Bat Fatality Monitoring Report for the Pigeon Creek Wind Turbine Adams County, near Payson, Illinois.

Final Report for the Habitat Conservation Plan, Adams Electric Cooperative

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Executive Summary

This research effort was conducted as part of the Habitat Conservation Plan for Adams Electric Cooperative for the Pigeon Creek Wind Turbine, Adams County, Illinois. A contractual agreement was made with John Wood Community College, Quincy, Illinois and research was conducted by Sharon DeWitt, a faculty member, and Cindy Spohr, a student intern in the Natural Sciences Department. Monitoring of the wind facility was conducted during the summers of 2010 and 2011 and occurred from mid June through September 30th both years. Our primary objective was to determine the impact of the turbine on bat populations, with a specific focus on two endangered species of concern: *Myotis sodalis* (Indiana bat) and *Myotis grisescens* (Gray bat). We were also interested in assessing if the turbine was above, at, or below the national average for bat fatalities.

The monitoring site consists of a 55 m^2 area surrounding the turbine base which has been cleared of vegetation and the ground surface covered with gravel. A six foot chain link fence enclosure separates the site from the surrounding agricultural fields. Monitoring was done twice weekly, June 14 to September 30, 2010 and June 17 through September 30, 2011. Originally, the plan proposed beginning the process on May 15 of each year to include spring bat migration. Unfortunately, the turbine was not operational, May 15-mid June either year, thus data for spring migration of bats was entirely missed during both monitoring periods.

Searcher efficiency and carcass removal trials were performed in an effort to remove bias from fatality data. Searcher efficiency was calculated at 90% in 2010 when the search plot was freshly constructed. Searcher efficiency declined to 70% in the 2011 trials, as weed growth and debris left from turbine repairs made location of carcasses more difficult.

Carcass removal trials were also conducted during each monitoring year in an attempt to estimate removal by scavengers. The average removal rate was calculated at 7.5 days for the monitoring period in 2010, with 15% of the carcasses being removed within 48 hours. The estimated removal rate for 2011 was calculated at 2.75 days with 68% of the carcasses removed within 48 hours.

A total of 23 bats were collected during the fatality searches in 2010. Consistent with other wind turbine studies, (Arnett et al. 2008; Kunz et al. 2007) the majority of the bat fatalities, 52%, belonged to migratory tree roosting species; eastern red bat (*Lasiurus borealis*) and hoary bat (*Lasiurus cinereus*). Of the remaining fatalities, 37% consisted of little brown bat (*Myotis lucifugus*) and big brown bat (*Eptesicus fuscus*). A total of 4 bats were collected during 2011, with only one migratory bat, silver-haired bat (*Lasionycteris noctivagens*). The rest of the bat carcasses belonged to three resident species, eastern pipistrelle

(*Perimyotis subflavus*), evening bat (*Nycticeius humeralis*), and little brown (*Myotis lucifugus*) bats. No species of concern were found during either monitoring period.

The Jain estimate (2005) was used to correct for carcasses missed by the searcher and removed by scavengers. Performance of the calculation returned an estimate of 30 fatalities for 2010 and 18 fatalities for 2011. Both estimates are above the reported national average of 3.4 bats per turbine per year (AWEAABC, 2004).

GPS data collected, regarding position of the carcass with respect to the turbine base, produced a pattern with most bat carcasses, 70%, clustered in the NW quadrant of the base. In terms of distance from the turbine base, 59% of the carcasses were found between 16-25 meters, 26% were located at a distanced <15 meters and 15% were located > 25 meters.

Examination of weather data was consistent with previous research in terms of finding more fatalities occurring on nights with low wind speed. Mean wind speed on nights with fatalities was <2.76 m/s at 50 meter height compared to 4.27 m/s at 50 m height on nights with no bat fatalities. Performance of a Student T test on wind speed data comparing nights with fatalities to those without fatalities returned a significant result, p 0.0001, $\alpha = 0.05$ level. Comparison of relative humidity, temperature, and barometric pressure were not found to be statistically significant. Moon illumination produced mixed results. The highest number of fatalities, 44%, occurred on nights with <25% moon illumination and 37% of fatalities occurred on nights with >75% moon illumination.

INTRODUCTION

Initial concern regarding wind power generation focused on avian fatalities, but as studies monitoring avian collisions proceeded, large numbers of bats were discovered within the turbine sites being monitored (Erickson 2003, Kunz et al. 2007; Arnett et al. 2008). Consequently, the focus of wind turbine studies has shifted to include studying their impact on bat populations. Most of the work has been done at wind fields with multiple turbines in operation (Kunz et al. 2007, Baerwald et al. 2009, and Cryan et al. 2009). This study was designed to assess the impact of a single wind turbine, located in an agricultural row crop field, in Adams County Illinois.

The Pigeon Creek Wind Turbine is a EWT 900 kilowatt, mounted on a 75-meter hub-height tower. The rotors are 54 meters which yields a 108 meter diameter blade arc. It is situated within an agricultural row crop field northeast of Payson, in Adams County, Illinois. The forest cover near the facility occurs primarily as buffer strips along small streams and field edges and consists mainly of young trees belonging to early succession tree species. The nearest contiguous stands of trees are several miles away from the turbine location. This site is located approximately 3-4 miles east of the Mississippi River valley which serves as a major migratory flyway and is approximately 5 miles from Burton Cave, a known bat hibernaculum (Habitat Conservation Plan).

Our objectives were to 1) determine the impact of the turbine on bat populations, with specific focus on two endangered species of concern: *Myotis sodalis* (Indiana bat) and *Myotis grisescens* (Gray bat) and 2) assess if the turbine is above, below, or at the national average of 3.4 bats per turbine per year (AWEAABC, 2004). In addition to the bat species of concern, the IDNR included four endangered bird species in the plan: *Asio flammeus* (Short-eared owl), *Bartramia longicuada* (Upland sandpiper), *Circus cyaneus* (Northern harrier) and *Lanius ludovicianus* (Loggerhead shrike). With the exception of the Loggerhead shrike, which was last recorded in Adams County in 1989, none of the bird species of concern have been recorded in recent years in Adams County (Habitat Conservation Plan).

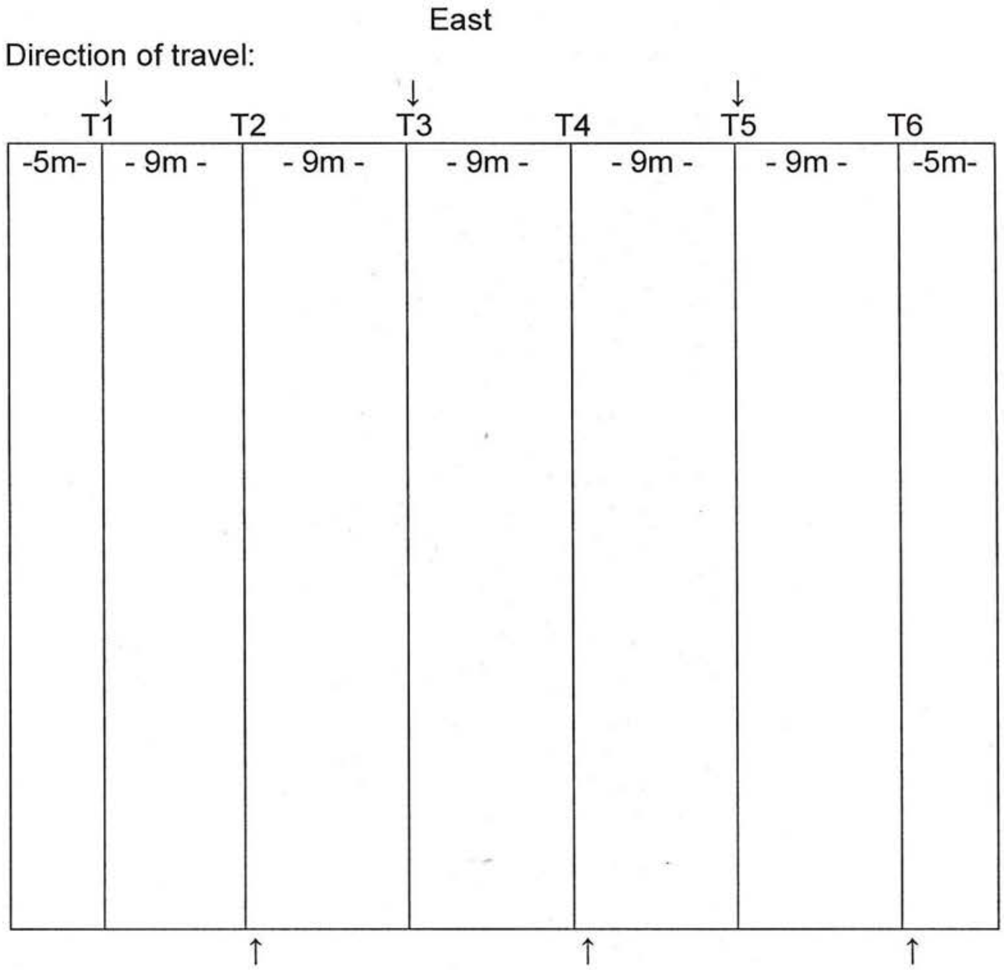
FATALITY MONITORING

Our procedure was similar to other monitoring plans that have been developed for larger wind turbine fields, but has been downscaled for a single wind turbine. An effort to determine the impact of this wind turbine on bat populations was done by estimating the number of fatalities based upon the number of carcasses collected, correcting for bias by taking into account, scavenging by predators and efficiency of search effort.

Field Methods

A 55 m^2 plot, with the wind turbine located centrally, was searched by walking parallel transects that ran in an east to west direction. The first transect (T1) was located 5 meters inside the fence. The next set of transects, (T2 -T6) were spaced a distance of 9 meters apart, withT6 also located 5 meters inside the fence enclosure. The area surrounding the turbine was relatively flat, covered with gravel, and surrounded by a 6 foot chain link fence enclosure.

Figure 1. Diagram of the turbine site showing location of transects.



During the search effort, the searcher started on the east end of the first transect, walked west, searching both sides for a distance of 4.5-5 meters, then moved to the next transect and proceeded to walk east, again searching both sides of the transect a distance of 4.5-5 meters, until all transects were completed. The searcher also walked the perimeter of the plot to inspect the chain link fence for signs of digging or damage by scavengers.

Searches were conducted twice weekly, and began June 14th, in 2010 and June 17th, in 2011. Both search periods continued through September 30th of each year. All bird and bat fatalities discovered within the search area were recorded, including all intact carcasses, remains of scavenged carcasses, and feather spots. When carcasses were found, the following data were recorded: species, sex, age (adult or juvenile), location relative to the turbine, GPS coordinates, and condition of the body (intact or scavenged). For the purposes of this study an "intact carcass is one that has no scavenger evidence and is not badly decomposed. A scavenged carcass has evidence of being fed upon and may consist of wings or skeletal remains." (Erickson 2003; Koford & Jain 2005)

Weather conditions are thought to influence risk factors for bat impacts with wind turbines. In an effort to ascertain weather related influences, this monitoring plan gathered meteorological information regarding precipitation, wind speed, wind direction, relative humidity, temperature, barometric pressure, and moon phase/% illumination for 24 hours previous of the search effort.

GPS data, regarding location of bat fatality with respect to the turbine base, were collected and plotted using ArcView 3.2. Distance and direction of the carcass with respect to the turbine base were also recorded

Physical data collected on the bat carcasses consisted of weight and measurements taken of wing span and body length. In addition, wing biopsy punches were performed and shipped to Joseph Kath, IDNR, in a separate effort to check for WNS. Following the collection of data, bat carcasses were uniquely tagged, bagged, and frozen for shipment to UIUC for verification of identification by Dr. Joyce Hofmann, Illinois Natural History Survey.

Searcher efficiency and estimation of carcass removal

Two searcher efficiency trials were conducted during the monitoring periods for each year. Each trial consisted of 10 carcasses of bats and birds discreetly marked and randomly placed in the search area. The searcher walked transects as if conducting a routine search, without prior knowledge that an efficiency trial was taking place. At the conclusion of the trails, the number of carcasses collected was used to determine searcher efficiency (Erickson, 2009).

Carcass removal trials were also conducted twice during each monitoring year, one at the beginning of the monitoring period, mid June for both 2010 and 2011, and a second trial was performed during the latter half of the monitoring period, mid September in 2010 and late July in 2011. Performance of the removal trials consisted of discreet marking of carcasses and random placement in a variety of locations to simulate different situations of impact with the turbine. Carcasses were left for a period of 10 days and checked daily for the first five days, after which they were only checked during the regular search effort. At the end of ten days, any remains of carcasses were removed from the search area and the estimate of removal was used to adjust for removal bias in fatality searches.

The fatality estimate was performed using the formula from Koford and Jain (2005):

$$M = \mu M / ((1-SC)*(1-E)*P)$$

Where: M = mortality rate adjusted for entire project, μM is the observed mortality, SC is the rate of scavenging or the percentage of carcasses removed within 2 days, E is the searcher efficiency based upon percentage of test carcasses missed and P is the proportion of turbines in search area, in this case one.

Results

In 2010, a total of 23 bats were collected, 22 fatalities and one injured hoary bat, with a broken wing, was captured and euthanized by a local veterinarian. The majority of the bats collected, 52%, belonged to migratory tree roosting species, eastern red bat (*Lasiurus borealis*) and hoary bat (*Lasiurus cinereus*). The remaining fatalities primarily consisted of little brown (*Myotis lucifugus*) and big brown (*Eptesicus fuscus*). Of these carcasses, 36% had broken wings and lesions consistent with collision, the remaining carcasses showed no external signs of injuries.

Table 1. Collision fatalities throughout sampling period.

Month	Migratory bats	Resident bats	Total
2010			
June 14-30	2	1	3
July 11-31	6	5	11
August	2	1	3
September	2	4	6
% of Fatalities	52%	48%	
2011			
June 17-30	0	1	1
July	0	0	0
August	0	2	2
September	1	0	1
% of Fatalities	25%	75%	

Searcher efficiency trials in 2010 returned an estimate of 90% efficiency, and carcass removal trials returned an estimate of 7.5 day removal rate with only 15% of carcasses placed removed within 48 hours. Searcher efficiency dropped to 70% efficiency in 2011 and the carcass removal estimate returned a 2.75 day removal rate, with 54% of carcasses removed within 48 hours.

Table 2. Bat fatality data calculation for Pigeon Creek Wind Turbine.

Year	# of Fatalities	Searcher Efficiency	Carcasses Removed In 48 hrs	Corrected Estimate
2010	23	90%	15%	30
2011	4	70%	68%	18

The majority of all bat fatalities, 56.5%, occurred on nights with winds out of the south to south southeast and an average wind speed of 2.76 m/s at 50 meter height. In general, wind direction varied on nights with no fatalities and average wind speeds were above 4.27 m/s at 50 meter height. However, 35% of nights without fatalities had wind directions out of the south to south southeast, but average wind speed on those nights was 4.8 m/s. Performance of a Student t test comparing average wind speed for nights with fatalities to nights without fatalities returned a significant p value of 0.0001, $\alpha = 0.05$ level. No significant differences were found to exist in the data comparison for average temperature, relative humidity, or barometric pressure data, $\alpha = 0.05$ level.

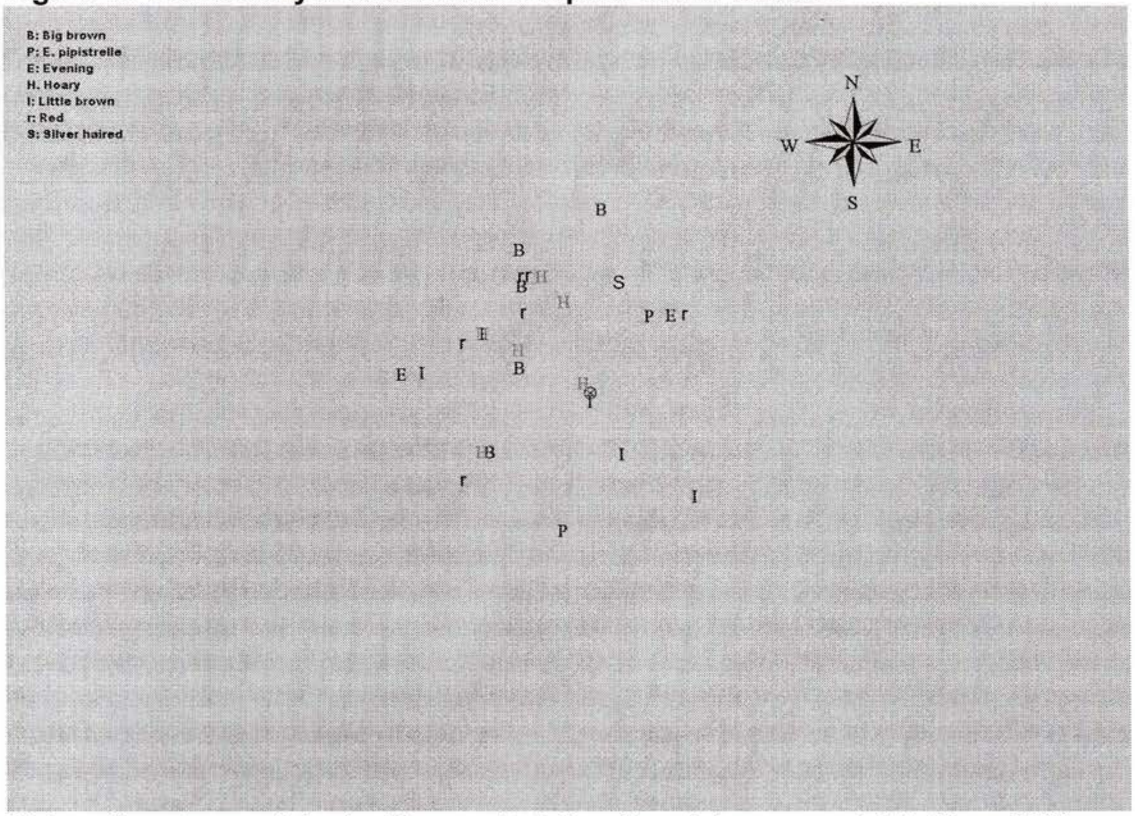
Table 3. Mean weather variables for nights with bat fatalities compared to nights without bat fatalities for 2010 and 2011 monitoring periods.

	Bat fatality	No bat fatalities	P-values (T test)
Barometric Pressure	29.93	29.96	1.5×10^{-1}
Relative Humidity	86%	79%	1.0×10^{-2}
Temperature	73°F	70°F	9.0×10^{-2}
Wind speed	2.76 m/s	4.27 m/s	1.4×10^{-4} *

* indicates significant difference

GPS data collected, regarding position of the carcass with respect to the turbine base, produced a pattern with most bat carcasses clustered in the northwest quadrant of the base (Figure 2).

Figure 2. Bat fatality location with respect to the turbine.



This pattern is consistent with our wind direction data, as most fatalities, 69%, occurred on nights with winds out of the south to south southeast. No fatalities were found following nights with winds out of the north, northeast, or northwest directions.

Table 4. Wind direction, in % of nights, with fatalities and without fatalities.

Direction	% with # fatalities		% without fatality	
	2010	2011	2010	2011
Calm	3.1 (1)	0	0	6.6
Variable	3.1 (2)	0	0	3.3
W/WNW	0	0	3.1	10.0
N/NW	0	0	15.6	13.3
NE/ENE	0	3.3 (2)	3.1	3.3
E/ESE	9.4 (4)	3.3 (1)	6.25	20.0
S/SE/SSE	31.25 (16)	0	21.9	16.6
SW/SSW	0	3.3 (1)	6.25	16.6

% out of 32 observations in 2010 and 30 observations in 2011

Percent of moon illumination was also recorded. We found that most fatalities, 44%, occurred on nights with <25% of moon illumination. However, 37% of fatalities occurred on nights with >75% moon illumination. Thus fatalities occurred on nights with the least and greatest amount of illumination.

Table 5. Species of fatality with percent of moon illumination.

% illumination	Hoary	Red	BB	LB	Eve	E. P	SH
< 25	2	2	3	2	1	1	1
25-50		1	1				
51-75	2		1				
76>	2	3		3	1	1	

Only one bird carcass was collected in 2010 and no bird carcasses were found during the 2011 monitoring effort.

Discussion

The purpose of this study was to examine the impact of this wind turbine upon bat populations in general, but two species, *Myotis sodalis* (Indiana bat) and *Myotis grisescens* (Gray bat) were identified as species of concern. In addition, four endangered bird species, *Asio flammeus* (Short-eared owl), *Bartramia longicuada* (Upland sandpiper), *Circus cyaneus* (Northern harrier) and *Lanius ludovicianus* (Loggerhead shrike) were also included in the Habitat Conservation Plan. One bird fatality, a field sparrow (*Spizella pusilla*), was found during the 2010 monitoring season and no birds were found during 2011. Since most bird fatalities are associated with lattice type turbine towers that are less than 50 meters in height, the monopole structure coupled with the height of this tower, 75 meters, resulted in few bird fatalities.

We found that this turbine site has an above average number of bat fatalities per year. The number of fatalities in 2010 was well above the 3.4 national average reported by the AWEAABC in 2004. Our data for 2011 is close to the reported national average, however, when carcass removal by scavengers and reduced searcher efficiency were factored in, a corrected estimate of 18 fatalities was returned for this monitoring period.

We collected a total of 27 bat carcasses belonging to seven species during the monitoring of this turbine site, but none of the carcasses were species of concern. Our fatality data for 2010 are consistent with findings at other wind facilities with the majority of carcasses collected, 52%, belonging to two species of migratory bats; eastern red (*Lasiurus borealis*), hoary bat (*Lasiurus cinereus*). The remaining fatalities consisted of resident bat species, but consisted primarily of little brown (*Myotis lucifugus*) and big brown (*Eptesicus fuscus*) bats. Our 2011 data contains only one migratory bat fatality, a silver haired bat (*Lasionycteris noctivagens*), and the occurrence again, coincides with fall migration. The other three fatalities belong to small resident bats (Table1).

We also found that the majority of bat fatalities occurred mid July through September which coincides with the timeframe reported by Arnett, (2008) who states that fatality rates are highest during late summer through autumn, reaching a peak during the fall migratory period. The greatest number of fatalities in 2010 occurred during the latter half of the month of July, with more than 50% of them migratory red and hoary bats. A second spike in fatalities was also observed in September, but most of them were resident bat species. Unlike 2010, no bats were found during the month of July in 2011 (Table 1). Carcass removal by scavengers is thought to be largely responsible for the reduced number of carcasses collected in 2011. Two carcass removal trials were conducted which yielded an estimated removal rate of 2.75 days. We conducted searches twice weekly at 3 to 4 day intervals, thus carcasses of bats killed the day following a search would likely be removed prior to the next search effort. This statement is also supported by the fact that all carcasses collected this year were fresh fatalities which is in contrast to 2010, when 43% of the carcasses showed various stages of decomposition (maggots, smell, etc.). Inspection of the fence enclosure further supports the argument for scavenger presence which showed signs of entry beneath the fence and scat in various locations within the enclosure.

Reduced searcher efficiency is also implicated in the lower number of carcasses. The newly constructed site with fresh gravel made it easy to spot fatalities when present. Debris left from turbine repairs, coupled with weed growth at the site, made it more difficult to spot carcasses this monitoring season. The efficiency of search effort dropped from 90% in 2010 to 70% this year. Correction for fatality bias, using the Jain estimator, returned a corrected estimate of 30 bats for 2010 and 18 bats for this year (Table 2).

Work done at other wind facilities have found more fatalities occur on nights with low wind speeds (Arnett 2008; Baerwald and Barclay, 2011). Our data also found this to be the case, with most fatalities occurring on nights with average wind speeds of $<$2.76 m/s at 50 meter height. Average wind speed on nights with no bat fatalities was 4.27 m/s at 50 m height. Performance of a Student T test on wind speed data comparing nights with fatalities to those without fatalities returned a significant result, p 0.0001, $\alpha = 0.05$ level (Table 3).

Comparison of relative humidity, temperature, and barometric pressure were not found to be statistically significant (Table 3). A great deal of variation regarding weather influences is found within the literature. It has been proposed by Baerwald (2011) that these differences may be a result of species specific variation in response to environmental conditions. For example, he found silver haired bats were more active on nights with low wind speed and warm temperatures, but activity declined with wind direction from the north or northeast. Activity of hoary bats increased when barometric pressures fell, but was not influenced by any other weather variable. In general, when environmental variables are conducive to bat activity, there is an increased risk of collisions with wind turbines, resulting in more bat fatalities.

In this study, wind direction is implicated as an environmental variable that may influence bat collisions with the turbine. While average wind speeds were comparable for both years, wind direction differences seem to exist. In 2010, wind direction was out of the south to south southeast on 53% of monitoring nights. The majority of bat fatalities occurred on nights when wind direction was out of the south-southeast in 2010. Wind direction during 2011 was much more variable with no one direction being more prevalent, which may have resulted in fewer collisions (Table 4).

As with other environmental variables, positive and negative associations have been found for moon illumination and fatalities. Again Baerwald (2011) found silver haired bat fatalities increased with increased activity, moon illumination, and winds out of the southeast. While 37% of the fatalities we found occurred on nights with >75% moon illumination, 44% of fatalities occurred on nights with <25% moon illumination. Furthermore, we found fatalities of all species of bat, with the exception of big brown (*Eptesicus fuscus*), occurred with equal frequencies in low and high moon illumination. All big brown bat fatalities occurred with moon illumination of 55% or less (Table 5). Unfortunately, our data sample is very small making it difficult to detect an overall pattern of activity with respect to moon illumination.

A number of mitigation studies have examined altering cut in speed and/or altering the pitch angle of blades on nights with low wind speed, both of which have been found to reduce fatalities. Baerwald (2011) suggests adding migratory bat responses to changing barometric pressure and fraction of moon illumination to existing mitigation strategies. Mitigation of this nature would include altering turbine operation during certain weather parameters, but to minimize loss of power production, relationships of weather, bat activity, and fatality, must be understood for both migratory and resident bats.

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