ranges of *L. cinereus* (Fig. 4) and *T. brasiliensis* (Fig. 5) in the continental U.S. and Mexico alone, the opportunity to apply this technology to aid the conservation of these species extends well beyond our study site.

Although deterrents were effective for some species, we did not detect an effect for northern yellow bats, confirming species-specific responses. Arnett et al. (2013) also reported differences among species, using a different manufacturer's technology, with significant reductions in fatalities for *L. cinereus* and *Lasionycteris noctivagans* only. Species-specific responses are not surprising, given differences in echolocation call characteristics and behaviors (Schnitzler et al., 2003; Jones and Holderied, 2007). For example, *L. cinereus* and *T. brasiliensis* calls have lower characteristic frequencies (19–24 kHz and 22–26 kHz, respectively; Szewczak et al., 2011) than that of *L. intermedius* (27–30 kHz; Szewczak et al., 2011). Sound attenuates faster as frequency-level increases (Griffin, 1971). Therefore, the deterrent's effective range is shorter at higher frequencies. Based on deterrent testing conducted at ponds, bats detect and respond to deterrent ultrasound between 50 and 55 dB (M. Chaffee, personal communication, April 15, 2020). If this is true, then at the more conservative estimate of 55 dB bats would be able to detect deterrent broadcasts of 20 kHz from 82 m away, which is 35 m farther than 30 kHz (Fig. 6). Thus, bats using lower-frequency calls may respond to deterrents at a greater distance from turbines, compared to those using higher-frequency calls. However, other reasons for species-specific effectiveness, such as behavioral differences, should be investigated. Additional studies should also be conducted to determine if effectiveness will vary with increasing blade lengths.

Because of sound attenuation, it is not possible for nacelle-mounted deterrents to ensonify the entire rotor-swept area at all frequencies (Arnett et al., 2013). As a result, it has been suggested that bats may shift their activity centers toward the edge

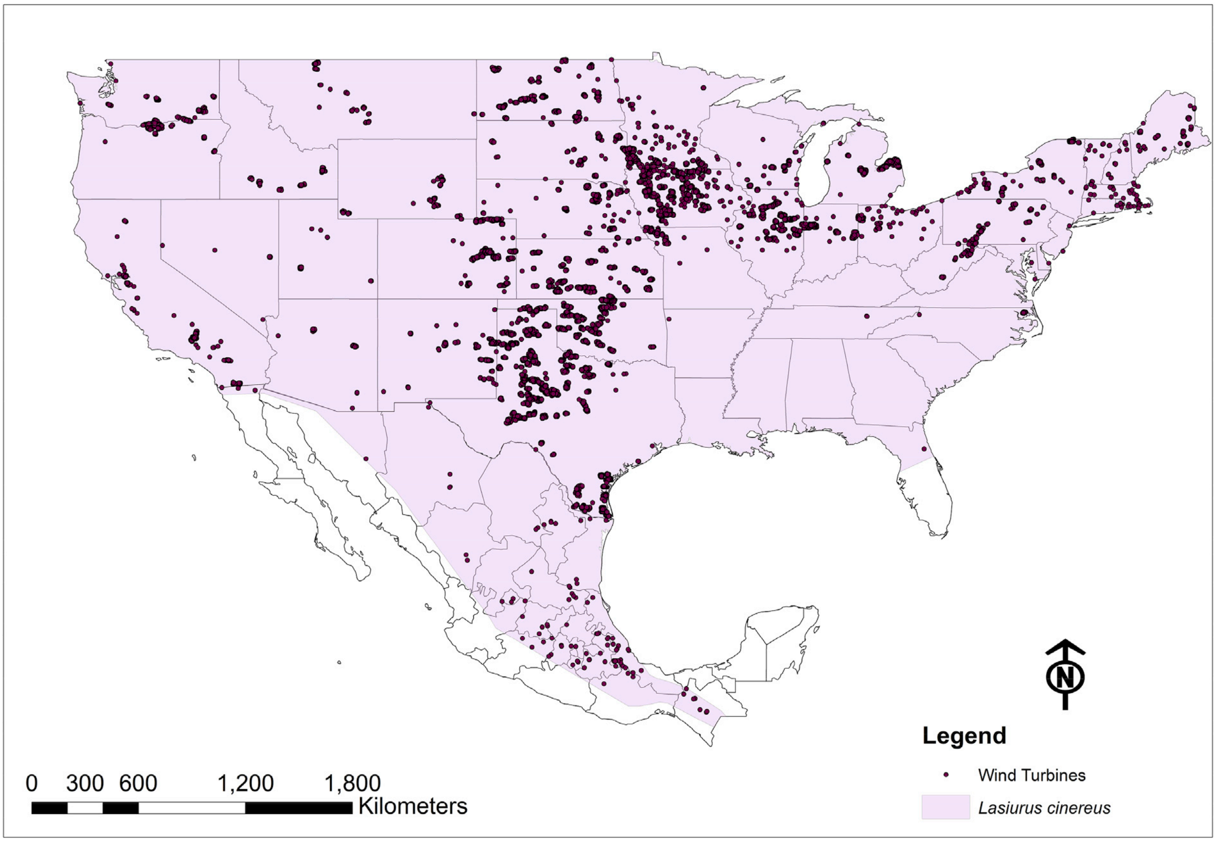

Fig. 4. *Lasiurus cinereus* IUCN (International Union for the Conservation of Nature) Red List range map (Gonzalez et al., 2016) and commercially operating wind turbines within its range in the continental U.S. (Hoen et al., 2020) and Mexico (Draxl et al., 2015). Areas with larger circles indicate higher densities of wind turbines. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

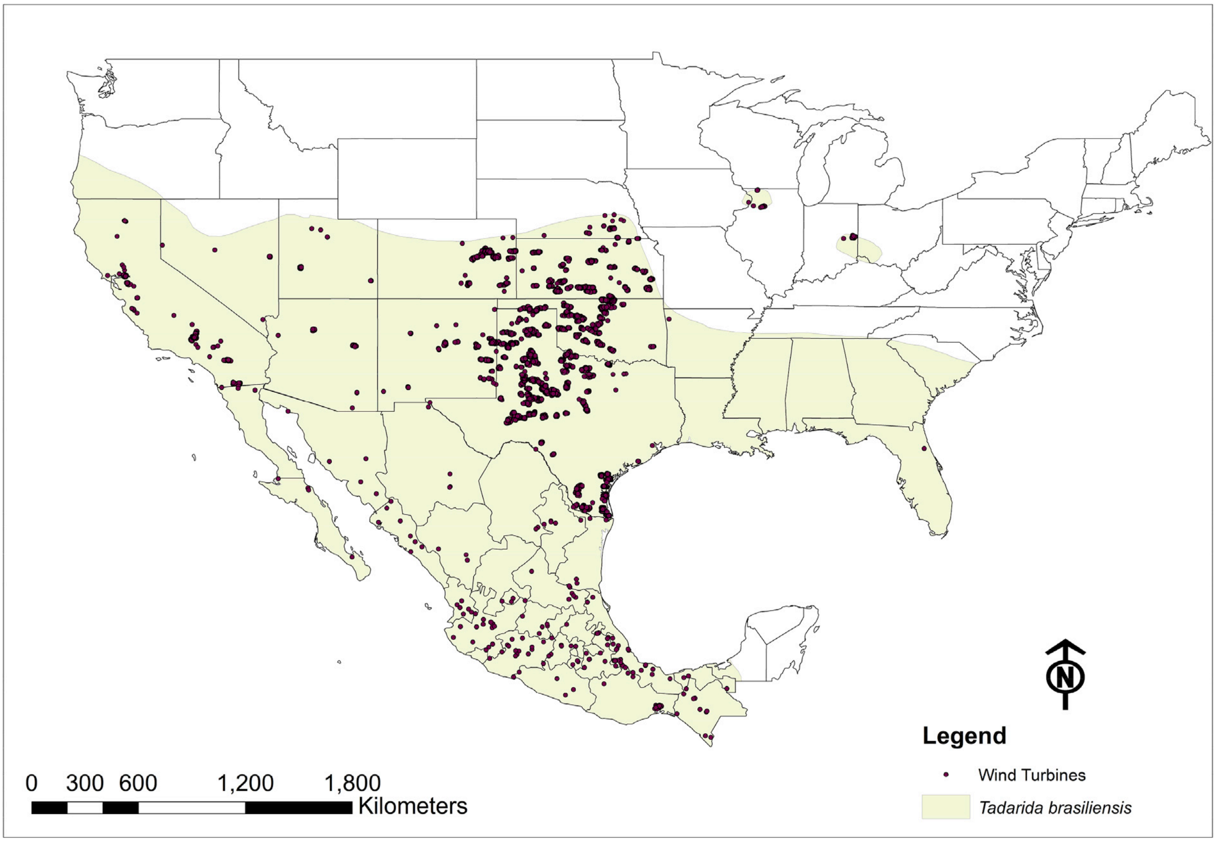

Fig. 5. *Tadarida brasiliensis* IUCN (International Union for the Conservation of Nature) Red List range map (Barquez et al., 2015), and commercially operating wind turbines within its range in the continental U.S. (Hoen et al., 2020) and Mexico (Draxl et al., 2015). Areas with larger circles indicate higher densities of wind turbines. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

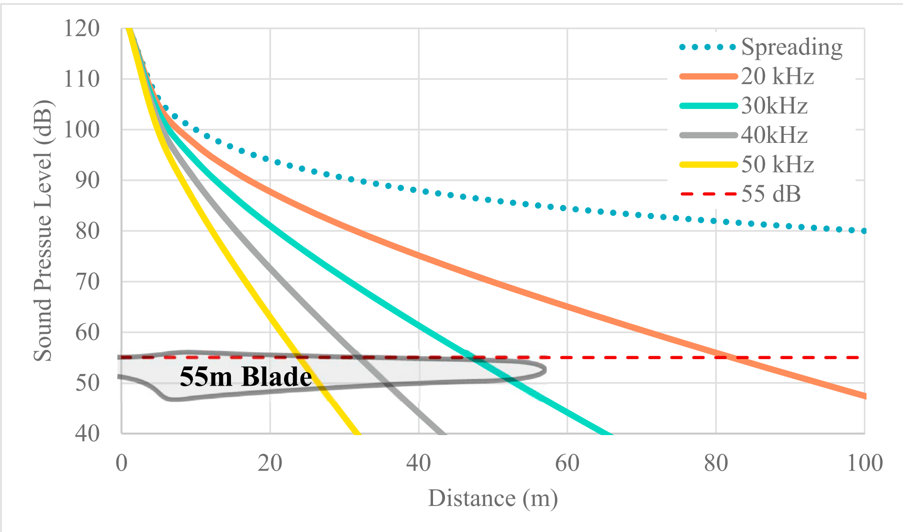

Fig. 6. Sound pressure level (SPL) of ultrasound produced at 20 kHz (solid orange), 30 kHz (solid teal), 40 kHz (solid gray), and 50 kHz (solid yellow) between 0 and 100 m based on a starting SPL of 120 dB measured at 1 m. Calculations incorporate spreading loss (dotted blue) due to distance and mean attenuation coefficients based on hourly temperature (°C), relative humidity (%), and pressure (kPa) acquired from a meteorological tower at Los Vientos wind energy facility in Starr County, Texas, USA. The red dashed line represents the presumed SPL (55 dB) necessary to deter bats. The turbine blade length of the Vestas V-110, 2-MW turbines used at the Los Vientos is included for reference. Figure adapted from NRG Systems. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

of the rotor-swept area where blade speed is highest to avoid deterrent broadcasts (Romano et al., 2019). If this occurs, then distances bats fall from turbines might differ, with bats being found farther from treatment turbines than from controls. However, based on carcass distribution data, this pattern did not emerge, indicating it is not a concern for the species in our study. Moreover, Romano et al. (2019) also found similar carcass distribution patterns between control and treatment turbines, providing further support that current deterrent technologies do not cause a “push” effect.

Deterrents were exposed to rain, ice, and temperatures exceeding 33 °C during our trials. Despite this, the failure rate was <1%, which is encouraging, given equipment malfunctions experienced by Arnett et al. (2013). However, it remains unclear how long deterrents can withstand extreme weather conditions and the long-term functioning of these devices is unknown.

5. Conclusions

Few studies have evaluated the use of acoustic deterrents through experimental field studies at wind energy facilities, and this study represents an important advance in our understanding of deterrent effectiveness. In the U.S., curtailment is the only available impact reduction strategy supported by U.S. Fish and Wildlife Service in Habitat Conservation Plans to minimize or eliminate take of listed bat species at wind energy facilities (Arnett et al., 2016; MidAmerican Energy Company, 2019). Based on our results, fatality rates of *L. cinereus* and *T. brasiliensis* at wind turbines may be significantly reduced if deterrents are installed at wind energy facilities within the range of these species, particularly in lower latitudes of the U.S. and Latin America where timing of migration and behaviors are most likely to be similar. However, additional studies in other regions to support this conclusion are necessary. Moreover, other impacted species occurring outside our study site with similar flight behaviors and/or echolocation characteristics may benefit from deterrents, such as *L. noctivagans* and *Eptesicus fuscus* in North America, and other Molossid bats around the world such as *T. aegyptiaca*, *T. australis*, and *T. insignis* (Arnett et al., 2016).

Our results indicate deterrents successfully reduced fatality for certain species of bats but warrants additional research to improve their applicability for a wider range of species. We recommend continued studies to assess species-specific responses and further refinement of deterrents (e.g. increases in sound pressure levels) to increase the effectiveness of this technology; one such study is currently underway at an outdoor bat flight facility constructed at Texas State University in San Marcos, Texas in collaboration with the National Renewable Energy Laboratory (Department of Energy, 2019). . The wind energy and wildlife community needs multiple options to achieve common goals of maximizing wind power generation and minimizing impacts to bats. Deterrent technology may provide an additional impact reduction option for wind energy operators worldwide by offering a solution that does not result in a loss of power generation (i.e., curtailment).

Declaration of competing interest

No part of the research has been published in any peer-reviewed journal and the manuscript is not being considered for publication elsewhere. The manuscript has been approved by all authors and institutions, and all individuals entitled to authorship have been so named. Any research not conducted by the authors is cited in full in the manuscript, and all appropriate ethics, permits and approvals were obtained for the research. No authors have a conflict of interest for the work conducted in this manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gecco.2020.e01099.

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