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Short communication

When the excrement hits the fan: Fecal surveys reveal species-specific bat activity at wind turbines

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ABSTRACT

The reasons why bats are coming into contact with wind turbines are not yet well understood. One hypothesis is that bats are attracted to wind turbines and this attraction may be because bats perceive or misperceive the turbines to provide a resource, such as a foraging or roosting site. During post-construction fatality searches at a wind energy facility in the southern Great Plains, U.S., we discovered bat feces near the base of a wind turbine tower, which led us to hypothesize that bats were actively roosting and/or foraging at turbines. Thus over 2 consecutive years, we conducted systematic searches for bat feces on turbines at this site. We collected 72 bat fecal samples from turbines and successfully extracted DNA from 56 samples. All 6 bat species known to be in the area were confirmed and the majority (59%) were identified as *Lasiurus borealis*; a species that also comprised the majority of the fatalities (60%) recorded at the site. The presence of bat feces provides further evidence that bats were conducting activities in close proximity to wind turbines. Moreover, feces found in areas such as turbine door slats indicated that bats were using turbines as night or foraging roosts, and further provided evidence that bats were active near the turbines. Future research should therefore aim to identify those features of wind turbines that bats perceive or misperceive as a resource, which in turn may lead to new minimization strategies that effectively reduce bat fatalities at wind farms.

As the demand for renewable energy has grown, it has led to the rapid installation of wind power facilities worldwide. As a result, many utility-scale wind farms became operational before it was apparent that wind turbines could have a negative impact on bats (Arnett and Baerwald, 2013). Subsequently there have been reports of bat fatalities, many of which represent multiple mortality events, from operational wind facilities globally (O'Shea et al., 2016; Chou et al., 2017). The majority of these mortality events appear to involve highly mobile or migratory bat species that cover a large geographic range (Arnett and Baerwald, 2013; Lehnert et al., 2014; Roscioni et al., 2014) and can potentially be impacted by the cumulative effects of multiple wind farms (Roscioni et al., 2013). With continued wind energy expansion, there are increasing concerns that there could be population-level implications for bats (O'Shea et al., 2016; Frick et al., 2017).

Thus, understanding why bats are coming into contact with wind turbines is crucial if we are to implement minimization strategies that effectively reduce bat fatalities. One hypothesis proposed by Cryan and Barclay (2009) is that bat fatalities occur because bats are attracted to wind turbines. By identifying the source of the bats' attraction we could potentially devise more targeted minimization strategies that limit bat activity in proximity to wind turbines, which in turn would reduce bat fatalities. A possible explanation for why bats may be attracted to wind turbines is that the turbines themselves provide a resource(s) for bats, such as foraging, mating, or roosting sites (Horn et al., 2008; Rydell et al., 2016). In support of this rationale, Cryan et al. (2014) suggested that the bat behavior they observed on the leeward side of wind turbines was similar to bat behavior seen at tall trees; structures that would provide bats with roosting, foraging, and mating opportunities. Another study by Long et al. (2011) demonstrated that the light grey color of turbine towers and blades attracted insects, suggesting that wind turbines could serve as a foraging resource that would be attractive to insectivorous bats. Given that wind turbines could potentially provide or be misperceived to provide one or more resources, the next step would be to identify those features of wind turbines that could be attractive to bats. Moreover, as the resource requirements of bats are species-specific, the features of wind turbines that attract bats will likely vary among species (e.g., Ammerman et al., 2011).

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For any bat species to be actively roosting and/or foraging at wind turbines, we would expect to find other signs or evidence of use by bats on or around the turbines, not just bat fatalities. For example, there are 3 signs that would indicate that bats are roosting at wind turbines: 1) the presence of roosting bats; 2) the presence of feces within or beneath a suitable roost site; and 3) staining, the brown patches left when bat urine evaporates beneath or on the walls of a roost site (Mitchell-Jones and McLeish, 2004). Furthermore, if bats were to frequently spend time, for example, foraging in close proximity to wind turbines we would expect fecal material to be deposited on the wind turbines and transformers. During post-construction fatality searches at a wind energy facility in the southern Great Plains, U.S., we discovered bat feces on a wind turbine tower. These observations led us to hypothesize that bats were actively roosting and/or foraging at the turbines. Thus over 2 consecutive years, we conducted systematic searches for bat feces around the bases of wind turbine towers at this wind facility to determine if any or all of the 6 bat species known to be in the area were active at turbines.

Our study site was Wolf Ridge Wind, LLC (33°43′53.5″N, 97°24′18.2″W) in the cross timbers and prairies ecoregion of north-central Texas. This facility, owned by NextEra Energy Resources, became operational in October 2008 and consists of 75 1.5-megawatt (MW) General Electric wind turbines (model GE 1.5xle) extended over 48 km^2. The wind turbines have a hub height of 80 m, blade length of 42 m, maximum tip height of 122 m, and are spaced at least 1 ha apart in a general east-west direction across open agricultural land used predominantly for cattle grazing (pastures), native hay harvesting, and winter wheat *Triticum aestivum* cultivation. There is an extensive shrub-woodland along the northern boundary of the wind resource area that leads down to the Red River escarpment. During a 5-year period (2009–2013) in which post-construction fatality monitoring took place at this site, 916 bat carcasses were collected (551 *Lasiurus borealis*, 258 *Lasiurus cinereus*, 3 *Lasionycteris noctivagans*, 22 *Perimyotis subflavus*, 49 *Nycticeius humeralis*, 30 *Tadarida brasiliensis*, and 3 unidentified bats; Bennett and Hale 2014), and species identifications were confirmed using DNA barcoding (Korstian et al., 2016).

From July to November 2011 and April to October 2012, we searched all 75 wind turbines for bat feces. These searches were conducted once a week over 2 consecutive days, in which half the wind turbines were searched the first day and the other half were searched on the second. Searchable areas at the wind turbines were separated into 3 sections: 1) the turbine tower (up to 3 m from the ground), stairs, and associated concrete pad; 2) the turbine door; and 3) the transformer and associated concrete pad. We then divided each of these sections into specific zones, parts, or sides. The turbine tower was divided into 5 zones, comprising four quarters of the turbine tower (i.e., zone 1 started after the stairwell next to the transformer), and the stairwell area leading to the turbine door (zone 5). The turbine door was divided into 4 parts including the door frame and light fixture, door face, and 2 sets of slats in the door face (an upper and lower set). Finally, the transformer next to the turbine tower was divided up by its 4 sides and top.

Searching for bat feces, we slowly walked around each wind turbine and transformer making sure we inspected 1) the door slats and gills of transformers (i.e., sides 1, 2 and 4), 2) the surface of the turbine tower, stairwell, door, light fixture, and flat surfaces of transformers (i.e., side 3 and the top), and 3) all areas with concrete, including the 0.5 m wide concrete pad surface surrounding the base of the turbine tower and 0.25 m wide concrete platform of the transformer. Once found, we placed bat fecal pellets in 1.5 ml plastic tubes and stored them at room temperature.

We extracted DNA from each fecal sample collected using the QIAamp DNA Stool Mini-kit (Qiagen Genomics, Valencia, CA). A negative control was used with each round of extraction to ensure that the extraction reagents used were not contaminated. All extractions were completed in a dedicated extraction AirClean® 600 PCR workstation to minimize contamination and the subsequent polymerase chain reactions (PCR) were conducted in a separate dedicated PCR workstation. We employed the DNA barcoding procedure described in Korstian et al. (2015) to identify each fecal sample to species. We reviewed species composition and explored whether there were any trends or species-specific patterns in the locations where fecal samples were found on wind turbines and across the wind facility.

Each of the 75 wind turbines was surveyed 53 times (22 in 2011 and 31 in 2012) for a total of 3975 searches. Fecal samples were found in 29 of the 53 weeks the turbines were searched. We collected a total of 72 bat fecal samples from the surfaces of turbines, transformers and associated concrete pad. The most samples per month were found in July in 2011 (n = 24) and May and June in 2012 (n = 13 and n = 16, respectively), while all other months had <10 samples. DNA was successfully extracted from 56 of these samples (i.e., 78%). The DNA in the remaining 16 bat fecal samples was found to be degraded and could not be processed successfully to identify species.

Among the samples that were identified to species, all 6 bat species known to be in the wind resource area were confirmed: *Lasiurus borealis* (n = 33 samples), *Lasiurus cinereus* (n = 4 samples), *Lasionycteris noctivagans* (n = 2 samples), *Perimyotis subflavus* (n = 7 samples), *Nycticeius humeralis* (n = 9 samples), and *Tadarida brasiliensis* (n = 1 sample). Fecal samples from *Lasiurus borealis* comprised the majority (59%) of the 56 samples.

We found bat feces in all searched areas of the wind turbines, except for the lower slats of the door (Fig. 1). Nineteen fecal samples (26% of the 72) were collected from between the upper slats of the door, between the gills of the transformer, on the frame beneath the gills of the transformer, and beneath the stairwell on the plastic-covered steel rods anchoring the base of the turbine tower. Note that in order for fecal samples to be in these locations, bats would have to physically be within the structures as it is not possible for wind or water to have moved the feces into such locations. Species composition of the fecal samples in these locations comprised *Lasiurus borealis* (n = 8 samples), *Perimyotis subflavus* (n = 4 samples), *Nycticeius humeralis* (n = 3 samples), *Tadarida brasiliensis* (n = 1 sample), and unknown bats (n = 3 samples).

Of the 75 wind turbines searched, we found bat feces on 41 of them: 20 wind turbines had 1 fecal sample, 13 had 2 samples, 6 had 3 samples, and 2 wind turbines had 4 fecal samples collected from them (Fig. 2). The bat fecal samples were widely distributed on turbines across the wind facility, ranging from wind turbines in close proximity to wooded areas to turbines in open cattle pastures. With regards to species-specific patterns, fecal samples from *Lasiurus borealis* were found throughout the site, whereas fecal samples from *Nycticeius humeralis* appeared to be concentrated in 2 areas, one at the western end of the wind farm and a second towards the center of the wind farm. Fecal samples from *Perimyotis subflavus* were primarily found at turbines near the scrub-woodland area located towards the center of the wind farm. Finally, despite the low number of fecal samples found for *Lasiurus cinereus* and *Lasionycteris noctivagans*, these appeared to be distributed across the wind facility.

The presence of bat feces provides further evidence that bats are conducting activities in close proximity to wind turbines. Furthermore, DNA analysis of the fecal samples confirmed that all 6 bat species known to occur in north-central Texas were active at wind turbines and concurs with fatality data reported at our study site. As expected, the majority of fecal samples were identified as *Lasiurus borealis* (59%), corresponding with the proportion of *Lasiurus borealis* carcasses found in fatality monitoring surveys at the site (60%; Bennett and Hale, 2014).