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BAT MORTALITY AT A WIND POWER FACILITY IN CENTRAL CANADA

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ABSTRACT—Bat mortality has been reported at industrial scale wind facilities across North America, with tree-roosting bats accounting for most fatalities, but no data exist for central Canada. We quantified rates of mortality at a wind energy facility in Manitoba, Canada by conducting standardized carcass searches corrected for searcher efficiency and scavenging from mid-August to mid-September 2007. We found that mortality was consistent with, but qualitatively higher than that at comparable wind facilities in western Canada. Mortality of the species most commonly killed, Silver-haired Bats, was evenly distributed across the wind facility, but mortality of Hoary and Eastern Red Bats was higher at some turbines than others.

Key words: bat, *Lasionycteris noctivagans*, *Lasiurus borealis*, *Lasiurus cinereus*, migration, mortality, turbine, wind energy

There are many benefits of wind energy (see Hoogwijk 2004 for a review), but a number of studies have reported mortality of bats at wind energy facilities worldwide (Arnett and others 2008). In North America, the migratory tree-roosting bats [Hoary (*Lasiurus cinereus*), Eastern Red (*Lasiurus borealis*), and Silver-haired Bats (*Lasionycteris noctivagans*) (hereafter tree bats)] account for most recorded fatalities (>85%) (Arnett and others 2008), whereas birds and other bat species are less affected (Baerwald and others 2009; Willis and others 2010). In the eastern United States, Tricolored Bats (*Perimyotis sublavus*) have accounted for as much as 25% of fatalities, and similar proportions of Little Brown Bats (*Myotis lucifugus*) have been documented at one facility in Canada and one in the midwestern United-States (Arnett and others 2008). No reliable estimates exist on baseline population sizes of these bat species (Carter and others 2003), but Cryan (2011) recently estimated that at least 450,000 bats are killed at wind turbines in North America each year. Given the long lifespans and low reproductive rates of bats (Barclay and Harder 2003), and the high proportion of adults versus juveniles recovered at wind facilities (Cryan 2008), the rate of mortality documented so far has raised concern among biologists (Arnett and others 2008). This is especially true given recent work highlighting the economic value of bats for agro-ecosystems in the United States ($3 to $55 billion/y; Boyles and others 2011).

Although bat fatalities have been reported at virtually all US wind facilities where fatality surveys for bats have been conducted, mortality varies widely among sites (0.1 bats/turbine/y at Buffalo Ridge, MN Phase I to 69.6 bats/turbine/y at Buffalo Mountain, TN; Arnett and others 2008). Fatality rates in the US are highest during late summer and fall when tree bats migrate south and mating occurs (Cryan 2008). To our knowledge, the only published reports of mortality for Canada are from a group of wind facilities in southern Alberta (Baerwald and Barclay 2009), despite the fact that tree bats summer in forests throughout Canada (Barclay 1984; Cryan 2003; Willis and Brigham 2003, 2005). Barclay and others (2007) reported 3 estimates of bat mortality calculated for wind facilities in Ontario and 1 for Saskatchewan, but the Ontario surveys were designed to find birds, not bats, and none of these are published in the peer-reviewed literature. More data are needed from wind facilities across Canada to assess patterns throughout the large geographic ranges of affected species and identify high-priority sites for mitigation.

We conducted mortality surveys for bats at a wind facility in southern Manitoba to determine if mortality at the eastern edge of the Canadian prairies is similar to that in the western prairies

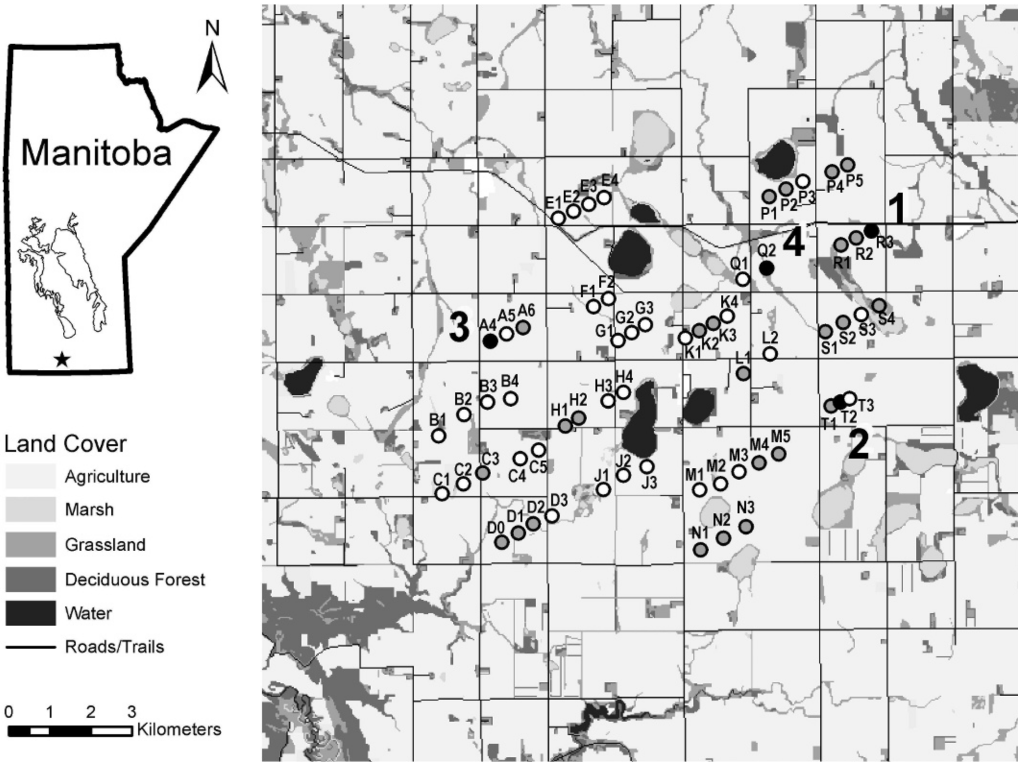

FIGURE 1. Land cover map of the St. Léon wind facility showing the 4 primary turbines (black) around which mortality searches were focused, as well as the 25 other turbines (grey) where we were permitted to search for bat carcasses. White-filled circles are turbines we did not search. The location of the wind facility within Manitoba is shown by the star on the inset map of the province in the top left corner.

of Alberta (Baerwald and Barclay 2009), and to mortality at wind facilities south of Manitoba in the US (Arnett and others 2008) that have similar habitat and topography to our study site in Manitoba. We also aimed to assess species and age composition of mortality, and to test for spatial variation in mortality across the facility.

METHODS

We conducted this study at the St. Léon Wind Energy Project near the town of St. Léon in the Pembina Hills of southwestern Manitoba (UTM: Zone 14 U, 0529767E, 5468329N, WGS84) between 16 August and 11 September 2007. The facility was composed of 63 Vestas NM 82 1.65 megawatt (MW) wind turbines with a total installed capacity of 99 MW (Fig. 1). Each turbine had three 41-m blades and each nacelle was supported on an 80-m monopole on a circular gravel pad approximately 21 m in diameter. The 63 turbines were widely spaced across an area of 93 km^2. The wind facility fell within Manitoba's prairie ecozone, and vegetation consisted of a forest-agricultural matrix dominated by wheat and canola cropland with small woodlots, wetlands, and cattle pasture.

Mortality Surveys

We searched for bat carcasses beginning at sunrise along a square grid centered on each turbine (Johnson and others 2004; Gritski and others 2010). Each grid comprised 21 parallel transects, 80 m in length and spaced at 2-m intervals. We used handheld GPS units and compasses to maintain position along the grid. When carcasses were found, we recorded species and estimated whether the bat had been freshly killed (within 1 to 2 nights). We readily identified carcasses greater than approximately 2-d old based on desiccated wing membranes and obvious odor. Three searchers conducted 126 searches at 29 turbines over 22 d. Depending on our access to turbines, the availability of crew members, and weather (for example, lightning) we searched an average (± SD) of 5.6 ± 2.5 turbines/d. Crops had been harvested when we started the study, which allowed us to conduct full searches (6400 m^2) at all of the turbines we searched.

Our sampling design was complicated by our access to turbines. We were granted access to a subset of turbines by the facility operator, and at most of these we were also able to negotiate site access from landowners, but were only permitted to search turbines where the crop had been harvested. In addition, the list of accessible turbines changed continually throughout the season because of ongoing maintenance at the facility. This made it impossible to randomly select turbines for searching although we did survey as systematically as possible. We began by selecting 4 primary turbines spread throughout the facility for which we knew we would have consistent access (Fig. 1). Each morning we began searching at one of these primary turbines and continued searching as many additional turbines as possible in that vicinity of the wind facility. On the following morning we searched the 2nd primary turbine and additional turbines in its vicinity. On the 3rd day we began at the 3rd primary turbine and so on. Occasionally lightning, maintenance, and searcher availability interfered with a strict 4-d cycle and the actual duration of our search cycle averaged 4.8 ± 0.84 d. We completed 5 of these search rotations during the study. Although not the ideal sampling design, our selection of turbines for searching was not based on any pre-conceived bias but was dictated by the maintenance schedule of the facility operator which had nothing to do with bat mortality. Given this, and combined with the fact that we conducted multiple searches at most turbines we sampled, maintained a consistent search cycle, and sampled across a large proportion of the turbines throughout the facility, we argue that our sampling approach provided a reliable indication of mortality at this site.

We tested searcher efficiency for all personnel (Arnett and others 2005). We placed from 9 to 15 recently recovered, discrete labeled carcasses at random locations beneath a turbine in a canola field and another 9 to 15 bats beneath a turbine in a wheat field. Searchers then attempted, one at a time, to find the test carcasses at each turbine using the same protocol employed during actual searches. Searchers were aware they were being tested. Some studies have used blind tests of searchers, based on the hypothesis that searchers will be more vigilant if they know they are being evaluated (Baerwald and others 2009). However, this hypothesis has not been tested, and our average searcher efficiency varied from 50 to 57.9%, which is comparable to, if not slightly lower than many studies employing blind tests (Arnett and others 2005; Barclay and others 2007; Jameson and Willis, unpubl. data). We calculated a coefficient of searcher efficiency for the facility as the average proportion of trial carcasses found across all searchers, weighted by the total number of searches conducted by each searcher.

Scavenging also can affect the accuracy of mortality surveys (Arnett and others 2008). In 2007, we tested for scavenging by deploying 10 dead mice within the standard search area at 2 randomly selected turbines (Brinkmann and others 2006). We used mice because early during our study we had not yet found enough bat carcasses to use for scavenging trials. Although the mice we used were similar in size and color to bats, bat carcasses are thought to provide better estimates of scavenging than frozen mice (Kunz and others 2007). We therefore conducted additional scavenging tests in 2008 using 10 recently recovered bat carcasses. In both years, we checked carcasses for 11 d and noted the number taken by scavengers each day. Both methods provided identical results, as there was no effect of the type of scavenging test on any of our mortality estimates (General Linear Model, $F_{1,42} = 0.1$, $P = 0.74$); but to be consistent with other studies we report mortality estimates based on the bat scavenging trial.

To estimate the overall seasonal mortality rate for this facility, we adapted recently published equations from Smallwood (2007) and Baerwald and others (2009) to calculate the effective nightly fatality rate for each turbine (F_e) using all carcasses recovered:

$$F_e = \left\{ \frac{C_i/(S_e \times R_c)}{I} \right\} - \left\{ \frac{[(C_{i-1}/S_e) - C_{i-1}] \times R_c}{I} \right\} \quad (1)$$

where:

C_i = number of carcasses found at a given turbine on a given day (''day i'');

C_{i-1} = number of carcasses found at a given turbine during the previous search;
S_e = searcher efficiency;
R_c = proportion of carcasses remaining to be found after removal by scavengers during the interval between the previous search and the current search; and
I = the interval between the previous search and the current search in days.

We averaged values of F_e across all turbines searched on a given day to obtain a nightly mortality rate.

The 1st term of equation 1 corrects for searcher efficiency and scavenging. The 2nd term of equation 1 corrects for the fact that a small proportion of carcasses recovered during a given search could actually have been bats that we failed to detect during the previous search because our searcher efficiency was less than 100% (Baerwald and Barclay 2009). We determined R_c by first fitting a least-squares linear regression line to the data from our scavenger removal trial. We then used Equation 2 to calculate a variable called *RI*:

$$RI = (-7.9545 \times I) + 102.08 \quad (2)$$

Equation 2 predicts the percentage of carcasses that we missed during the previous search but which were taken by scavengers after the interval *I*. However, carcasses also may have accumulated on each of the intervening nights between searches and a proportion of these would have been scavenged as well (Smallwood 2007). Therefore, to determine the cumulative numbers of bats remaining to be found (R_c) if multiple nights passed between consecutive searches, we calculated the average proportion of carcasses remaining after interval *I* as:

$$R_c = (RI_1 + RI_2 + RI_3 \ldots + RI_i)/(i \times 100) \quad (3)$$

where: RI_i = the value calculated by Equation 3 for the *i*th day of the interval *I*.

In other words, if 2 nights passed between consecutive searches at a given turbine, fewer bats would have been removed by scavengers than if 4 nights had passed between searches. Using R_c in Equation 1 controlled for this effect and provided the best method to account for scavenging during the intervals between consecutive carcass searches (Smallwood, 2007; Baerwald and Barclay 2009, 2011). Use of this method for estimating fatalities, which is similar to methods used for studies in Alberta and parts of the US (for example, Baerwald and Barclay 2009; Huso 2011), allowed us to compare mortality rates at our site to those at similar facilities.

Statistical Analysis

We compared the proportion of each age and sex class killed for each species using a manually calculated Chi-square test of independence with a Yates correction when sample sizes were <20. We used SAS 9.2 (SAS Institute, Cary, NC) for all other statistical analyses. We used generalized linear models (GENMOD procedure in SAS) to test for spatial variation in mortality across the wind facility (differences among turbine groups and among turbines within groups). For this spatial analysis we only used mortality estimates based on all recovered carcasses, as opposed to just fresh carcasses, and limited our analyses to turbines we were able to search during all 5 rotations. We assessed model fit from the scaled deviance (valued/df), scaled Pearson χ^2 and the log likelihood values provided by GENMOD and selected model parameters (distribution, link function) that provided the best fitting model. We conducted separate analyses for individual turbines and for turbine groups as well as for each species. In all analyses we included the factor 'day^2' to account for seasonal variation (Baerwald and Barclay 2011). We obtained this factor by first examining nightly mortality rates calculated from all fresh carcasses, because fresh carcasses provided a more accurate depiction of actual variation in mortality from night to night. A quadratic curve best described the relationship between mortality and day (R^2 = 0.34). Therefore, we designated the peak of the curve to be day '0' and days before this peak as '−1,−2,−3. . .x' and days after the peak as '1, 2, 3. . .x'. We then squared these values to linearize the data and obtain the variable 'day^2'. When testing for differences in overall mortality among turbines and among turbine groups, in all cases the best fitting models were obtained by specifying a Gamma distribution, a log link function, and by transforming the dependent variable according to $\sqrt{(\chi)} + \sqrt{(\chi+1)}$(Zar 1999). We also conducted Wald Chi-square pairwise contrasts among the 4 turbine groups using the

TABLE 1. Sex and age (based on the degree of fusion of the phalangeal epiphyses) of those dead bats found at the St. Léon wind facility, that were not too decayed to characterize.

	Sex		Age	
Species	Male	Female	Adult	Juvenile
Lasionycteris noctivagans	13	7	3	8
Lasiurus cinereus	3	9	11	0
Lasiurus borealis	6	0	2	1

DIFF option of the LS MEANS statement in GENMOD. For all statistical tests we assessed significance at $\alpha = 0.05$ and report all values of bat mortality as the mean ± SE.

RESULTS

We found 98 bat carcasses during the study, 25 of which had clearly died within the 1 to 2 nights prior to being found. Silver-haired Bats accounted for 56.1% ($n = 55$) of these fatalities, Hoary Bats accounted for 28.6% ($n = 28$), Eastern Red Bats accounted for 14.3% ($n = 14$), and there was 1 Little Brown Bat (*Myotis lucifugus*; 1.0%). Average searcher efficiency was 52.8% and the average time carcasses from scavenging trials remained on site was 6.0 ± 1.3 d. Correcting for searcher efficiency, the time between consecutive searches and scavenging, the average mortality rate for the survey period calculated using all carcasses amounted to 13.49 ± 3.59 bats/turbine (0.50 ± 0.13 bats/turbine/night) or 8.18 ± 2.17 bats/megawatt (0.30 ± 0.08 bats/MW/night) for all species combined. Broken down by species these rates were 6.28 ± 1.48 bats/turbine (0.23 ± 0.05 bats/turbine/night) or 3.81 ± 0.90 bats/MW (0.14 ± 0.03 bats/MW/night) for Silver-haired Bats; 4.63 ± 1.87 bats/turbine (0.17 ± 0.07 bats/turbine/night) or 2.81 ± 1.13 bats/MW (0.10 ± 0.04 bats/MW/night) for Hoary Bats; and 2.32 ± 1.00 bats/turbine (0.09 ± 0.04 bats/turbine/night) or 1.40 ± 0.61 bats/MW (0.05 ± 0.02 bats/MW/night) for Eastern Red Bats.

Sex was readily identifiable for 38 of the carcasses, and age (adult or juvenile) was identifiable for 26 of the carcasses (Table 1). We found almost twice as many males as females and almost 3 times as many juveniles as adults for Silver-haired Bats, but these differences were not significant (sex: $\chi^2_1 = 1.8$, $P = 0.18$; age: $\chi^2_1 = 2.3$, $P = 0.13$). We found 3 times more female than male Hoary Bats, but again there was not a significant difference between sexes ($\chi^2_1 = 3.0$, $P = 0.083$). All Hoary Bat carcasses that could be aged were adult and the age effect for this species was significant ($\chi^2_1 = 11.0$, $P = 0.001$). There were not sufficient data to analyze age and sex differences for Eastern Red Bats. We found 6 males (2 adult, 1 juvenile), but no females of this species (Table 1).

When we restricted our analysis to turbines that we visited during all search cycles, we found evidence that some groups of turbines and specific turbines within groups resulted in consistently high levels of mortality for Hoary Bats (group: $\chi^2_3 = 8.9$, $P = 0.03$; turbine: $\chi^2_{10} = 26.3$, $P = 0.003$) and Eastern Red Bats (group: $\chi^2_3 = 14.4$, $P = 0.003$; turbine: $\chi^2_{10} = 24.3$, $P = 0.007$), but not for Silver-haired Bats (group: $\chi^2_3 = 1.6$, $P = 0.65$; turbine: $\chi^2_{10} = 4.7$, $P = 0.91$) (Fig. 2). For Hoary and Eastern Red Bats, Turbine Group 3 (the western most group, Fig. 1, Fig. 2) resulted in consistently high mortality relative to all other groups, accounting for 50% ($n = 8$) of all Hoary Bat fatalities and 80% ($n = 4$) of Eastern Red Bat fatalities, although our sample size for Eastern Red Bats was small. Due to insufficient data, we did not test for statistical differences among individual turbines. However, we found 31.3% ($n = 5$) of all Hoary Bat and 40% ($n = 2$) of all Eastern Red Bat carcasses at a single turbine (Turbine C3) within Group 3 (Fig. 2).

DISCUSSION

Our results provide the 1st evidence of bat mortality at wind turbines in central Canada, 970 km east of the facilities studied so far in Alberta. Baerwald and Barclay (2009) quantified fatality rates at 9 wind energy facilities that, like St. Léon, were sited on primarily flat, cultivated farmland or grassland. Four of the facilities had fatality rates >23.5 bats/turbine/y. However, 3 of these differed from St. Léon in that they were

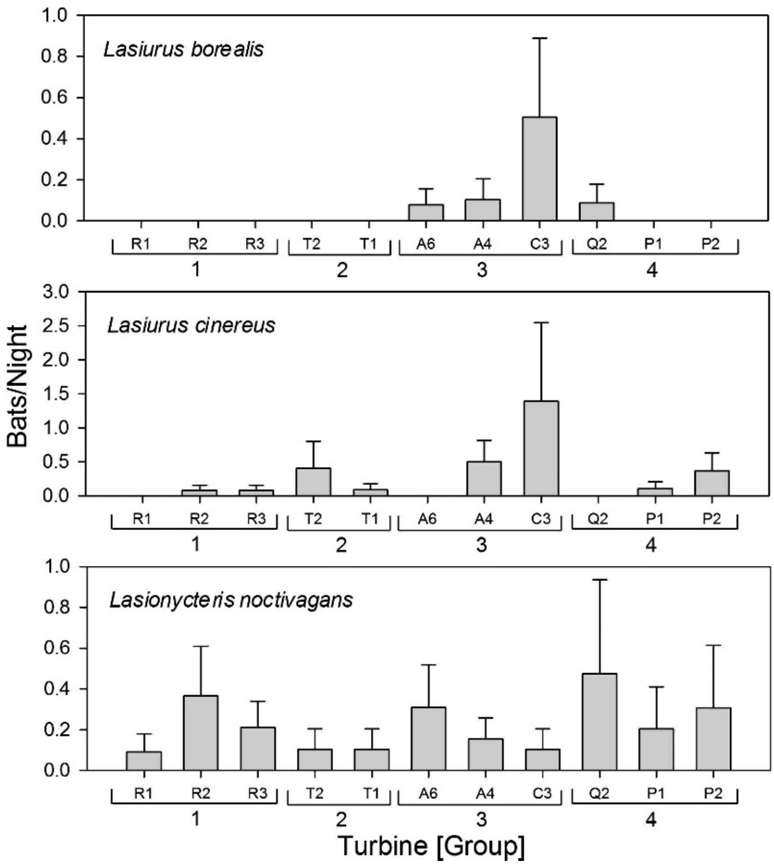

FIGURE 2. Average mortality rate (± SE) estimated from all bat mortalities collected at the 11 turbines visited during all 4-d cycles of the study period. The x-axis specifies the turbines searched and the group to which each turbine belonged during a cycle. Mortality estimates are corrected for searcher efficiency and carcass removal by scavengers (see Methods).

located approximately 10 to 25 km south of a ridge-line along the forested foothills of the Rocky Mountains, which Baerwald and Barclay (2009) hypothesized should concentrate bats because of high roost availability. The 4th of these facilities consisted of only 1 turbine (Table 2), compared to the 63 turbines at St. Léon. Lower per-turbine mortality rates are predicted at facilities with larger numbers of turbines because bats arriving at a facility may spread out among available turbines (Baerwald and Barclay 2009). The other 5 facilities studied by Baerwald and Barclay (2009) were more comparable to St. Léon in terms of habitat and numbers of turbines, although most had fewer than 63 (Table 2). Published fatality rates also exist for 3 US facilities south and south-east of Manitoba, which are also comparable to St. Léon in terms of habitat, topography, and numbers of turbines (Table 2). Mortality at the St. Léon wind facility during our survey period was double or more than double rates at the 5 comparable Alberta sites, and nearly double rates for all of the sites in the mid-western US. Moreover, our survey period was only about half that of the comparable studies above because we were not granted permission for site access until mid-August. This means we likely missed recording mortality for a significant proportion of the migration season. Thus, the relative impact of the St. Léon wind facility for bats appears to be higher than at comparable sites, highlighting the important potential for mitigation at this facility. Given the limited time-frame of our survey, additional work is needed to quantify mortality of

TABLE 2. Bat mortality estimates for 9 wind energy facilities west of the St. Léon facility in Canada and 3 facilities south-east of St. Léon in the United States. Site numbers for the facilities in Alberta are from Baerwald and Barclay (2009) because the names of these facilities have not been made public. Values for each phase of the BRMN facility are included separately.

Name of Facility	State/ Province of Facility	Number of Turbines	Turbine Capacity (MW)	Height of Turbine (m)	Bats/ turbine	Bats/ MW	Literature Source
Site 1	Alberta	60	0.66	50	2.8	4.4	Baerwald and Barclay (2009)
Site 2	Alberta	2	1.8	65	31.4	17.5	Baerwald and Barclay (2009)
Site 3	Alberta	39	1.8	65	23.5	13.1	Baerwald and Barclay (2009)
Site 4	Alberta	35	1.8	65	28.6	15.9	Baerwald and Barclay (2009)
Site 5	Alberta	114	0.66	50	1.3	2.1	Baerwald and Barclay (2009)
Site 6	Alberta	1	3	67	27.4	9.1	Baerwald and Barclay (2009)
Site 7	Alberta	20	1.5	65	5.7	3.9	Baerwald and Barclay (2009)
Site 8	Alberta	20	1.5	80	2.9	2.0	Baerwald and Barclay (2009)
Site 9	Alberta	37	2.2	84	1.7	0.8	Baerwald and Barclay (2009)
LIWI	Wisconsin	31	0.66	65	4.3	6.5	Arnett and others (2008)
TOIA	Iowa	89	0.9	72	7.8	8.7	Arnett and others (2008)
BRMN1	Minnesota	73	0.33	36	0.1	0.2	Arnett and others (2008)
BRMN2	Minnesota	143	0.75	50	2.0	2.7	Arnett and others (2008)
BRMN3	Minnesota	138	0.75	50	2.1	2.7	Arnett and others (2008)
St. Léon[1]	Manitoba	63	1.65	80	13.49	8.18	This study

[1] Our survey period only lasted 22 d.
Facility names: LIWI = Lincoln, TOIA = Top of Iowa, BRMN = Buffalo Ridge.

bats earlier in the migration period at this facility.

One possible explanation for the relatively high mortality rates we observed is the geographic relationship of our study site to Delta Marsh, Manitoba (approximately 100 km due north of St. Léon). This site is a known stopover of international significance for migratory songbirds and other avian migrants and appears to concentrate migratory bats during migration as well (Barclay 1984; Rolseth and others 1994). The presence of Delta Marsh in Manitoba also highlights the importance of detailed mortality surveys for the newest wind energy facility in Manitoba, the 138 MW St. Joseph wind facility, <120 km east of St. Léon, which became operational in January 2011 (Government of Manitoba 2011).

All of the Eastern Red Bat carcasses we were able to sex were male. Consistent with this, Barclay (1984) captured only male red bats in the fall at Delta Marsh. A bias toward adult males is also consistent with data from the majority of wind facilities across North America (for example, Cryan 2008). For Hoary Bats, although we observed more adults than juveniles, we were surprised not to observe greater numbers of males relative to females. Indeed, our data suggest a trend for higher female mortality although the effect was non-significant. We also observed greater mortality of juvenile Silver-haired Bats compared to adults. These unexpected findings could reflect a small sample size, but also could reflect a different pattern for this wind facility compared to other sites, perhaps due to differences in the migratory behavior of tree bats at high latitudes, or a predominance of bats from a local population recovered in our carcass searches. In Alberta, Baerwald and Barclay (2011) found more adult male Hoary Bats than adult females, and more adult Hoary and Silver-haired Bats than subadults in 2006, but these patterns were reversed in 2007. This indicates that patterns in age-sex composition of observed fatalities can vary among years. It is important to note that the age and sex distribution of fatalities we observed is based on a relatively small number of fresh carcasses that could be reliably sexed or aged. It may also have become more difficult to identify sub-adults later in the year as these individuals begin to reach adult size. To sample a wide area throughout the wind facility, and examine spatial variation in mortality in the face of continually changing access to turbines, we rotated throughout the facility. However, searches at the same randomly selected turbines each day could increase the chance of recovering fresh carcasses that may be easily aged and sexed. Given the preliminary patterns we observed, a meta-analysis examining age and sex ratios for fatalities at multiple sites over multiple years, would be useful to help resolve questions about large-scale patterns of age-sex composition and migratory behavior of males versus females.

For Silver-haired Bats, the species most commonly killed at the St. Léon facility, there was no evidence of spatial variation in mortality across the facility. For Hoary and Eastern Red Bats, however, mortality in our study was significantly higher for the western group of turbines (Group 3; Fig. 1, Fig. 2). This effect was likely driven, in part, by especially high mortality rates at one turbine within the group (C3), although interestingly, this turbine was responsible for relatively low mortality of Silver-haired Bats. The majority of forest fragments close to the facility were located on the western side (Fig. 1), which could explain the higher concentration of mortality at these turbines if this habitat concentrated migratory bats either for foraging or roosting. The pattern we observed at St. Léon suggests that moving some of these western turbines (especially C3), or targeting them for curtailment via cut-in speed adjustments (Baerwald and others 2009; Arnett and others 2011) could help reduce mortality for Hoary and Eastern Red Bats. However, this approach would not benefit Silver-haired Bats, and mitigation across the facility would be needed to reduce mortality for this species.

Our study confirms that bat mortality, comparable to and qualitatively greater than that reported at comparable sites in central and western North America, is occurring in a previously unstudied region of the continent. Standardized surveys at other wind facilities across Canada, and published in the peer-reviewed literature, are needed to help assess the impact of wind energy throughout the northern part of the ranges for these species. These data would also help identify specific locations where mitigation is most needed and determine the time periods most important for mitigation. Our study design allowed us to assess spatial variation in mortality in the face of access limitations and a limited search crew, but this cost us the ability to conduct daily searches at specific turbines. Daily searches would improve the ability to determine the age and sex of carcasses and could possibly reduce the occurrence of 'zeros' in the dataset which can lead to underestimates of mortality. Additionally, it is important to note that our results are based on 2 mo of data collection from a single year. Longer-term studies based on multiple years of data will be needed to provide a full picture of mortality at this wind facility. For example, it would have been ideal to start the study in the spring, which would have allowed us to estimate mortality for the full year and record temporal patterns of mortality throughout the season. All of this work will depend on cooperation between industry and researchers to enable researchers to collect data necessary for implementing the most effective mitigation strategies that optimize a balance between bat mortality and revenue loss for wind companies.

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