Operational Monitoring at the Hoopeston Wind Project Vermilion County, Illinois

Fall 2017

Prepared for:

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EXECUTIVE SUMMARY

Western EcoSystems Technology, Inc. (WEST) completed operational monitoring in fall 2017 at the Hoopeston Wind Project (Project) in Vermilion County, Illinois. The purpose of the monitoring was to estimate facility-wide fatality rates of bats and record bird fatalities for the fall season. The Project is comprised of 49 2.0-megawatt (MW) wind turbine generators capable of generating 98 MW. The Project began commercial operation in January 2015. Operational monitoring began fall 2015 and has been completed during spring and fall since then, in accordance with the Project's Bird and Bat Conservation Strategy and with requirements of a Technical Assistance Letter issued by the US Fish and Wildlife Service. As part of this adherence, turbine blades were feathered at night when wind speeds were below 5.0 meters/second (16.4 feet/second) from August 1 to October 15, 2017.

Weekly carcass searches were completed at all of the 49 Project turbines from August 1 to October 10, 2017. Full plots were searched within a 40-meter (m; 131 feet [ft]) radius of five turbines (i.e., "full plot turbines") and gravel access roads and turbine pads were searched within 100 m (328 ft) of the remaining 44 turbines (i.e., "road and pad turbines"). Searcher efficiency and carcass persistence trials were also conducted using bats and split evenly between full plot and roads and pad turbines. Bat fatality estimates were calculated using the Huso and Shoenfeld estimators, and using the Hull and Muir area correction method to account for carcasses that fell outside of plot boundaries.

A total of 55 full plot and 484 road and pad turbine searches were completed during the fall monitoring period. The searcher efficiency rate for bats was 58.3% at full plots and 100% at roads and pads. Bat carcasses were estimated to persist an average of 5.4 days using an loglogistic distribution for the Huso estimator and 8.3 days using an exponential distribution for the Shoenfeld estimator.

No state or federally listed bird or bat species were found. A total of 46 bats and six birds were found during the scheduled carcass searches. The most common bats found were silver-haired (*Lasionycteris noctivagans*), followed by eastern red bats (*Lasiurus borealis*) and hoary bats (*Lasiurus cinereus*). Bat and bird casualties were not concentrated within a specific area of the Project.

Bat fatalities estimates for fall 2017 were similar to estimates from previous years for both the Huso and Shoenfeld estimators. The lack of *Myotis* carcasses found during all years of study to date provides continued evidence that the blade feathering strategy to 5 m/s may be effective in minimizing direct impacts to the federally endangered Indiana bat and federally threatened northern long-eared bat during the fall migration period. Based upon the low numbers of bird carcasses found during the study, the Project does not appear to be substantially impacting birds during this period.

STUDY PARTICIPANTS

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REPORT REFERENCE

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

Western EcoSystems Technology, Inc. (WEST) completed operational monitoring during the fall of 2017 at the Hoopeston Wind Project (Project) located in Vermilion County, Illinois. The purpose of the monitoring was to evaluate facility wide bat and bird mortality during the fall migration season. The Project became operational in January 2015 and is comprised of 49 2.0-megawatt (MW) wind turbines generators capable of generating 98 MW. All turbines are 2.0-MW Vestas turbines with a 100-meter (m; 328 feet [ft]) hub height and 49 m (161 ft) blade length.

Operational monitoring was completed in accordance with the Bird and Bat Conservation Strategy (BBCS; Apex 2013) developed for the Project and in accordance with requirements in a Technical Assistance Letter BBCS issued by the US Fish and Wildlife Service (USFWS). As part of this adherence, turbine blades were feathered at night when wind speeds were below 5.0 meters/second (m/s; 16.4 feet/second [ft/s]) from August 1 – October 15 to reduce direct impacts to the federally endangered Indiana bat (*Myotis sodalis*) and federally threatened northern long-eared bat (*Myotis septentrionalis*), and to minimize overall risk to all bats.

STUDY AREA

The Project is within the Central Corn Belt Plains Ecoregion, which encompasses a large portion of central Illinois (Woods et al. 2007). This ecoregion is composed of vast glaciated plains and is scattered with sand sheets and dunes. Much of the region was originally dominated by tall-grass prairie and had scattered groves of trees and marshes occurring on level uplands. Today, most of the area has been cleared to make way for highly productive agricultural uses. The dominant land use within the Project is tilled agriculture, consisting primarily of corn (*Zea mays*) and soybeans (*Glycine max*). In addition, there are scattered residences, and small areas of pasture, grasslands, and shelterbelts (Figure 1; US Geological Survey [USGS] National Land Cover Database 2011, Homer et al. 2015).

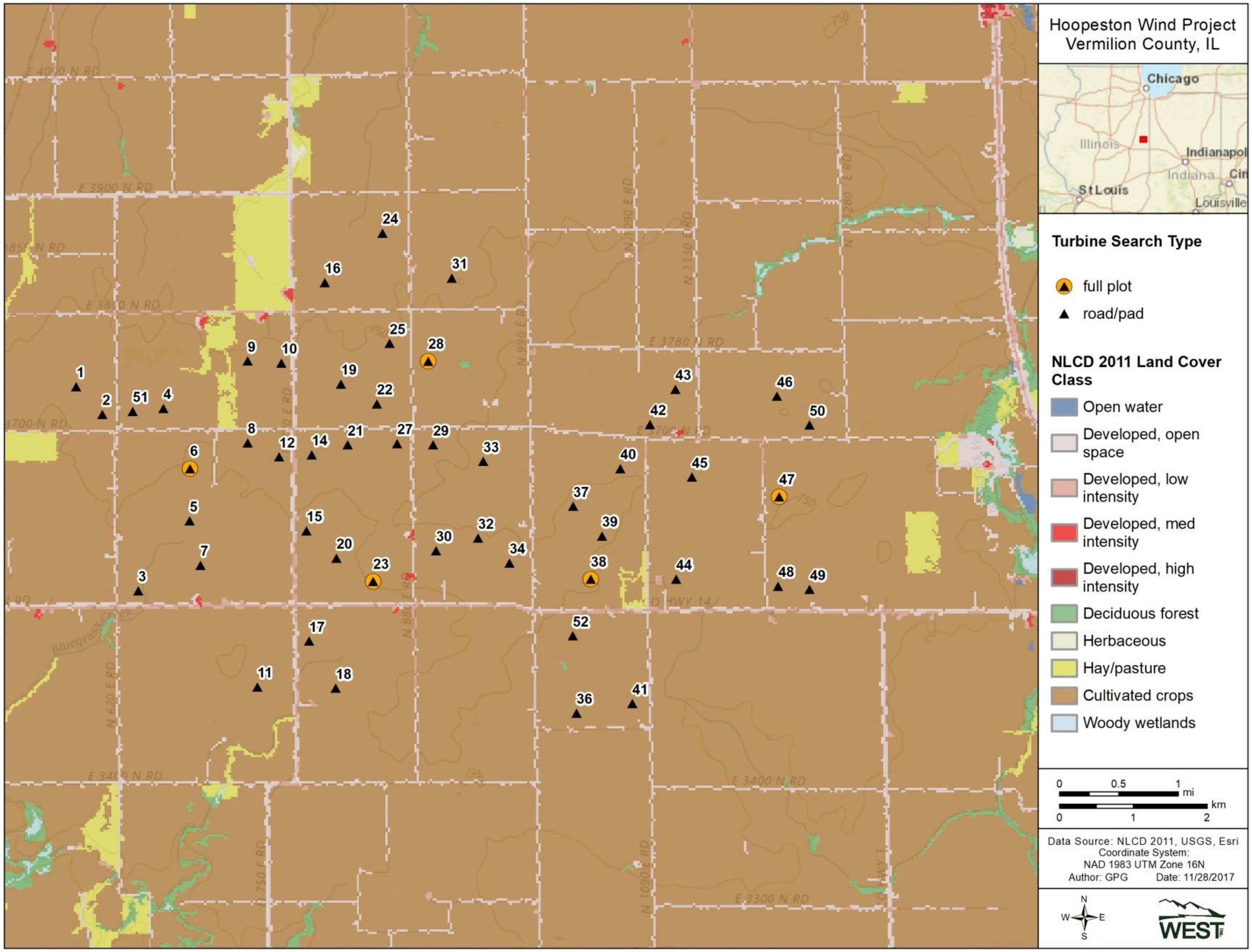

Figure 1. Turbine layout and search plot types at the Hoopeston Wind Project (US Geological Survey National Land Cover Database 2011, Homer et al. 2015).

METHODS

The study was comprised of two components: 1) standardized carcass searches, and 2) searcher efficiency and carcass removal trials (bias trials) using bat carcasses. Carcasses were found under two possible scenarios: 1) during standardized carcass surveys on survey plots or; 2) incidentally (i.e., off survey plots, outside of the search interval, or by operations personnel).

All bird and bat carcasses found, regardless of species, were assumed to be due to collision with a wind turbine due to the difficulties in determining an exact cause of death. This approach can lead to an overestimate of the true number of turbine collision fatalities, but many wind projects have used this conservative approach because of the costs associated with estimating natural and reference mortality (Johnson et al. 2000) or determining cause of death. To estimate fatality rates, the total number of bat carcasses found was adjusted for search frequency, removal bias (length of stay in the field), searcher efficiency bias (proportion found), and carcass-density weighted proportion of the survey plot searched (i.e., area correction factor).

Field Methods

Standardized Carcass Searches

All carcass searches were conducted by a WEST biologist trained to follow carcass search protocols, including proper handling and reporting of carcasses. Bats were handled in accordance with WEST's Illinois Department of Natural Resources (IDNR) Scientific Permit 2007; NH15.5223) and WEST's IDNR Permit for Possession of Endangered or Threatened Species (17-034S). Bird carcasses were recorded but left in place. The identification of bird and bat carcasses were verified by WEST biologists experienced with bird identification and all bats were also verified in person by a WEST USFWS-permitted bat biologist.

Survey methods were consistent with the Project BBCS (Apex Clean Energy, Inc. 2013). Weekly searches were completed at all 49 project turbines from August 1 – October 10, 2017. Five of the turbines (10%) were searched as full plots within a 40 m radius of the turbine (i.e., "full plot turbines") and the gravel access roads and turbine pads within 100 m of the turbine were searched at the remaining 44 turbines (i.e., "road and pad turbines;" Figure 1). The same full plot turbines were used during the study since monitoring began in the fall of 2015. The perimeter of each of the full plots was recorded using a Global Positioning System and used for the analysis of the data and to verify if carcasses were found inside the full plot areas. Vegetation at full plot turbines was mowed to six inches in height to enhance detectability of carcasses. Full plot searches were conducted by walking at a rate of approximately 45 – 60 m per minute and scanning the ground out to 2.5 m on either side of the transect. Biologists started at one side of the plot and systematically searched in a north/south or east/west direction, switching the search pattern on a weekly basis. At road and pad turbines, biologists began searches starting at 100 m (328 ft) from the turbine and walked towards the turbine at a rate of approximately 45 – 60 m per minute, around the turbine, and back towards their vehicle scanning out 2.5 m on each side until the entire access road and turbine pad was searched.

The condition of each carcass found was recorded using the following categories:

- Live/Injured – a live or injured bat or bird;
- Intact – a carcass that is completely intact, is not badly decomposed, and shows no sign of being fed upon by a predator or scavenger;
- Scavenged – an entire carcass, which shows signs of being fed upon by a predator or scavenger, or a portion(s) of a carcass in one location (e.g., wings, skeletal remains, portion of a carcass, etc.), or a carcass that has been heavily infested by insects; or
- Feather Spot (for bird carcasses only) – 10 or more feathers (not including down) at one location indicating predation or scavenging.

The following information was recorded for each carcass found during standardized surveys:

- Date and time;
- Initial species identification;
- Sex, age, and reproductive condition (if identifiable);
- Geographic coordinate;
- Distance and bearing to turbine;
- Substrate/ground cover conditions;
- Condition (intact, scavenged); and
- Estimated time since death (number of days).

Searcher Efficiency Trials

The objective of the searcher efficiency trials was to estimate the proportion of bat carcasses found by searchers. Searcher efficiency trials were conducted at a subset of full plot and road and pad turbines. Searcher efficiency was estimated by plot type (full plot turbine or road and pad turbine) and used to adjust the total number of carcasses found by searchers, correcting for detection bias.

Personnel conducting carcass surveys did not know when searcher efficiency trials were being conducted or the location of the trial carcasses. A total of 25 bats salvaged from previous and current studies at Hoopeston were used during two trials conducted on August 16 and September 12, 2017.

All trial carcasses were placed at random locations on search plots prior to the carcass search that day. Trial carcasses were dropped from waist height and allowed to land in a random posture. Each trial carcass was discreetly marked with a black zip-tie around the upper arm of bats prior to placement so that the carcasses could be identified as a trial carcass after it was found. The number and location of the trial carcasses found during the carcass search was recorded. The number of carcasses available for detection during each trial was determined immediately after the trial by the person responsible for distributing the carcasses.

Carcass Persistence Trials

The objective of carcass persistence trials was to estimate the average length of time a detectable bat carcass remained in the field. Carcass persistence trials were conducted at subset of full plot and road and pad turbines. Estimates of carcass persistence rates were used to adjust the total number of carcasses found by searchers, correcting for detection bias. Trials were conducted throughout the study period to incorporate the effects of varying weather, climatic conditions, and carcass persistence rates. The same carcasses used during the searcher efficiency trials were also used for carcass persistence trials.

Personnel monitored the trial carcasses over a 30-day period, checking the carcasses on days 1, 2, 3, 4, 7, 10, 14, 20, and 30. Carcasses were left at the location until the carcass was completely removed or the trial period ended. If the carcass remained at the end of the 30-day period, any remaining evidence of the carcass was removed.

Statistical Analysis

Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) measures were implemented at all stages of the study, including in the field, during data entry and analysis, and report writing. Following field surveys, observers were responsible for inspecting data forms for completeness, accuracy, and legibility. Potentially erroneous data were identified using a series of database queries. Irregular codes or data suspected as questionable were discussed with the observer and/or project manager. Errors, omissions, or problems identified in later stages of analysis were traced back to the raw data forms, and appropriate changes were made in all affected steps.

Data Compilation and Storage

A Microsoft SQL server database was developed to store, organize, and retrieve survey data. Data were keyed into the electronic database using a pre-defined protocol to facilitate subsequent QA/QC and data analysis. All data forms and electronic data files were retained for reference.

Fatality Surveys

Fatality estimates were based on:

1) Observed number of carcasses found within standardized search plots during the monitoring period;
2) Searcher efficiency, expressed as the proportion of trial carcasses found by searchers during searcher efficiency trials;

3) Persistence rates, expressed as the estimated average probability a carcass is expected to persist in the search area and be available for detection by the searchers during persistence trials; and
4) Area correction estimates.

Fatality estimates were calculated for bats using the Huso and Shoenfeld estimators (Huso 2011; Huso USGS Guide 2015; Shoenfeld 2004).

Definition of Variables for Huso Estimator

The following variables were used in the equations below for the Huso estimator (Huso 2011; Huso USGS Guide 2015):

c_i	total number of carcasses in category *i* (bat), search type (full plot and road and pad plot), and season (fall)
n	number of turbines sampled at the Project
k	number of carcass categories
$\hat{a}_i$	area correction for category *i*
I_i	time interval between the previous search and discovery for category *i*
$\hat{\hat{I}}_i$	effective search interval for carcasses in category *i*
$\hat{r}_i$	average probability of persistence for carcass in category *i*
$\hat{p}_i$	probability of detection for carcass in category *i*
$\hat{\pi}$	the estimated probability that a carcass was both available to be found during a search and was found, as determined by the persistence trials and the searcher efficiency trials
$\widehat{F}_i$	per turbine mortality for category *i*
$\widehat{m}$	total per turbine mortality

Estimation of Searcher Efficiency Rates

Searcher efficiency rates ($\hat{p}_i$) were estimated using logistic regression modeling, with plot type considered as a potential covariate. The logistic regression modeled the natural logarithm of the odds of finding an available carcass as a function of the above covariates. The best model was selected using corrected Akaike Information Criteria (AICc). Estimated searcher efficiency rates were then generated using the best model.

Estimation of Carcass Persistence Rates

Estimates of carcass persistence rates were used to adjust carcass counts for removal bias. Plot type was considered as a potential covariate. Exponential, log-logistic, lognormal, and Weibull distributions were fit, and the best model was selected using AICc (Burnham and

Anderson 2002). Average carcass persistence time and average probability of persistence of a carcass ($\hat{r}_i$) were estimated using this best model.

Adjusted Facility-Related Fatality Rates

The estimated probability that a carcass in category i was available and detected was calculated as:

$$\hat{\pi}_i = \hat{a}_i \cdot \hat{p}_i \cdot \hat{r}_i \cdot \hat{v}_i$$

where $\hat{v}_i$ = min(1, $\hat{\hat{I}}_i / I_i$). The model assumed that searchers had a single opportunity to find each carcass, even though some carcasses persisted through multiple searches before being detected. Therefore, a carcass was included in adjusted fatality estimates if it was available since the last search, and not longer. The probable time since death was recorded in the field and used to evaluate each carcass for inclusion in the final fatality estimates. The total number of fatalities ($\hat{f}_i$) in category i, based on the number of carcasses found in category I, was calculated by:

$$\hat{f}_i = \frac{c_i}{\hat{\pi}_i}.$$

The total per turbine fatality rate *($\hat{m}$)* was estimated by:

$$\hat{m} = \frac{\sum_{i=1}^{k} \hat{m}_i}{n}$$

Definition of Variables for Shoenfeld Estimator

We used the following variables for the Shoenfeld estimator equations (Shoenfeld 2004):

c_i	the number of carcasses detected at plot *i* for the study period of interest (e.g., the fall period)
n	the number of search plots
k	the number of turbines searched
$\bar{c}$	the average number of carcasses observed per turbine per survey period
s	the number of carcasses used in persistence trials
s_c	the number of carcasses in persistence trials that remained in the Project after 30 days
t_j	the time (in days) carcass *j* remained in the Project before it was removed, as determined by the persistence trials
$\bar{t}$	the average time (in days) a carcass remained in the Project before it was removed, as determined by the persistence trials

p	the estimated proportion of detectable carcasses found by searchers, as determined by the searcher efficiency trials
I	the average interval between standardized carcass searches, in days
A	proportion of the search area of a turbine actually searched
$\hat{\pi}$	the estimated probability that a carcass was both available to be found during a search and was found, as determined by the persistence trials and the searcher efficiency trials
m	the estimated annual average number of fatalities per turbine per year, adjusted for persistence and searcher efficiency bias

Observed Number of Carcasses

The average number of carcasses ($\bar{c}$) observed per turbine during the study period was estimated using the following:

$$\bar{c} = \frac{\sum_{i=1}^{n} c_i}{k \cdot A} \quad (1)$$

Estimation of Searcher Efficiency Rates

Searcher efficiency rates ($\hat{p}_i$) were estimated using logistic regression modeling, with plot type considered as a potential covariate. The logistic regression modeled the natural logarithm of the odds of finding an available carcass as a function of the above covariates. The model assumes that searchers have a single opportunity to discover a carcass. The best model was selected using corrected AICc. Estimated searcher efficiency rates were then generated using the best model.

Estimation of Mean Carcass Persistence Time

Estimates of carcass persistence rates were used to adjust carcass counts for persistence bias. Plot type was considered as a potential covariate. Only exponential distributions were fit to remain consistent with Shoenfeld assumptions. The best model was selected using AICc (Burnham and Anderson 2002). The average carcass persistence time ($\bar{t}$) for bats was generated using predictions from these models.

$$\bar{t} = \frac{\sum_{i=1}^{s} t_i}{s - s_c} \quad (2)$$

Estimation of Facility-Related Fatality Rates

The estimated per turbine annual fatality rate (*m*) was calculated by:

$$m = \frac{\bar{c}}{\hat{\pi}} \quad (3)$$

where $\hat{\pi}$ included adjustments for both carcass removal (from scavenging and other means) and searcher efficiency bias. Data for carcass persistence and searcher efficiency bias were pooled across the plot types to estimate $\hat{\pi}$.

$\hat{\pi}$ was calculated as follows:

$$\hat{\pi} = \frac{\bar{t} \cdot p}{I} \cdot \left[\frac{\exp\left(\frac{I}{\bar{t}} \right) - 1}{\exp\left(\frac{I}{\bar{t}} \right) - 1 + p} \right] \quad (4)$$

The estimates, standard errors, and 90% confidence intervals were calculated using bootstrapping (Manly 1997). Bootstrapping is a computer simulation technique that is useful for calculating point estimates, variances, and confidence intervals for complicated test statistics. A total of 1,000 bootstrap samples were used. The standard deviation of the bootstrap estimates was the estimated standard error. The lower 5th and upper 95th percentiles of the 1,000 bootstrap estimates were estimates of the lower limit and upper limit of 90% confidence intervals.

Area Correction

An area correction was used to adjust for bat carcasses that fell outside the area searched for road and pad and cleared plot turbines. The area corrections used to adjust fatality estimates were calculated by estimating the proportion of carcasses expected to fall within searched areas:$a = \sum_{j=1}^{r} F(j) \times p(j)$

where a is the area correction factor, j indexes a series of 1-m-wide (3 ft) annuli centered on the turbine, r is the maximum search radius, $p(j)$ is the fraction of the j^{th} annulus that was searched (calculated in Geographical Information System), and $F(j)$ is the proportion of all carcasses expected within the j^{th} annulus. $F(j)$ is calculated from $f(j)$, the estimated density distribution of carcasses with respect to distance from turbines.

A physics-based model was used to estimate the carcass-density distribution, $f(j)$, for the area correction for the Fall 2015 and Spring 2016 study due to the number of low carcasses found during standardized carcass searches; the same method was also used in this report to allow a better comparison between studies. This method estimates the maximum fall distance for a given turbine height and rotor diameter (Hull & Muir 2013), and the relative carcass-density was assumed to follow a linear decrease from the turbine base out to the maximum predicted fall distance (Huso and Dalthorp 2014).

RESULTS

Standardized Carcass Searches

A total of 55 full plot searches and 484 road and pad searches were conducted during the fall (August 1 – October 10, 2017) monitoring period. Details of all of the carcasses found during the study are presented in Appendix A. No state or federally listed bird or bat species were found.

Bat Fatalities

A total of 46 bats belonging to five species were found during scheduled carcass searches and incidentally, with 44 bats found during scheduled carcass searches and two bats found incidentally during carcass persistence trial checks. Thirteen of these bats were found on full plots and 33 bats were found on road and pad plots. Silver-haired bats (*Lasionycteris noctivagans*; 22 carcasses; 47.8%) were the most common bat found, followed by eastern red bat (*Lasiurus borealis*; 16 carcasses, 34.8%), and hoary bats (*Lasiurus cinereus*; six carcasses, 13.0%). In addition, one individual of each species: big brown bat (*Eptesicus fuscus*; 2.2%) and evening bat (*Nycticeius humeralis;* 2.2%; Table 1) were found. No Indiana or northern long-eared bat carcasses were found during the study (Table 1).

Table 1. Total number of bird and bat carcasses and the percent composition of carcasses found during monitoring at the Hoopeston Wind Project from August 1 through October 10, 2017.

Species	Carcasses found during scheduled searches		Incidental carcasses		Total	
	Total	% Comp.*	Total	% Comp.*	Total	% Comp.*
Bats						
big brown bat	1	2.3	0	0	1	2.2
eastern red bat	16	36.4	0	0	16	34.8
evening bat	1	2.3	0	0	1	2.2
hoary bat	6	13.6	0	0	6	13.0
silver-haired bat	20	45.5	2	100	22	47.8
Total Bats	**44**	**100**	**2**	**100**	**46**	**100**
Birds						
American redstart	0	0	1	100	1	16.7
cliff swallow	1	20	0	0	1	16.7
Dickcissel	1	20	0	0	1	16.7
horned lark	2	40	0	0	2	33.3
unknown vireo	1	20	0	0	1	16.7
Total Birds	**5**	**100**	**1**	**100**	**6**	**100**

*may not add to 100% due to rounding

The majority of the bat carcasses were found between 30 – 40 m on full plots (n=8; 66.7%), and between 0 – 10 m (n=7; 23.3%) and 30 – 50 m (n=12; 40%) on roads and pads (Table 2). Overall, the highest numbers of carcasses were found between 30 – 40 m followed by 0 – 10 m (Figure 2). Bats carcasses were found at 28 of the 49 study turbines. The highest number of bats (four bats per turbine) were found at turbines 38 (full plot) and 50 (road and pad; Figure 3).

Table 2. Distribution of bat carcasses included in Shoenfeld analysis by distances from turbines found on full plots and road and pad plots at the Hoopeston Wind Project from August 1 through October 10, 2017.

Distance from Turbine	Number of Bat Carcasses Found on Full Plots (%)	Number of Bat Carcasses Found on Road and Pad Plots (%)
0 to 10	2 (16.7%)	7 (23.3%)
10 to 20	0	3 (10.0%)
20 to 30	2 (16.7%)	3 (10.0%)
30 to 40	8 (66.7%)	6 (20.0%)
40 to 50	0	6 (20.0%)
50 to 60	0	1 (3.3%)
60 to 70	0	2 (6.7%)
70 to 80	0	2 (6.7%)
80 to 90	0	0
90 to 100	0	0

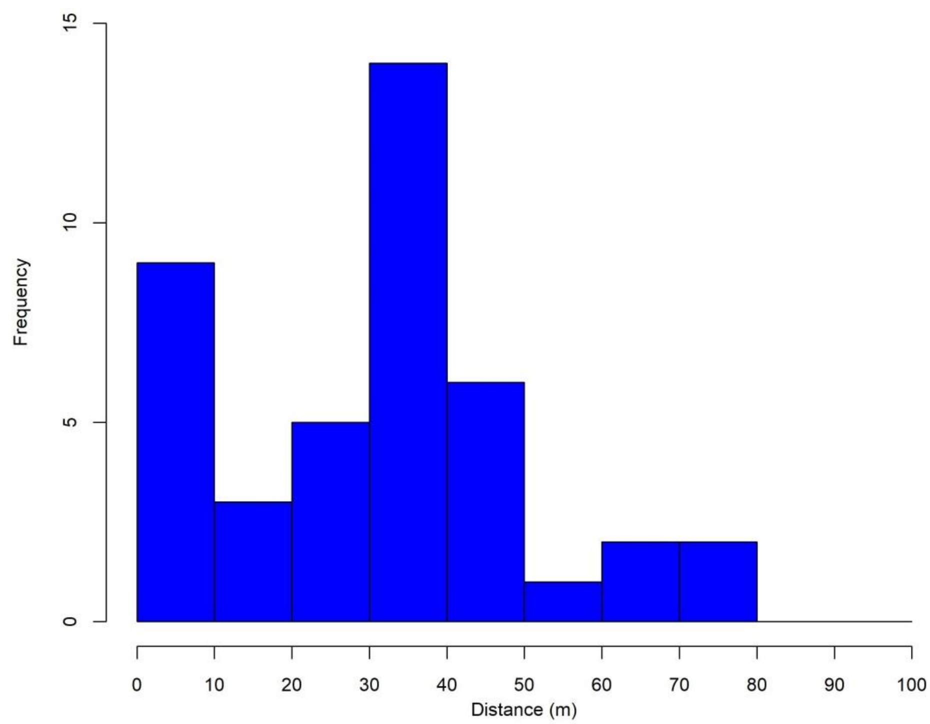

Figure 2. Distance of bat carcasses from turbines for full plot and road and pad turbines combined at the Hoopeston Wind Project from August 1 through October 10, 2017.

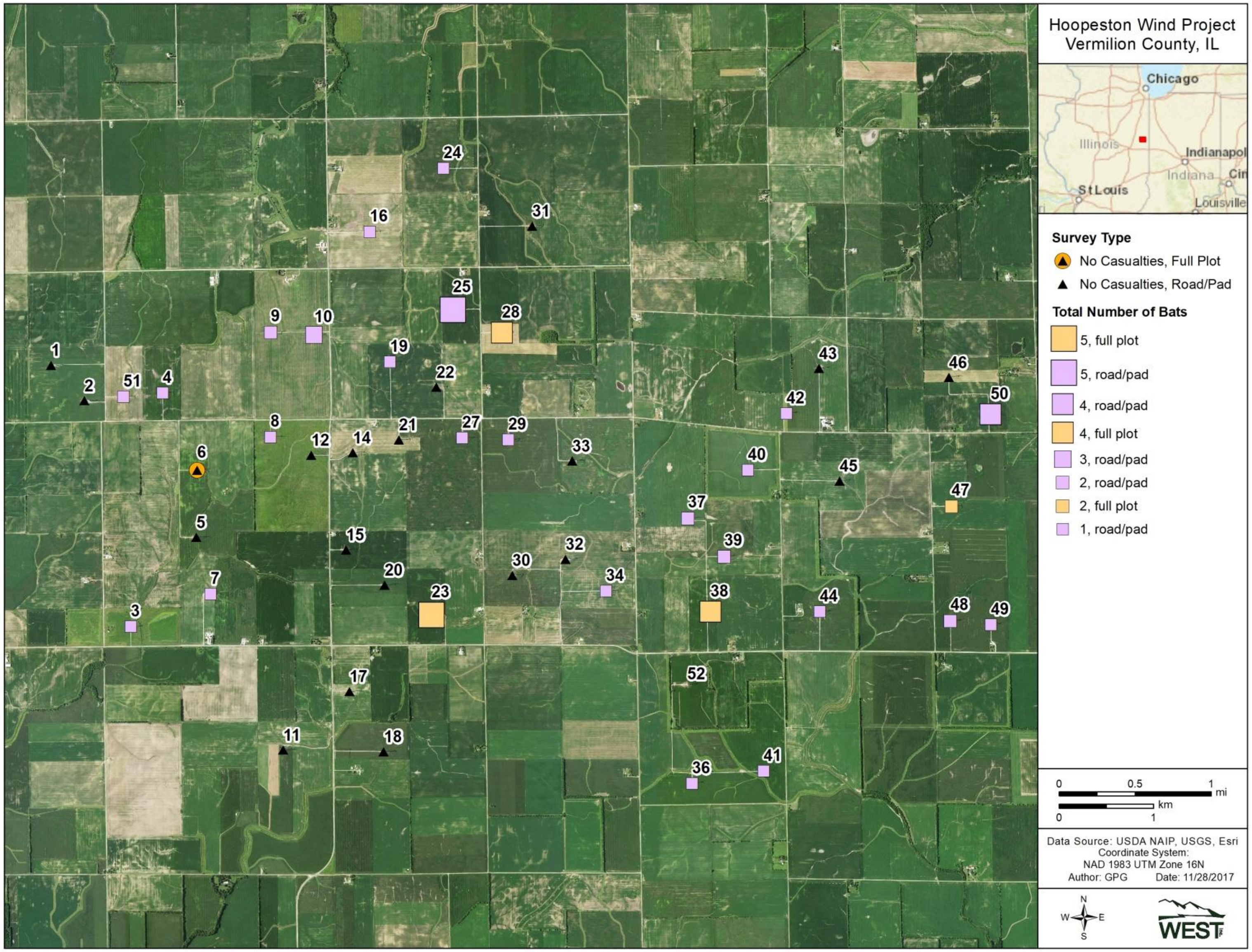

Figure 3. Location of all bat carcasses found during the operational monitoring at the Hoopeston Wind Project, August 1 – October 10, 2017.

Bird Fatalities

Six birds of five unique species were found during scheduled carcass searches; one of the bird carcasses was found off-plot and therefore marked as incidental (Table 1). Three of the birds were found on full plots and three were found on road and pad plots. The most common bird found was horned lark (*Eremophila alpestris*). Bird carcasses were found at six different turbines spread throughout the Project (Figure 4).

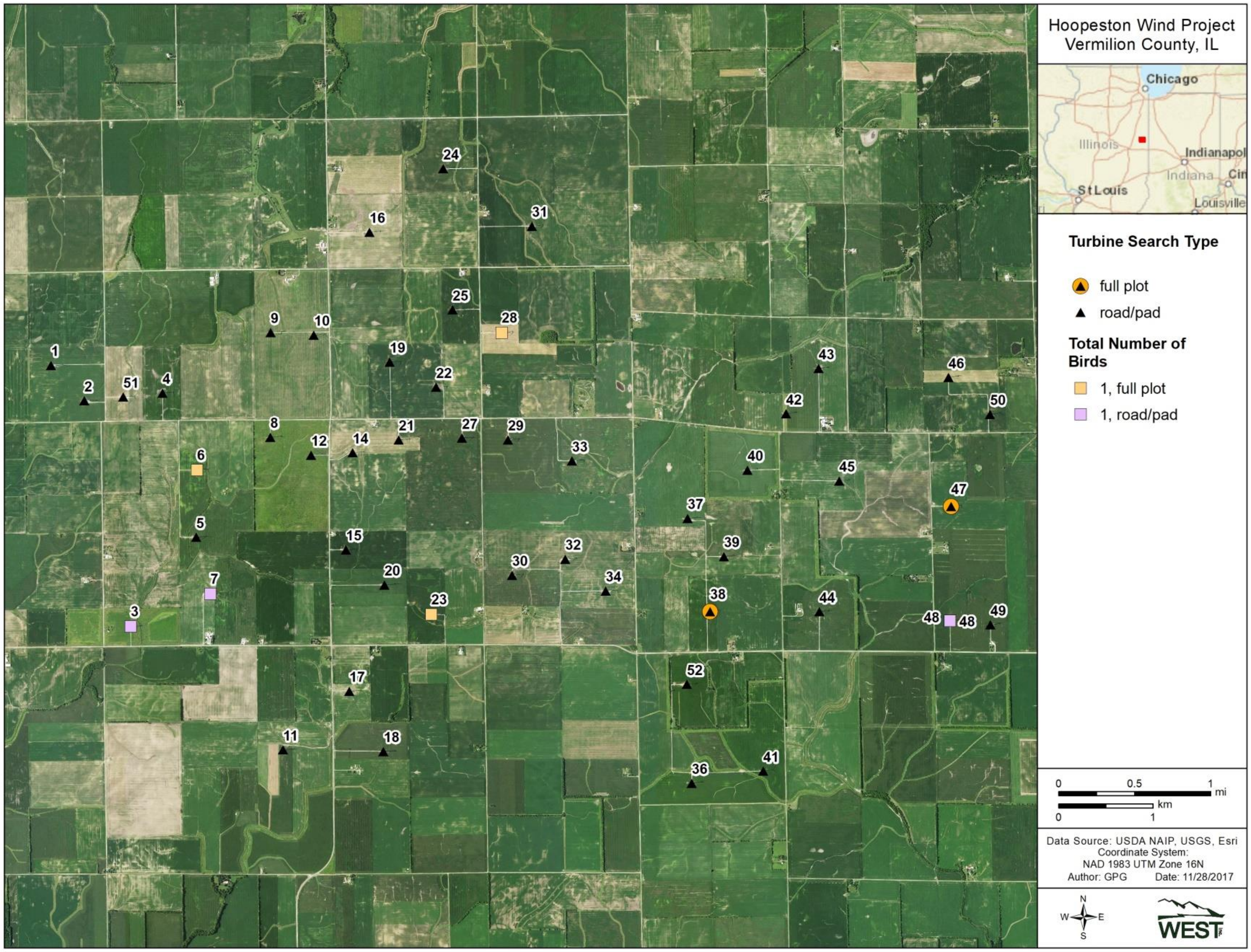

Figure 4. Location of all bird carcasses found during the operational monitoring at the Hoopeston Wind Project, August 1 – October 10, 2017.

Searcher Efficiency Trials

Twenty-four of the 25 bats placed for trials were used to estimate searcher efficiency because one bat was determined to not have been available to the observer prior to searches. Raw searcher efficiency rates for bats ranged from 58.3% for full plots to 100% for road and pad plots (Table 3). Searcher efficiency rates were calculated using the best fit logistic regression model and plot type was a covariate in the best fit model. Modeled searcher efficiency rates were higher on roads and pads compared to cleared plots (Table 4).

Table 3. Carcasses placed for searcher efficiency and carcass persistence trials, and raw searcher efficiency rates by carcass type and plot type at the Hoopeston Wind Project during the study period, August 1 through October 10, 2017.

	Road and Pad				Full Plot			
Size	**# Placed**	**# Available**	**# Found**	**%**	**# Placed**	**# Available**	**# Found**	**%**
Bat	12	12	12	100	13	12	7	58.3

Table 4. Overall searcher efficiency percentages for bats calculated using a logistic regression model for the Huso and Shoenfeld estimators at the Hoopeston Wind Project.

Size	Estimated Searcher Efficiency Rates for Full Plots (%)	Estimated Searcher Efficiency Rates for Roads and Pads (%)
Bat	58.3	100

Carcass Persistence Trials

Twenty-five bats were used to estimate carcass persistence. The mean carcass persistence times were 5.4 days and 8.3 days for bats using the loglogistic distribution for the Huso estimator and exponential distribution Shoenfeld estimator, respectively (Table 5). Approximately 30% of bat carcasses remained after seven days (Figure 5). Carcass persistence rates were calculated using a survival regression model with a logistic distribution for the Huso estimator. Average probability of persistence ($\bar{t}$) for the Shoenfeld estimator was calculated using a survival regression model with an exponential distribution (the Shoenfeld model assumes exponentially distributed persistence times; Shoenfeld 2004). The best fit models for carcass persistence did not contain plot type, indicating that carcass persistence did not vary between plot types.

Table 5. Carcass removal top models with covariates, distributions, and model parameters for the Hoopeston Wind Energy Facility.

Estimator	Size	Distribution	Predicted Values	Scale
Huso	Bat	Loglogistic	5.42	0.52
Shoenfeld	Bat	Exponential	8.33	1

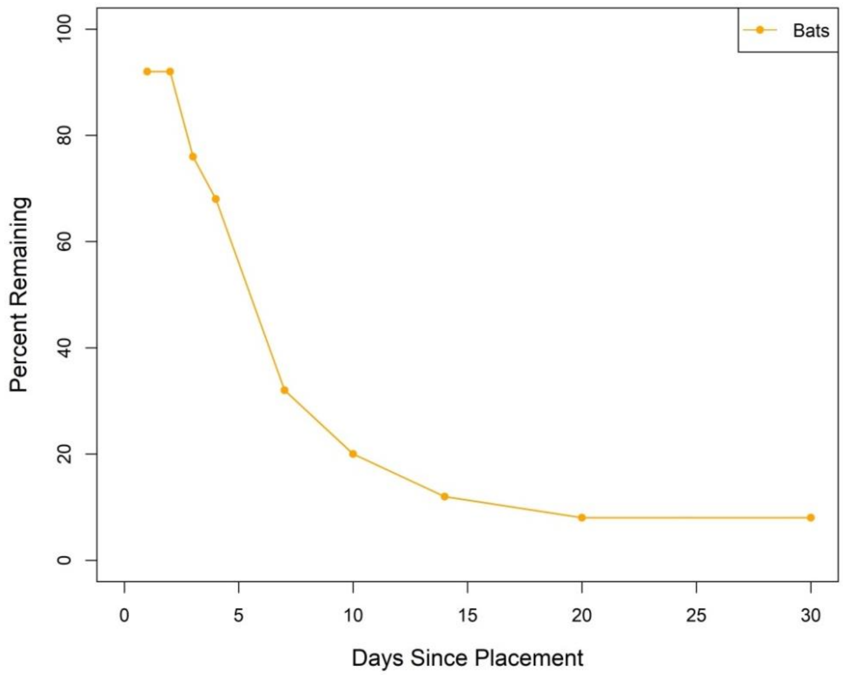

Figure 5. The percentage of carcasses remaining during carcass persistence trials at the Hoopeston Wind Project during the study period August 1 through October 10, 2017.

Adjusted Fatality Estimates

Estimates of mortality, standard errors, and confidence intervals were calculated for bats using both the Shoenfeld and Huso estimators. Overall fatality estimates for bats were similar between the two estimators (Table 6). Fatality estimates were adjusted based on carcass persistence, searcher efficiency, and the area correction. Adjusted fatality estimates were calculated for each of the plot types (full plot and road and pad) as well as for the entire facility. The adjusted fatality rate for the entire facility was calculated using a weighted average of the adjusted fatality rates for the search types. Weights were assigned as the proportion of all turbines covered by each search type (5/49 for cleared plots, 44/49 for road and pad plots). Bats were excluded from the Shoenfeld and Huso fatality estimates if they were estimated to have occurred before the start of the fall season. In addition, bats were excluded from the Huso estimates if they were estimated to have occurred outside of the search interval period. A list of the carcasses included for each estimator are presented in Appendix A. Descriptions of the variables used to calculate the fatalities estimates are described in Appendix B for Huso and Appendix C for Shoenfeld.

Table 6. Comparison of overall adjusted mortality estimates using the Shoenfeld and Huso estimators for bats for surveys at the Hoopeston Wind Project.

	Bat Fatality Estimate /MW	90% Confidence Limits
Huso	2.2	(1.6 – 3.1)
Shoenfeld	2.5	(1.9 – 3.5)

DISCUSSION

Bat Fatalities

No federally or state- listed bats were found. The overall lack of *Myotis* carcasses found during multiple monitoring periods suggests that *Myotis* bats are not being significantly impacted during the spring and fall migration period at the Project. Bat fatality estimates were similar to estimates from fall 2016 when turbines were also curtailed at 5.0 m/s (Stantec 2017; Table 6). The results of monitoring at Fowler Ridge (Good et al. 2012), and road and pad monitoring at the Project show that bat carcasses fall farther than 40-m. The distribution of carcasses from road and pad monitoring in 2017 can be used to further inform area corrections for future monitoring under the Project's incidental take permit for bats.

The Hull and Muir area correction method was used for comparison to previous studies at the Project. The Hull and Muir model assumes a linear decrease in carcass density from the turbine base out to the maximum predicted fall distance (Huso and Dalthorp 2014). A review of the distances at which carcasses fell relative to area searched suggests that this assumption may not be true (Figure 6). We recommend future monitoring at the Project consider pooling data across years or sampling using larger plot sizes in order to develop more robust estimates of carcass density for use in future fatality estimates.

Table 7. Comparison of overall adjusted mortality estimates using the Shoenfeld and Huso estimators for bats for surveys at the Hoopeston Wind Project from 2015-2017.

Season	Area Correction Method	R&P Area Correction Estimate	Size of Road and Pad Turbine Searches*	Cut-in speed	Huso Estimate		Shoenfeld Estimate	
					Bats/MW	Bats/ Turbine	Bats/MW	Bats/ Turbine
Fall 2015	Hull and Muir	0.28	40 m	6.9 m/s	0.68	1.36	0.57	1.15
Spring 2016	N/A	N/A	40 m	n/a	0.19	0.39	0.13	0.26
Fall 2016	Stantec Area Correction	~0.24	100 m	5 m/s	n/a[2]	n/a	2.2	4.3
Spring 2017	Hull and Muir	0.21	100 m	n/a	0.14	0.29	0.13	0.27
Fall 2017	Hull and Muir	0.21	100 m	5 m/s	2.2	4.5	2.5	4.9

*full plots had a 40-m radius for all survey years

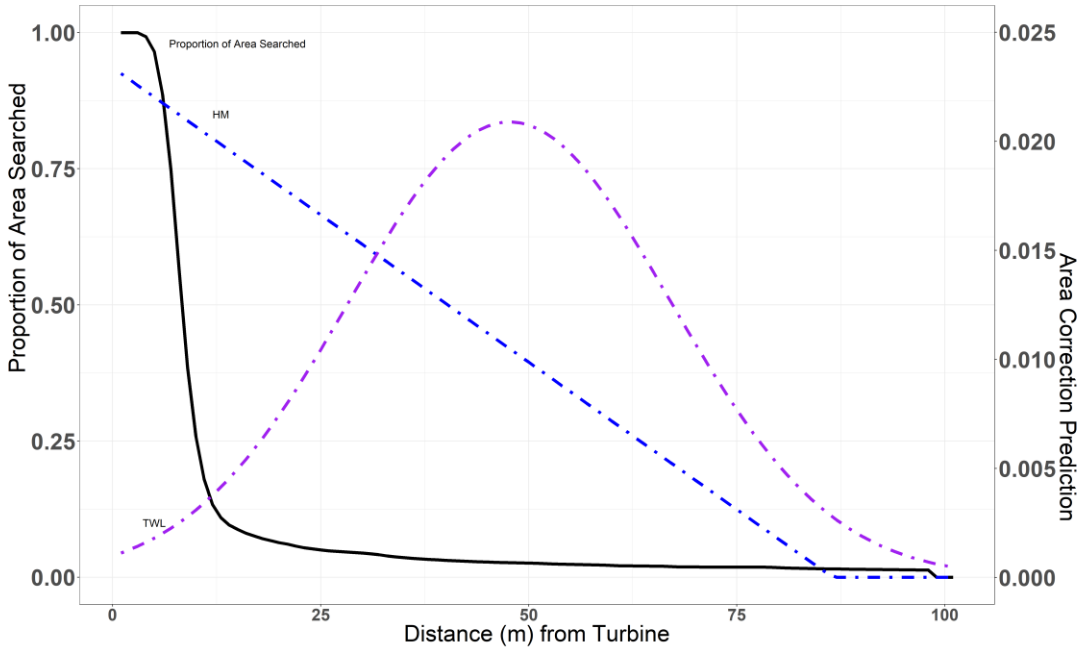

Figure 6. Proportion of area searched by distance, bat carcass density predicted by Hull and Muir (blue), and measured carcass density using truncated weighted likelihood (TWL) methods (purple). The TWL used the data collected on the distance from the turbine to the carcasses found during standardized carcass searches to estimate the carcass-distance density distribution. The density distribution of carcasses was determined by fitting truncated Weibull, truncated Rayleigh, truncated Normal, truncated Gamma, or truncated Gompertz density distributions (parameterized according to R Core Team [2016] and Thomas [2010]) to carcass distances (from turbines) and choosing the best-supported distribution through AICc.

Bird Fatalities

No federally or state- listed bird species were found. The plot sizes (i.e., 40 m [131 ft] radius for full plots and 100 m [328 ft] radius for road and pad) utilized in this study were designed to estimate bat mortality, and some bird carcasses likely occurred outside of the search radius that were not detected. However, based upon the very low number of birds found at the Project over multiple study periods (see Ritzert et al. 2016, Stantec 2017) including this study, the Project does not appear to be significantly impacting birds during the migration periods.

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Appendix A. Complete Casualty Listing for the Fall 2017 Casualty Monitoring at the Hoopeston Wind Project

Appendix A. Complete listing of carcasses found at the Hoopeston Wind Project.

Date	Turbine	Species	Plot Type	Distance from Turbine (m)	Estimated Time of Death(days)	Excluded from Huso	Excluded from Shoenfeld
8/1/2017	8	eastern red bat	road and pad	3	0-0	No	No
8/1/2017	10	eastern red bat	road and pad	75	4-7	Yes	Yes
8/1/2017	25	eastern red bat	road and pad	2	unknown	Yes	Yes
8/3/2017	41	hoary bat	road and pad	17	4-7	Yes	Yes
8/4/2017	48	hoary bat	road and pad	1	live	No	No
8/4/2017	51	eastern red bat	road and pad	45	15-30	Yes	Yes
8/8/2017	7	cliff swallow	road and pad	15	0-0	Yes	Yes
8/8/2017	19	hoary bat	road and pad	39	4-7	No	No
8/9/2017	38	eastern red bat	full plot	1	0-0	No	No
8/15/2017	27	eastern red bat	road and pad	4	4-7	No	No
8/15/2017	25	hoary bat	road and pad	6	14-30	Yes	No
8/16/2017	39	eastern red bat	road and pad	16	2-3	No	No
8/16/2017	50	big brown bat	road and pad	5	0-0	No	No
8/22/2017	9	eastern red bat	road and pad	36	4-7	No	No
8/22/2017	9	eastern red bat	road and pad	48	2-3	No	No
8/23/2017	39	hoary bat	road and pad	40	2-3	No	No
8/23/2017	42	eastern red bat	road and pad	22	4-7	No	No
8/29/2017	4	silver-haired bat	road and pad	44	8-14	Yes	No
8/29/2017	25	silver-haired bat	road and pad	4	2-3	No	No
8/29/2017	24	eastern red bat	road and pad	64	unknown	No	No
8/29/2017	16	eastern red bat	road and pad	14	2-3	No	No
8/30/2017	34	eastern red bat	road and pad	18	4-7	No	No
8/30/2017	38	silver-haired bat	full plot	21	2-3	No	No
8/30/2017	50	silver-haired bat	road and pad	32	4-7	No	No
9/5/2017	7	silver-haired bat	road and pad	70	0-0	No	No
9/5/2017	6	horned lark	full plot	35	unknown	Yes	Yes
9/5/2017	28	horned lark	full plot	7	2-3	Yes	Yes
9/6/2017	23	silver-haired bat	full plot	35	15-30	Yes	No
9/6/2017	37	silver-haired bat	road and pad	79	0-0	No	No
9/6/2017	47	silver-haired bat	full plot	38	2-3	No	No
9/11/2017	3	dickcissel	road and pad	3	0-0	Yes	Yes
9/11/2017	28	eastern red bat	full plot	35	4-7	No	No
9/11/2017	28	silver-haired bat	full plot	38	8-14	Yes	No
9/12/2017	23	hoary bat	full plot	29	8-14	Yes	No
9/16/2017	38	silver-haired bat	full plot	35	0-0	No	No
9/18/2017	3	silver-haired bat	road and pad	31	0-0	No	No
9/18/2017	29	eastern red bat	road and pad	30	4-7	No	No
9/18/2017	28	silver-haired bat	full plot	33	2-3	No	No
9/19/2017	23	unidentified vireo	full plot	2	4-7	Yes	Yes

Appendix A. Complete listing of carcasses found at the Hoopeston Wind Project.

Date	Turbine	Species	Plot Type	Distance from Turbine (m)	Estimated Time of Death(days)	Excluded from Huso	Excluded from Shoenfeld
9/19/2017	36	silver-haired bat	road and pad	75	2-3	No	No
9/19/2017	38	silver-haired bat	full plot	38	2-3	No	No
9/19/2017	48	silver-haired bat	road and pad	45	2-3	No	No
9/19/2017	49	silver-haired bat	road and pad	49	2-3	No	No
9/22/2017	47	silver-haired bat	full plot	8	2-3	No	No
10/3/2017	23	silver-haired bat	full plot	32	2-3	No	No
10/3/2017	37	silver-haired bat	road and pad	45	2-3	No	No
10/3/2017	44	evening bat	road and pad	52	2-3	No	No
10/3/2017	48	American redstart	road and pad	77	2-3	Yes	Yes
10/3/2017	50	silver-haired bat	road and pad	24	0-0	No	No
10/3/2017	50	silver-haired bat	road and pad	48	0-0	No	No
10/3/2017	40	silver-haired bat	road and pad	8	2-3	No	No
10/9/2017	10	eastern red bat	road and pad	34	2-3	No	No

Appendix B. Bat Fatality Rates at the Hoopeston Wind Project Using the Huso Estimator

Appendix B. Estimated fatality rates and correction factors, with 90% confidence intervals, using the Huso estimator for for operational monitoring studies conducted at the Hoopeston Wind Project, from August 1 to October 10, 2017

	full plot		road and pad	
Parameter	**Estimate**	**90% CI**	**Estimate**	**90% CI**
Search Area Adjustment (Hull & Muir method)				
A (Bats)	0.69		0.21	
Observer Detection Rate				
P (Bats)	0.58	0.31 - 0.77	1.0	1.0 - 1.0
Probability of a Carcass Persisting Through the Search Interval				
Bats	0.71	0.62 - 0.80	0.71	0.62 - 0.80
Probability of Available and Detected				
Bats	0.42	0.21 - 0.56	0.71	0.62 - 0.80
Unadjusted Number of Fatalities				
Bats	9.0	4.0 - 14.0	28.0	19.0 – 38.0
Observed Fatality Rates (Fatalities/Turbine/Season(s))				
Bats	1.80	0.80 - 2.80	0.41	0.25 -0.57
Adjusted Fatality Rates (Fatalities/Turbine/Seasons(s)) (Hull & Muir method)				
Bats	6.22	3.16 – 14.41	4.25	2.90 – 5.86
Adjusted Fatality Rates (Fatalities/MW/Seasons(s)) (Hull & Muir method)				
Bats	3.11	1.58 – 7.20	2.13	1.45 – 2.93

	Overall	
	Estimate	**90% CI**
Overall Bat Fatality Estimate/turbine	**4.45**	**3.19 – 6.29**
Overall Bat Fatality Estimate/MW	**2.23**	**1.60 – 3.14**

Appendix C. Bat Fatality Rates at the Hoopeston Wind Project Using the Shoenfeld Estimator

Appendix C. Estimated fatality rates and correction factors, with 90% confidence intervals, using the Shoenfeld estimator for operational monitoring studies conducted at the Hoopeston Wind Project, from August 1 to October 10, 2017.

	full plot		road and pad	
Parameter	**Estimate**	**90% CI**	**Estimate**	**90% CI**
Search Area Adjustment (Hull & Muir method)				
A (Bats)	0.69		0.21	
Observer Detection Rate				
P (Bats)	0.58	0.31 - 0.77	1.0	1.0 - 1.0
Mean Carcass Removal Time (Days)				
$\bar{t}$ (Bats)	8.33	5.49 - 12.42	8.33	5.49 - 12.49
Probability of Available and Detected				
Bats	0.49	0.27 - 0.62	0.69	0.58 - 0.77
Unadjusted Number of Fatalities				
Bats	12.0	6.0 - 17.0	30.0	21.0 – 40.0
Observed Fatality Rates (Fatalities/Turbine/Season(s))				
Bats	2.40	1.20 - 3.40	0.68	0.48 – 0.91
Adjusted Fatality Rates (Fatalities/Turbine/Seasons(s)) (Hull & Muir method)				
Bats	7.08	4.07 – 14.25	4.70	3.33 – 6.61
Adjusted Fatality Rates (Fatalities/MW/Seasons(s)) (Hull & Muir method)				
Bats	3.54	2.03 – 7.12	2.35	1.66 – 3.30

	Overall	
	Estimate	**90% CI**
Overall Bat Fatality Estimate/turbine	**4.94**	**3.72 – 7.02**
Overall Bat Fatality Estimate/MW	**2.47**	**1.86 – 3.51**