Operational Monitoring at the Hoopeston Wind Project Vermilion County, Illinois

April – October 2018

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EXECUTIVE SUMMARY

Western EcoSystems Technology, Inc. completed operational post-construction fatality monitoring during the spring, summer, and fall of 2018 at the Hoopeston Wind Project (Project) located in Vermilion County, Illinois. This report details the post-construction fatality monitoring studies conducted in accordance with the Hoopeston Habitat Conservation Plan (HCP) and Incidental Take Permit (ITP) **TE54252C-0** for Indiana bats and northern long-eared bats.

The operational Project is composed of 49 2.0-megawatt (MW) wind turbines capable of generating 98 MW. All turbines are Vestas V 100 turbines with a 100-meter (m; 328-feet [ft]) hub height, 49-m (161-ft) blade length, and feathered below normal cut-in from sunset to sunrise.

The post-construction fatality monitoring study objectives were to: 1) determine overall bat fatality rates, 2) estimate Indiana bat and northern long-eared bat take using the Species Composition approach and Evidence of Absence (EoA) framework outlined in the HCP, and 3) provide the necessary data to determine if adaptive management is triggered.

During the spring (April 1-March 15), full plot searches were completed weekly at five turbines within a 40-m (131-ft) radius of the turbine, and road and pad searches were completed weekly at the remaining 44 turbines on gravel areas within 95 m (312 ft) of the turbine. During the summer (March 16-July 31), road and pad searches were completed weekly at all 49 turbines. During the fall (Aug 1-October 15), 15 full plot turbines and 34 road and pad turbines were searched twice weekly. Searcher efficiency and carcass persistence trials were completed to estimate bat carcass detectability and persistence rates during each season and for each survey type. Overall bat fatality and Indiana bat and northern long-eared bat take estimates were calculated using searcher efficiency, carcass persistence and area correction estimates, or the proportion of bats estimated to fall within the search areas. Area correction estimates were calculated by using assumed values from the Project's HCP and Project-specific data from this study.

A total of 320 full plot searches and 1,441 road and pad searches were completed during the 2018 monitoring period. The estimated searcher efficiency rates for bats ranged from 44.4% for full plot searches to 92.5% for road and pad searches and did not vary by season. Bat carcasses were estimated to persist an average of 18.2 days, and rates did not differ by season or plot type.

No Indiana bats or northern long-eared bats, or any other federally or state-listed species, were found during the post-construction fatality monitoring studies. A total of 103 non-listed bats were found during the scheduled carcass searches. The most common non-listed bat species found was eastern red bat (46.6%), followed by silver-haired bat (27.2%) and hoary bat (12.6%). This bat species composition is similar to other wind energy facilities in the Midwestern U.S. Bats were mainly found in the fall season (81.6%) and were not concentrated within a specific area of the Project. In accordance with the HCP, an area adjustment of 0.706 for 40-m full plot turbines

and 0.233 for road and pads was used to estimate *g,* overall fatality estimates, and take estimates for Indiana bats and northern long-eared bats. Overall bat fatality estimates using the HCP-based area correction for the 2018 monitoring period were 4.2 bats per MW using the Huso estimator and 3.8 bats per MW using the Shoenfeld estimator. The EoA framework estimated that no Indiana bats or northern long-eared bats were killed during 2018, using the 50% credible estimate. Take estimates for the year using fall season overall bat fatality estimates and the Species Composition approach were 1.0 Indiana bat and 0.8 northern long-eared bat.

In addition to the HCP-based area correction, an additional Project-specific area correction was estimated for comparison purposes as recommended in the Project HCP if sufficient numbers of carcasses were found. Overall bat fatality estimates using the Project-specific area correction for the 2018 monitoring period were 10.9 bats per MW using the Huso estimator and 10.2 bats per MW using the Shoenfeld estimator. EoA estimated that one Indiana bat and one northern long-eared bat were killed during 2018, using the 50% credible estimate. Take estimates per year using fall season overall bat fatality estimates and the Species Composition approach were 2.4 Indiana bats and 2.0 northern long-eared bats.

The estimated levels of Indiana bat and northern long-eared bat take during 2018 were at or below levels predicted by the Project HCP and were below levels authorized within the ITP, depending on the method used to estimate take. The projected level of take for the remainder of the Project operation was also estimated to be lower than limits authorized by the HCP and ITP assuming similar levels of mortality in future years.

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INTRODUCTION

Western EcoSystems Technology, Inc. (WEST) completed operational post-construction fatality monitoring during the spring, summer, and fall of 2018 at the Hoopeston Wind Project (Project) located in Vermilion County, Illinois. The purpose of the study was to conduct monitoring in accordance with the Hoopeston Habitat Conservation Plan (HCP) and Incidental Take Permit (ITP) TE54252C-0 for Indiana bats (*Myotis sodalis*) and northern long-eared bats (*Myotis septentrionalis*). The Project is composed of 49 2.0-megawatt (MW) wind turbines capable of generating 98 MW. All turbines are V 100 Vestas turbines with a 100-meter (m; 328-feet [ft]) hub height and 49-m (161-ft) blade length.

As required in the HCP, turbines were feathered below manufacturer cut-in speed from sunset to sunrise each night from April 1 through October 15 to minimize impacts to Indiana bats and northern long-eared bats. The overall goal of this post-construction fatality monitoring study was to generate reliable fatality estimates for the covered species as specified in the HCP and to evaluate compliance with the incidental take authorization granted under ITP TE54252C-0. The objectives of this study were to: 1) determine overall bat fatality rates, 2) estimate Indiana bat and northern long-eared bat take using the Species Composition approach and Evidence of Absence (EoA) framework outlined in the HCP, and 3) provide the necessary data to determine if adaptive management is triggered (see Tables 7-2, 7-3 and 8-1 of the HCP).

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. Tall-grass prairie originally dominated much of the region, and scattered groves of trees and marshes occurred 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*), soybeans (*Glycine max*), and winter wheat (*Triticum sp.).* 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). Fatality monitoring was completed at 100% of the turbines as shown in Figure 1 and as described in the Methods section below.

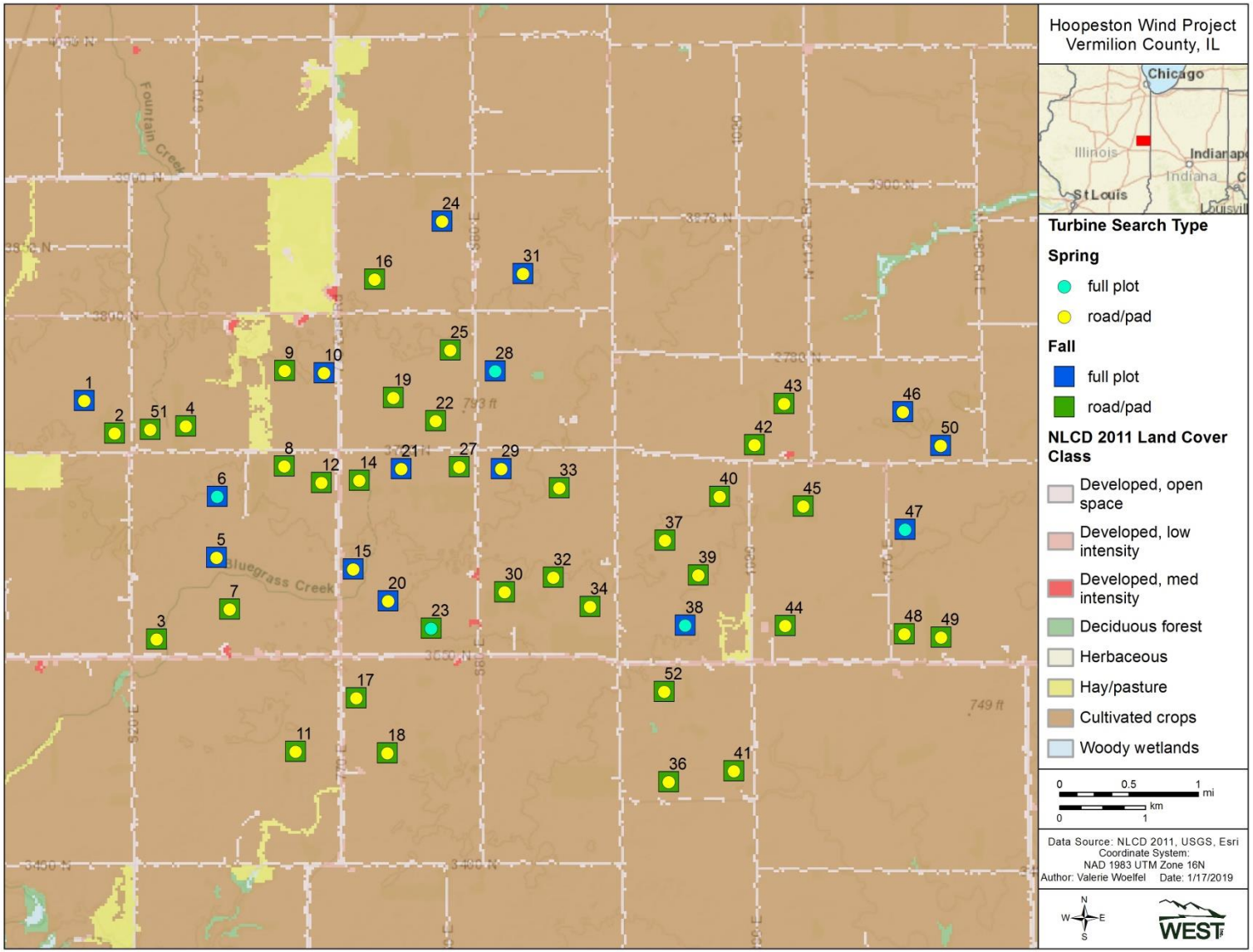

Figure 1. Land cover, turbine layout, and search plot types during the 2018 monitoring period at the Hoopeston Wind Project (US Geological Survey National Land Cover Database 2011, Homer et al. 2015).

METHODS

The study contained two components: 1) standardized carcass searches, and 2) searcher efficiency and carcass persistence trials using bat carcasses. Carcasses were found under two possible scenarios: 1) during standardized carcass surveys on survey plots or, 2) incidentally (i.e., outside of the search area or survey time or by operations personnel).

All bird and bat carcasses found, regardless of species, were assumed to be a result of 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 fatalities caused by turbine collision, 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 the Project's carcass search protocols, including proper handling and reporting of carcasses. Bat carcasses were collected in accordance with WEST's Illinois Department of Natural Resources (IDNR) Scientific Permit (2007; NH18.5223-1), WEST's IDNR Endangered and Threatened Species Permit (2514), WEST's U.S. Fish and Wildlife Service (USFWS) Native Endangered and Threatened Species Recovery Permit (TE234121-9), and the Project's ITP (TE54252C-0). The identification of all bats was verified in person by a WEST USFWS-permitted bat biologist (TE99051B-1). Bird carcasses were recorded but left in place, and all bird carcasses were verified by WEST biologists experienced with bird identification.

Survey methods were consistent with the Project HCP and varied by season and turbine. During the spring (April 1-March 15), full plot searches were completed weekly at five turbines within a 40-m (131-ft) radius of the turbine, and road and pad searches were completed weekly at the remaining 44 turbines within 95 m (312 ft) on the gravel area of turbines. During the summer (March 16-July 31), road and pad searches were completed weekly at all 49 turbines. During the fall (Aug 1-October 15), 15 full plot turbines and 34 road and pad turbines were searched twice weekly (Figure 1).

The perimeter of each full plot and road and pad area was delineated using a Global Positioning System and used to verify if carcasses were found inside the plot areas. During the spring and fall sample periods, vegetation at full plot turbines was mowed and maintained by Project staff within 10 to 15 centimeters (four 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 (148 – 197

ft) per minute and scanning the ground out to 2.5 m (8.2 ft) on either side of the transect. Biologists started at one side of the plot and systematically searched in a north-to-south or east-to-west direction, switching the search pattern on each visit to a plot. At road and pad turbines, biologists began searches starting at 95 m 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 was completely intact, was not badly decomposed, and showed no sign of being fed upon by a predator or scavenger
- Scavenged – an entire carcass, which showed 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), or a carcass that was heavily infested by insects
- 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)
- Estimated time since death (number of days)

Searcher Efficiency Trials

Searcher efficiency trials were conducted at a subset of full plot and road and pad turbines. The objective of the searcher efficiency trials was to estimate the proportion of bat carcasses found by searchers in each survey type and during each season. Twenty-four bats were used for the trials in the spring (12 full plots, 12 roads and pads), and 12 bats were placed on roads and pads during the summer. Thirty-three bats were placed on full plots and 16 bats were placed on road and pads during the fall. Searcher efficiency was estimated by survey type (full plot or road and pad) and season, and was 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. Eighty-five bats, provided by the Illinois Natural History Survey and found during this study, were used during 10 trials conducted between April 16 and October 8, 2018. The bats provided from the Illinois Natural History Survey consisted of big brown bats (*Eptesicus fuscus*), and the bats found during this study (and used for searcher efficiency trials) consisted of eastern red bats (*Lasiurus borealis*), hoary bats

(*Lasiurus cinereus*), evening bats (*Nycticeius humeralis*), and silver-haired bats (*Lasionycteris noctivagans*). Fresh and slightly decomposed carcasses were used for the searcher efficiency trials.

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 the bats prior to placement so that the carcasses could be identified as trial carcasses after they were found. The number and location of trial carcasses found during the carcass search were recorded. The number of carcasses available for detection during each trial was determined after the trial by the person responsible for distributing the carcasses, and any carcasses determined to be unavailable to the searcher were excluded from the searcher efficiency estimates. Searchers had one chance to locate trial carcasses, during the first search after carcass placement.

Carcass Persistence Trials

Carcass persistence trials were conducted using a subset of the carcasses used for searcher efficiency trials. The objective of carcass persistence trials was to estimate the average length of time a detectable bat carcass remained in the field. Six separate trials were conducted with start dates between April 16 and September 11, 2018. Estimates of carcass persistence rates were used to adjust the total number of carcasses found by searchers, correcting for removal bias. Trials were conducted throughout the study period to incorporate the effects of varying weather and climatic conditions on carcass persistence rates with seven bats placed on full plots and seven bats placed on roads and pads in spring, six bats on roads and pads during summer, and nine bats placed on full plots and 10 bats placed on roads and pads in fall. Bats used for carcass persistence trials were fresh.

Personnel monitored the trial carcasses over a 28-day period, checking the carcasses on days 1, 2, 3, 4, 7, 10, 14, 21, and 28 after placement. Carcasses were left at the location until the carcass was completely removed or the trial period ended. Any remaining evidence of the carcass was removed at the end of the 28-day monitoring period.

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 Estimates

Fatality estimates for bats were based on:

- Observed number of carcasses found within standardized search plots during the monitoring period
- Searcher efficiency, expressed as the proportion of trial carcasses found by searchers during searcher efficiency trials
- Persistence rates, expressed as the estimated average probability a carcass was expected to persist in the search area and be available for detection by the searchers during persistence trials
- Area correction estimates

Fatality estimates were calculated for bats using the Huso and Shoenfeld estimators (Huso 2011; Huso et al. 2015; Shoenfeld 2004) as requested by the USFWS (A. Schorg, USFWS, pers. comm., December 7, 2018). However, only the overall fatality estimates from the Huso estimator were used to determine take estimates for Indiana and northern-long eared bats using the Species Composition approach and EoA framework. More detailed methods for these take estimates are presented below.

Definition of Variables for Huso Estimator

The following variables were used in the equations below for the Huso estimator (Huso 2011; Huso et al. 2015):

c_i total number of carcasses in category *i* (bat), search type (full plot and road and pad turbines), and season (e.g., 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 and season considered as potential covariates. 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 and season were considered as potential covariates. 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 ($\widehat{r_i}$) were estimated using this best model.

Area Correction

In accordance with the HCP, the proportion of carcasses falling within searched areas was estimated to account for unsearched area and the carcass-density distribution. The Project HCP predicted an area adjustment of 0.706 for 40-m full plot turbines, based on Fowler Ridge Wind Farm in Indiana, and an area adjustment of 0.233 for road and pad turbines based on studies conducted by Stantec in similar landscapes. This HCP-based area correction was used for this study to estimate *g,* overall fatality estimates, and take estimates for Indiana bats and northern long-eared bats.

In addition to the HCP-based area correction, an additional Project-specific area correction was estimated for comparison purposes as recommended in the Project HCP if sufficient numbers of carcasses were found. As described within the Project HCP, a likelihood modeling approach was also used to estimate the carcass-distance density distribution based on the distances at which bat carcasses were found from turbines during 2018. The carcass-distance density distribution was combined with the proportion of area searched to calculate an area correction value. The Truncated Weighted Likelihood (TWL) was used to estimate the carcass-distance density distribution using Project-specific data of the distance of bat carcasses from the turbine. 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. Fits were obtained using a weighted maximum likelihood approach (Khokan et al. 2013), where the weight for each observed carcass distance was the inverse of the fraction of area searched at the distance where the carcass was found, multiplied by the inverse of the probability the carcass was

available to be found and detected by searchers. This approach results in weighted maximum likelihood estimates of carcass detection probabilities that vary systematically with distance from turbines. Areas near the turbine tend to have a higher density of bat carcasses than areas farther from the turbine (Huso and Dalthorp 2014) and, therefore, the search area was combined with the carcass-density distribution. The result was an estimate of the proportion of bat carcasses expected to land within searched and unsearched areas around the turbines.

Adjusted Fatality Rates

Adjusted fatality estimates were calculated for each of the seasons, plot types (full plot and road and pad turbines) and for the entire study period. The adjusted fatality rate for the entire facility in each season 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 in each season. The adjusted overall bat fatality estimates for the entire facility during the monitoring seasons was calculated as the sum of adjusted bat fatality estimates for each season and/or plot type.

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

$$\widehat{\pi_i} = \widehat{a_i} \cdot \widehat{p_i} \cdot \widehat{r_i} \cdot \hat{v}_i$$

where $\widehat{v_i}$ = 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 ($\widehat{f_i}$) in category *i*, based on the number of carcasses found in category *I*, was calculated by:

$$\widehat{f_i} = \frac{c_i}{\widehat{\pi_i}}.$$

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

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

Definition of Variables for Shoenfeld Estimator

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

c_i the number of bat 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 bat carcasses observed per turbine per survey period

s the number of bat carcasses used in persistence trials

s_c the number of bat carcasses in persistence trials that remained in the Project after 28 days

t_j the time (in days) a bat carcass j remained in the Project before it was removed, as determined by the persistence trials

$\bar{t}$ the average time (in days) a bat carcass remained in the Project before it was removed, as determined by the persistence trials

$\hat{p}$ the estimated proportion of detectable bat carcasses found by searchers, as determined by the searcher efficiency trials

I the average interval (in days) between standardized carcass searches

A area correction

$\hat{\pi}$ the estimated probability that a bat 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 bat fatalities per turbine per year, adjusted for persistence and searcher efficiency bias

Observed Number of Carcasses

The average number of bat 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 and season considered as a potential covariates. 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 bat carcass persistence rates were used to adjust carcass counts for persistence bias. Plot type and season were considered as potential covariates. The carcass persistence rates were assumed to follow an exponential distribution consistent with the assumptions of the

Shoenfeld estimator. 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.

Area Correction

The same area correction methods presented above for the Huso estimator were also used for the Shoenfeld estimator.

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:

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

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.

Indiana Bat and Northern Long-eared Bat Take and Detection Probability Estimates

The fall season was the only season with potential risk to covered species; therefore, species-specific fatality estimates were calculated for Indiana bats and northern long-eared bats using fall bat fatality estimates only.

Species Composition Approach

Indiana bat and northern long-eared bat fatalities were estimated for the year using the Species Composition approach by assuming that Indiana bat fatalities comprised 0.29% of all bat fatalities and northern long-eared bat fatalities comprised 0.24% of all bat fatalities, as specified

in the HCP. Take estimates using this approach were calculated two ways: 1) using the HCP-based area correction estimate and 2) using the Project-specific area correction estimates.

Evidence of Absence

The EoA framework (Dalthorp et al. 2014; Dalthrop et al. 2017)) utilized a statistical hierarchical model to estimate the actual number of fatalities from the number found, *g* (the site-wide probability that a carcass was available to be found and detected by searchers), the estimated mortality rate (λ), and the cumulative 30-year projected mortality based on the estimated rate. The site-wide probability that a carcass was available to be found and detected by searchers was based on:

- Searcher efficiency expressed as the proportion of placed carcasses found by searchers during searcher efficiency trials (see Estimation of Searcher Efficiency Rates on page 10)
- Carcass persistence rates expressed as the estimated average probability a carcass was expected to remain in the study area and be available for detection by the searchers during persistence trials (see Estimation of Carcass Persistence Rates on page 10)
- Search area adjustment based on the estimated carcass density within search areas and outside of search areas (see Area Correction section on page 10)
- Detection reduction factor (*k*), expressed as the fraction to which searcher efficiency was reduced with each successive search

Carcasses that were missed on the first search may have persisted and may have been detectable on subsequent searches, but may have had a lower probability of detection because carcasses begin to disintegrate with time, and easy-to-find carcasses were likely discovered early, so that the remaining carcasses were those that were inherently more difficult to see. Thus, if searcher efficiency was $\hat{p}$ during the first search after a carcass arrives, it was scaled by a factor, *k*, on each subsequent search so that the probability of detection during the first search was $\hat{p}$, during the second search was $\hat{p} * k$, during the third search was $\hat{p} * k^2$, and so-on. *k* was assumed to be 0.8 based on assumptions from the Project HCP.

The EoA estimator assumed the number of fatalities found during searches followed a binomial distribution

$$X \sim binomial(M, g)$$

where *X* was the count of Indiana bat or northern long-eared bat fatalities found during standardized carcass searches and *M* was the (unknown) number of bat fatalities. The statistical hierarchy of models inherent in EoA used an integrated reference prior distribution (Dalthorp et al. 2017) for Indiana bat or northern long-eared bat fatalities (*M*).

The Project HCP specified that a projection of take over 30 years of operation be calculated to evaluate if the long term permitted level of take may be exceeded. The EoA model estimated

total mortality (M) during the study period, which was always a whole number of bats. In addition, EoA produced an estimate of the underlying average fatality rate, (λ), which was not necessarily a whole number. For example, a facility may have an *average* take rate, λ, (over a large number of years) of 0.2 bats per facility per year. The estimated take cannot be 0.2 bats because it is nonsensical to take a fifth of a bat. However, during a given year, the actual take at a facility with a take rate of 0.2 bats per year may be zero, one, or in rare years, even two or three bats. The estimated take rate (λ) was used to estimate the life of Project mortality by drawing a sample of potential take rates from the posterior distribution of the estimated take rate, and then simulated take in each year based on that take rate. The take was summed over the permit duration (30 years), and the median overall projected take was calculated based on the distribution of projected take. For the take projections, it was assumed that there were no changes in operations in future years, and no reason to suspect mortality rates (ρ) varied systematically from year to year. These estimates were calculated two ways: 1) using the HCP-based area correction estimate and 2) using the Project-specific area correction estimates.

RESULTS

Standardized Carcass Searches

A total of 320 full plot searches and 1,441 road and pad searches were completed from April 2 to October 12, 2018. Details of all of the carcasses found during the study are presented in Appendix A. No Indiana bat or northern long-eared bat carcasses, or any other listed species were found during the study.

Overall Fatalities

A total of 103 non-listed bat carcasses belonging to five species were found during scheduled carcass searches and incidentally. Forty-three bats (0.13 bats per survey) were found during full plot searches, and 60 bats (0.04 bats per survey) were found during road and pad searches. Eastern red bat (n=48, 46.6%) was the most common species, followed by silver-haired bat (n=28, 27.2%), hoary bat (n=13, 12.6%), big brown bat (n=8, 7.8%) and evening bat (n=6, 5.8%). Five species of birds were found during the study (four killdeer [*Charadrius vociferous*], two golden-crowned kinglets [*Regulus satrapa*], one mourning dove [*Zenaida macroura*], one ring-necked pheasant [*Phasianus colchicus*], and one rock dove [*Columba livia*]; Table 1).

Table 1. Total number and composition of carcasses discovered at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 – October 12, 2018.

	Carcasses Included in Huso Estimates		Carcasses Off Plot		Estimated Time of Death was Greater than the Search Interval		Total	
Species	**Total**	**% Comp**	**Total**	**% Comp**	**Total**	**% Comp**	**Total**	**% Comp**
Bat								
eastern red bat	36	40.4	2	66.7	10	90.9	48	46.6
silver-haired bat	27	30.3	1	33.3	0	0	28	27.2
hoary bat	13	14.6	0	0	0	0	13	12.6
big brown bat	8	9.0	0	0	0	0	8	7.8
evening bat	5	5.6	0	0	1	9.1	6	5.8
Overall Bats	**89**	**100**	**3**	**100**	**11**	**100**	**103**	**100**
Bird								
killdeer	0	0	0	0	0	0	4	44.4
golden-crowned kinglet	0	0	0	0	0	0	2	22.2
mourning dove	0	0	0	0	0	0	1	11.1
ring-necked pheasant	0	0	0	0	0	0	1	11.1
rock pigeon	0	0	0	0	0	0	1	11.1
Overall Birds	**0**	**0**	**0**	**0**	**0**	**0**	**9**	**100**

% Comp = percent composition

Carcasses for Analysis

Bat carcasses were included in the analysis using the Huso estimator if they were found inside scheduled search plots and were found by searchers on the first search after their death. Eleven bat carcasses were excluded from the Huso fatality estimate because they did not meet the model assumption of the searcher having a single opportunity to find each carcass (i.e., the estimated time of death was greater than the search interval; Table 1), but were included in the Shoenfeld fatality estimate. Three bat carcasses were found outside of search plot boundaries and were excluded from the analysis using the Huso and Shoenfeld estimators. Bird fatality rates were not estimated and, therefore, bird carcasses were not included in the analyses.

Timing and Distribution of Bat Fatalities

The majority (85.4%) of bat carcasses were found after July 17, 2018 (i.e., in the late summer and fall; Figure 2). Approximately 78.2% of all bats found during road and pad surveys were found within 40 m of the turbine (i.e., the radius of the full plot survey), which comprised 48.3% of all bats included in the Huso estimates (Table 2). Bat carcasses were found at 47 of the 49 study turbines. The highest number of bats (one bat in the spring/summer [road and pad] and five in the fall [full plot]) were found at turbine 31, while five bats were found at turbine 44 and four bats were found at turbines 11 and 47 during all seasons. Turbines 11 and 44 had road and pad surveys during all seasons, and turbine 47 had a full plot survey during the spring and fall seasons.

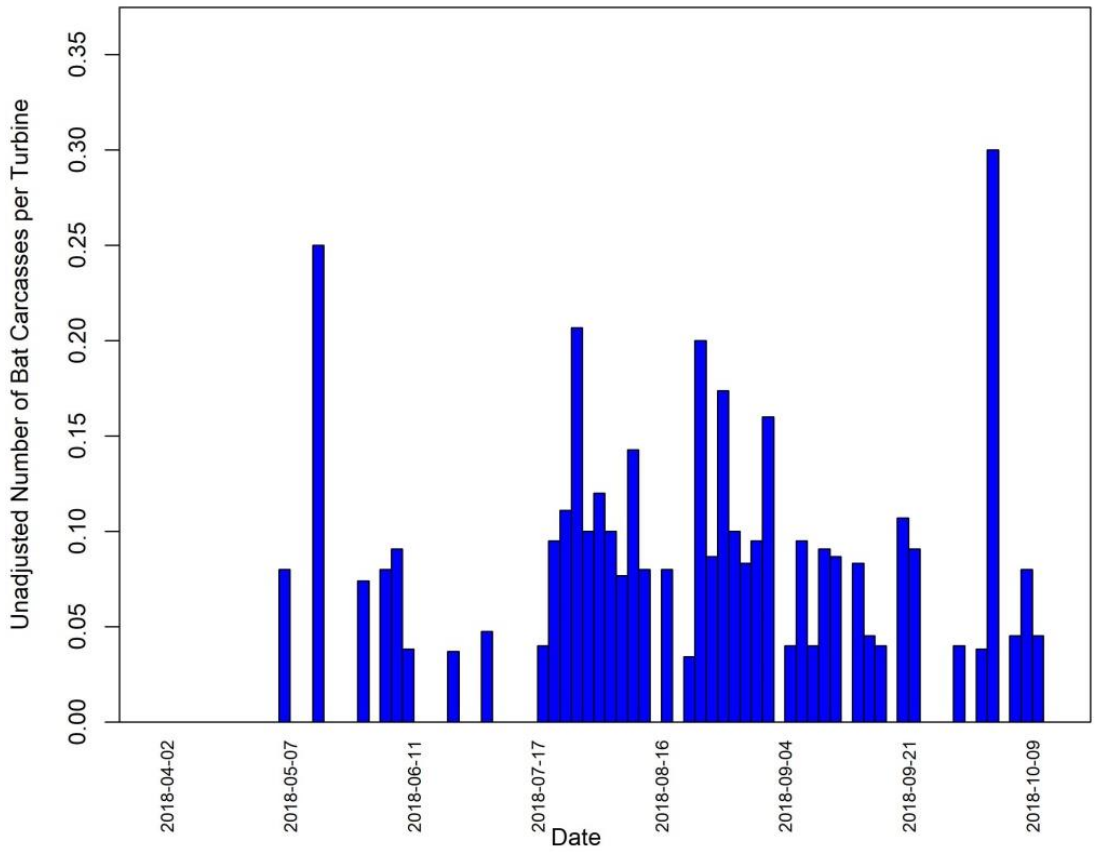

Figure 2. Timing of bat carcasses at the Hoopeston Wind Project from April 2 – October 12, 2018 for carcasses included in the Huso estimates.

Table 2. Distribution of bat carcasses included in Huso analysis and acres searched by distances from turbines found on full plot and road and pad turbines at the Hoopeston Wind Project from April 2 – October 12, 2018.

Distance from Turbine (m)	Acres Searched on Full Plot Turbines (%)	Number of Bat Carcasses Found on Full Plot Turbines (%)	Acres Searched on Road and Pad Turbines (%)*	Number of Bat Carcasses Found on Road and Pad Turbines (%)
0 to 10	0.11 (8.0%)	4 (11.8%)	0.07 (28.4%)	24 (43.6%)
10 to 20	0.26 (19.3%)	6 (17.7%)	0.02 (9.1%)	6 (10.9%)
20 to 30	0.42 (30.7%)	11 (32.4%)	0.02 (8.1%)	10 (18.2%)
30 to 40	0.57 (42.0%)	13 (38.2%)	0.02 (8.6%)	3 (5.5%)
40 to 50	0	0	0.02 (8.2%)	4 (7.3%)
50 to 60	0	0	0.02 (8.3%)	4 (7.3%)
60 to 70	0	0	0.02 (8.3%)	3 (5.5%)
70 to 80	0	0	0.02 (8.7%)	1 (1.2%)
80 to 90	0	0	0.02 (8.3%)	0
90 to 100	0	0	0.01 (4.1%)	0

*Totals may not add to 100% due to rounding

Searcher Efficiency Trials

Eighty-five bat carcasses were used to estimate searcher efficiency. Raw searcher efficiency rates for bats ranged from 42.4% to 100%, depending on plot type and season (Table 3). Searcher efficiency rates were calculated using the best-fit logistic regression model with plot type and season as potential variables; plot type was a covariate in the best-fit model. Season was not chosen in the best-fit model, indicating that rates did not vary substantially between seasons. Modeled searcher efficiency rates were higher on road and pad turbines compared to full plot turbines (Tables 4 and 5).

Table 3. Bat carcasses placed for searcher efficiency and carcass persistence trials, and raw searcher efficiency rates by plot type at the Hoopeston Wind Project during the study period, April 2 – October 12, 2018.

	Full Plot				Road and Pad			
Season	Number Placed	Number Available	Number Found	Percent	Number Placed	Number Available	Number Found	Percent
Spring	12	12	6	50.0	12	12	12	100
Summer*	-	-	-	-	12	12	11	91.7
Fall	33	33	14	42.4	16	16	14	87.5
Overall	**45**	**45**	**20**	**44.4**	**40**	**40**	**37**	**92.50**

*No full plot turbines were searched in summer

Table 4. Searcher efficiency logistic regression models for bats from the Hoopeston Wind Project search efficiency trials. Selected models are denoted by an asterisk in the 'Delta AICc' column.

Covariate	AICc	Delta AICc
Plot Type	87.3	0*
Season + Plot Type	90.7	3.5
Season	107.1	19.8
No Covariates (Intercept)	109.8	22.5

AICc = Akaike Information Criteria

Table 5. 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 Plot Turbines	Estimated Searcher Efficiency Rates for Roads and Pads
Bat	44.4%	92.5%

Carcass Persistence Trials

Thirty-nine bat carcasses were placed for carcass persistence trials and were used to estimate carcass persistence rates. The estimated mean carcass persistence time was 18.2 days for bats using the exponential distribution for the Huso and Shoenfeld estimators (Table 6). Approximately 50% of bat carcasses remained after 10 days (Figure 3). The best-fit models for carcass persistence did not contain season or plot type, indicating that carcass persistence did not vary between plot type and season. The average probability that a bat carcass persisted

through a 7-day search interval (spring and fall) was 0.83, and the average probability of bat carcass persistence through a 3.8-day search interval (fall) was 0.90.

Table 6. Carcass persistence top model with covariates, distributions, and model parameters for the Hoopeston Wind Project.

Size	Distribution	Predicted Values	Scale
Bat	Exponential	18.2	1

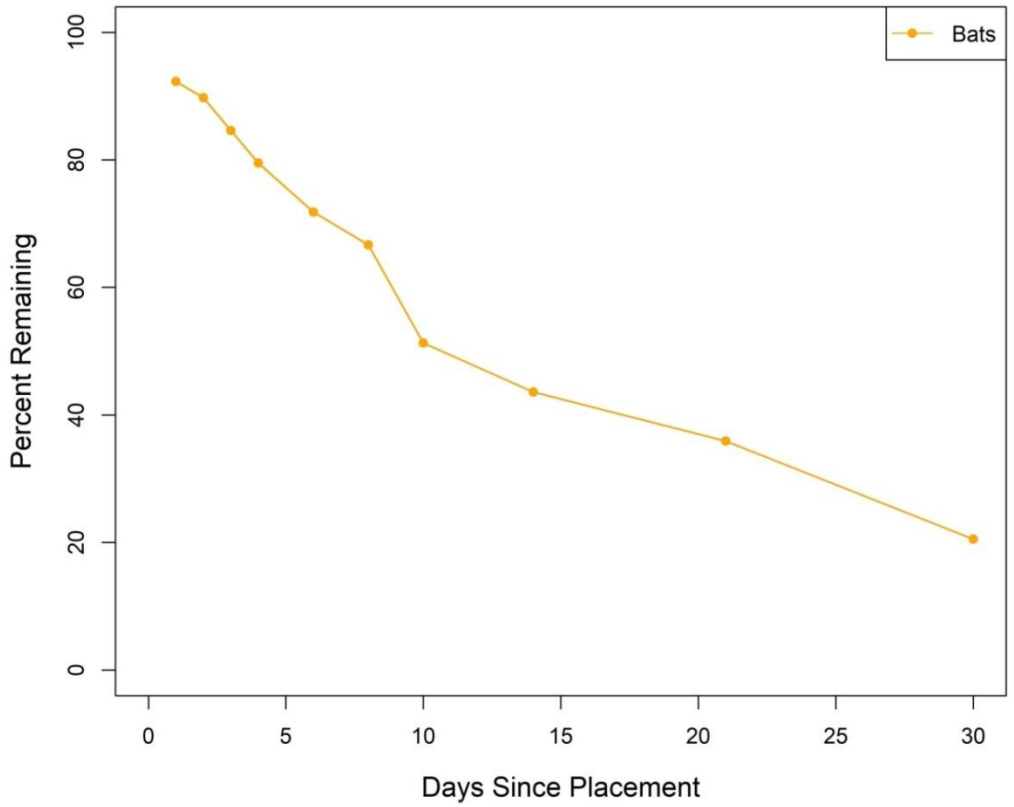

Figure 3. The percentage of carcasses remaining during carcass persistence trials at the Hoopeston Wind Project during the study period, April 2 - October 12, 2018.

Area Correction Using Project-Specific Data

The TWL method was one of the methods used to determine the proportion of carcasses estimated to have fallen within search areas using carcass distribution data collected during 2018. The same carcasses included in the Huso estimates were also used for the TWL method. The best-fitting distribution was the Gompertz model based on model selection using AICc (Appendix B). The TWL model estimated that approximately 44% of bats fell within the search areas of full plot turbines and 8% of bats fell within the search areas of road and pad turbines (Figures 4 and 5).

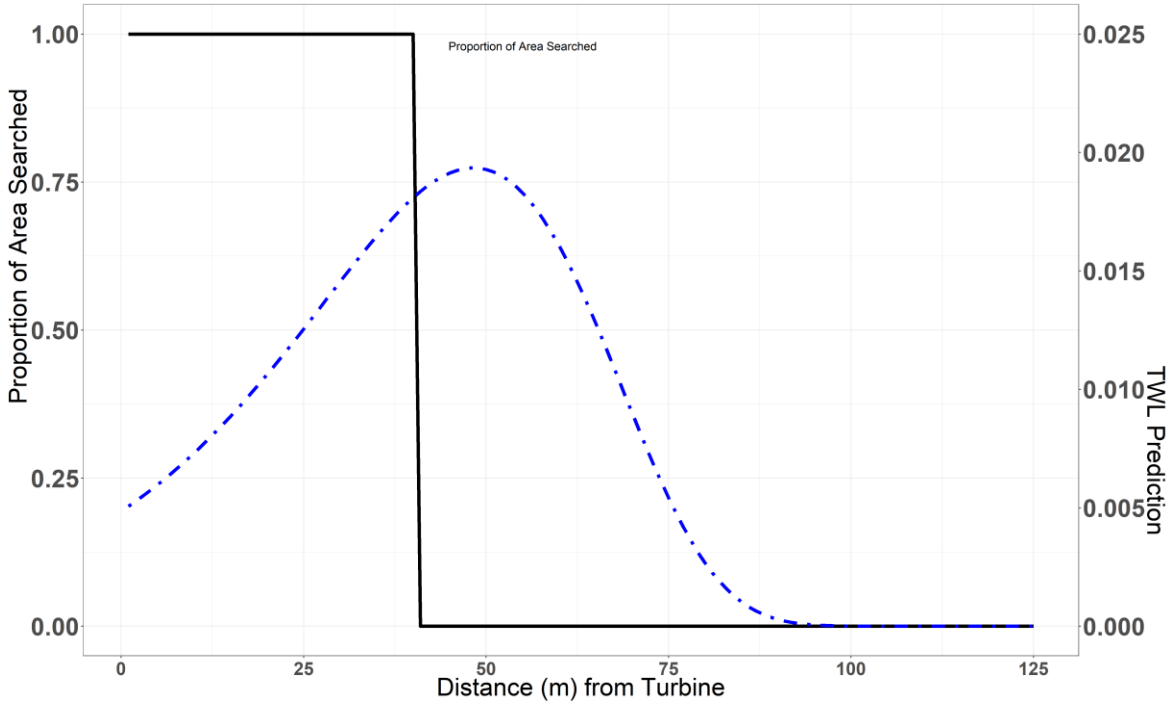

Figure 4. Proportion of area searched on full plot turbines by distance (black) and estimated carcass density using truncated weighted likelihood (TWL) methods (blue).

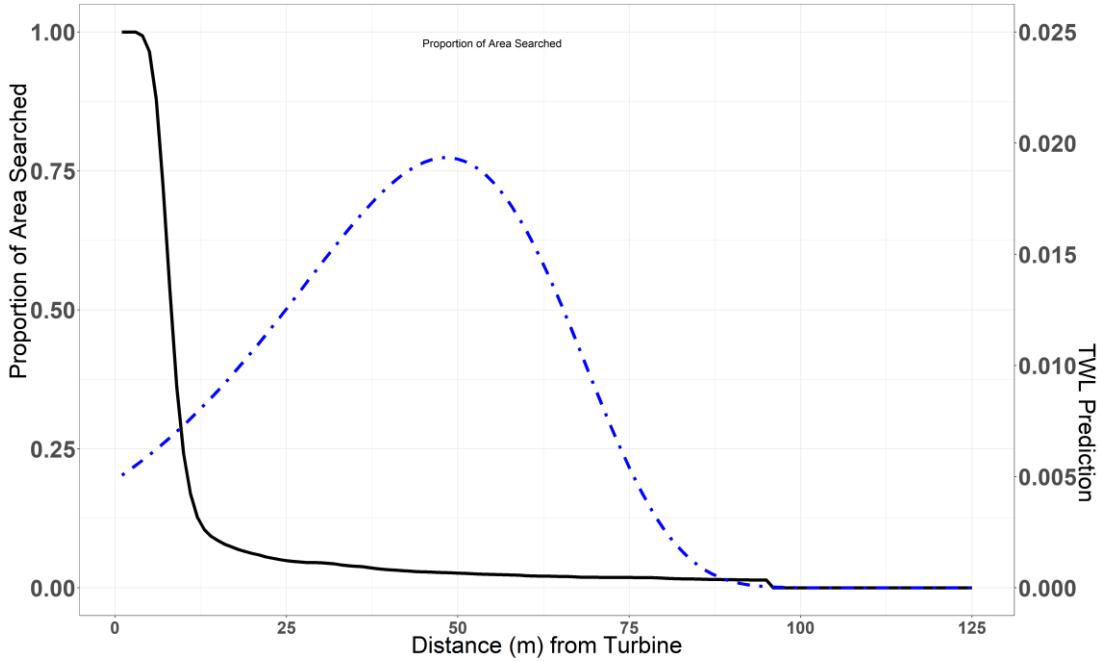

Figure 5. Proportion of area searched on roads and pads by distance (black) and estimated carcass density using truncated weighted likelihood (TWL) methods (blue).

Adjusted Overall Bat Fatality Estimates

Fatality estimates from the Huso estimator were used to calculate Indiana bat and northern long-eared bat take estimates; fatality estimates using Shoenfeld were calculated for comparison purposes only. Overall fatality estimates were slightly lower using the Shoenfeld compared to the Huso estimator (Tables 7a-b and 8a-b). Overall fatality estimates were lower using the HCP-based area correction (Tables 7a and 7b) compared to the Project-specific area correction (Tables 8a and 8b), and fewer carcasses were estimated to have fallen within search areas using the Project-specific area correction when compared to the HCP-specific area correction. A list of the carcasses included for each estimator are presented in Appendix A. Descriptions of the variables used to calculate the fatality estimates using the Huso and Shoenfeld estimators are described in Appendix C for the HCP-based area correction and Appendix D for the Project-specific area correction.

Table 7a. Overall bat fatality rates per turbine and megawatt using the Huso Estimator and HCP-based area correction method for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 – October 12, 2018.

Season	Bat Fatality Estimate per Turbine	90% Confidence Limits	Bat Fatality Estimate per Megawatt	90% Confidence Limits
Spring	0.35	N/A*	0.17	N/A
Summer	1.35	0.71 - 2.10	0.67	0.36 - 1.05
Fall	6.79	5.36 - 8.60	3.39	2.68 - 4.30
Overall	**8.48**	**6.78 - 10.63**	**4.24**	**3.39 - 5.32**

*Confidence limits not calculated due to the low number of bat carcasses

Table 7b. Overall bat fatality rates per turbine and megawatt using the Shoenfeld Estimator and HCP-based area correction method for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 – October 12, 2018.

Season	Bat Fatality Estimate per Turbine	90% Confidence Limits	Bat Fatality Estimate per Megawatt	90% Confidence Limits
Spring	0.25	N/A*	0.13	N/A*
Summer	1.41	0.78 - 2.13	0.70	0.39 - 1.07
Fall	5.94	4.84 - 7.36	2.97	2.42 - 3.68
Overall	**7.60**	**6.30 - 9.30**	**3.80**	**3.15 - 4.65**

*Confidence limits not calculated due to the low number of bat carcasses

Table 8a. Overall bat fatality rates per turbine and megawatt using the Huso Estimator and Project-specific area correction method for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 – October 12, 2018.

Season	Bat Fatality Estimate per Turbine	90% Confidence Limits	Bat Fatality Estimate per Megawatt	90% Confidence Limits
Spring	0.72	N/A*	0.36	N/A*
Summer	4.01	2.11 - 6.24	2.01	1.06 - 3.12
Fall	17.13	13.48 - 21.65	8.57	6.74 - 10.83
Overall	**21.86**	**17.53 - 27.49**	**10.93**	**8.76 - 13.75**

*Confidence limits not calculated due to the low number of bat carcasses

Table 8b. Overall bat fatality rates per turbine and megawatt using the Shoenfeld Estimator and Project-specific area correction method for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 – October 12, 2018.

Season	Bat Fatality Estimate per Turbine	90% Confidence Limits	Bat Fatality Estimate per Megawatt	90% Confidence Limits
Spring	0.56	N/A*	0.28	N/A*
Summer	4.19	2.06 - 7.04	2.10	1.03 - 3.52
Fall	15.63	10.41 - 23.06	7.82	5.20 - 11.53
Overall	**20.39**	**13.47 - 29.69**	**10.19**	**6.73 - 14.84**

*Confidence limits not calculated due to the low number of bat carcasses

Indiana Bat and Northern Long-Eared Bat Take Estimates

EoA Framework

The overall probability of detecting a single bat carcass (*g*), such as an Indiana bat and northern long-eared bat, varied by season due to the varying search intensity of each season and the estimated proportion of overall bats occurring in each season. The overall detection probability using the area correction assumptions outlined in the HCP was 0.25 for all seasons and 0.28 for the fall season when risk to Indiana bats and northern long-eared bats was expected (Table 9). For comparison purposes, the detection probability for the first year of monitoring following the HCP and using Project-specific area correction estimates was 0.12 for all seasons, and 0.13 for the fall season (Table 10). Only the fall season *g* estimate of 0.13 was used to determine EoA take estimates as described within the Project HCP (Table 11).

Table 9. Estimated detection probability for Indiana bats and northern long-eared bats using Evidence of Absence framework with the area correction outlined in the HCP. Weights were assigned proportionally to the estimated all-bat fatality rate.

Seasons	Huso Estimated All-Bat Fatalities/Megawatt/Season	Weight	$\hat{g}$
Spring	0.17	0.04	0.20
Summer	0.67	0.16	0.18
Fall	3.39	0.80	0.28
All Seasons	**4.23**	**1.00**	**$\hat{g}$ = 0.26 95% Confidence Interval = [0.23, 0.28]**

Table 10. Estimated detection probability for Indiana bats and northern long-eared bats using Evidence of Absence framework with area correction data collected at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 - October 12, 2018.

Seasons	Huso Estimated All-Bat Fatalities/Megawatt/Season	Weight	$\hat{g}$
Spring	0.36	0.03	0.08
Summer	2.01	0.18	0.06
Fall	8.57	0.78	0.13
All Seasons	**10.93**	**1.00**	**$\hat{g}$ = 0.12 95% Confidence Interval = [0.10, 0.13]**

Table 11. Variables used to estimate the detection probability for Indiana bats and northern long-eared bats using Evidence of Absence framework.

	Spring	Summer	Fall
Number of Searches	7	10	21
Search Interval	7.02	7.02	3.79
Full Plot Turbines Searched	5	0	15
Roads and Pad Turbines Searched	44	49	34
Probability of Detection - Full Plot	0.44 (95% CI: 0.31, 0.59)	-	0.44 (95% CI: 0.31, 0.59)
Probability of Detection - Road and Pad	0.93 (95% CI: 0.81, 0.98)	0.93 (95% CI: 0.81, 0.98)	0.93 (95% CI: 0.81, 0.98)
Probability a Carcass was available for detection (rHat)	0.83 (95% CI: 0.76, 0.87)	0.83 (95% CI: 0.76, 0.87)	0.90 (95% CI: 0.85, 0.93)
Area Correction - Full Plot (HCP-based)	0.70	-	0.70
Area Correction - Road Pad (HCP-based)	0.23	0.23	0.23
Area Correction - Full Plot (Project specific)	0.44	-	0.44
Area Correction - Road Pad (Project-specific)	0.08	0.08	0.08
k (as defined in HCP)	0.80	0.80	0.80

The EoA estimates with 50% credibility, which is equivalent to the median value, and using the HCP-based area correction method determined that zero Indiana bats and zero northern long-eared bats were estimated to have been taken during the study (Table 12). Using the Project-specific area correction, there was one Indiana bat and one northern long-eared bat estimated to have been taken during the study at 50% credibility (Table 13).

Table 12. Median take estimates per year using Evidence of Absence and the HCP-based area correction for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 – October 12, 2018.

Estimate Type	Bat Fatality Estimate per Year
Evidence of Absence - Indiana bat (50% credible bound)	0
Evidence of Absence - northern long-eared bat (50% credible bound)	0

Table 13. Median take estimates per year using Evidence of Absence and the Project-specific area correction for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 – October 12, 2018.

Estimate Type	Bat Fatality Estimate per Year
Evidence of Absence - Indiana bat (50% credible bound)	1
Evidence of Absence - northern long-eared bat (50% credible bound)	1

Projected Mortality for Remainder of the Project ITP

Using the EoA approach, the estimated fatality rates (λ) for Indiana bat and northern long-eared bat were calculated based on the fall season estimated *g* value for each area correction value (Tables 14 and 16). The cumulative median 30-year mortality projection at 50% credible interval for both Indiana bat and northern long-eared bat using the HCP-based area correction and Project-specific area correction was 24 and 53 fatalities, respectively (Tables 15 and 17), both of which are below the life of project permitted take described within the Project HCP. The project ITP authorized the take of 60 individuals of each species over the life of the permit.

Table 14. Estimated fatality rate (λ) using Evidence of Absence and the HCP-based area correction for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 – October 12, 2018.

Estimate Type	Bat Fatality Rates
Evidence of Absence - Indiana bat (50th credible bound)	0.83
Evidence of Absence - northern long-eared bat (50th credible bound)	0.83

Table 15. Cumulative median 30-year projected bat fatalities using Evidence of Absence and the HCP-based area correction for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 – October 12, 2018.

Estimate Type	Cumulative median projected mortalities
Evidence of Absence - Indiana bat (α = 0.5)	24
Evidence of Absence - northern long-eared bat (α = 0.5)	24

Table 16. Estimated fatality rate (λ) using Evidence of Absence and the Project-specific area correction for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 – October 12, 2018.

Estimate Type	Bat Fatality Rates
Evidence of Absence - Indiana bat (50th credible bound)	1.75
Evidence of Absence - northern long-eared bat (50th credible bound)	1.75

Table 17. Cumulative median 30-year projected bat fatalities using Evidence of Absence and the Project-specific area correction for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 – October 12, 2018.

Estimate Type	Cumulative median projected mortalities
Evidence of Absence - Indiana bat (α = 0.5)	53
Evidence of Absence - northern long-eared bat (α = 0.5)	53

Species Composition Approach

Take estimates for Indiana bats and northern long-eared bats were also calculated using the Species Composition approach, as outlined in the HCP. The rate of Indiana bat and northern long-eared bat fatalities was calculated by multiplying the species composition of the total bat fatality pool described within the Project HCP by the total number of estimated bats killed during

the fall season using the Huso estimator. Estimates were calculated using the HCP-based area correction (Table 18) and the Project-specific area correction (Table 19).

Bat fatality rates included fractions of bats; however, a fraction of a bat cannot be taken in a given year. Therefore the rates calculated in Tables 18 and 19 were rounded to whole integers to calculate take estimates for 2018. The Species Composition approach determined that approximately one Indiana bat and one northern long-eared bat were taken during the study, when using the HCP-based area correction. When using the Project-specific area correction, two Indiana bats and/or two northern long-eared bats were estimated to be taken during the study.

Table 18. Bat fatality estimates using the Huso estimator and HCP-based area correction and Species Composition Approach.

Bat Species	Bats per Megawatt	Total Bats*	Correction	Bats per Year	Take Estimate
Indiana Bats	3.39	332.22	0.0029	**0.96**	**1.0**
Northern Long-eared Bats	3.39	332.22	0.0024	**0.79**	**1.0**

* 3.39 bats/megawatt x 98 megawatts = 332.22 total bats.

Table 19. Bat fatality estimates using the Huso estimator and Project-specific area correction and Species Composition Approach.

Bat Species	Bats per Megawatt	Total Bats*	Correction	Bats per Year	Take Estimate
Indiana Bats	8.57	839.86	0.0029	**2.43**	**2.0**
Northern Long-eared Bats	8.57	839.86	0.0024	**2.02**	**2.0**

* 8.57 bats/megawatt x 98 megawatts = 839.86 total bats.

DISCUSSION

No federally or state-listed bats were found during the study. The species of bats found during the study were commonly found fatalities at other wind projects in the region (Ellison 2012; Arnett et al. 2008). The majority of the bats were found in late summer and fall, which is the seasonal pattern observed at other wind projects in the Midwestern U.S. Bat fatalities were not concentrated at any particular area of the Project.

Take estimates for both covered species were below the authorized and expected level of take and below the threshold that would trigger adaptive management responses specified in the HCP using both the HCP-estimated and Project-specific area corrections. The data collected during 2018 can be used to evaluate if changes to carcass search methods are warranted in 2019, through consultation with the USFWS.

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Appendix A. Complete List of Carcasses Found at the Hoopeston Wind Project during 2018.

Appendix A. Complete listing of carcasses found at the Hoopeston Wind Project during the 2018 study.

Date	Turbine	Species	Plot Type	Distance from Turbine (meters)	Estimated Time of Death (days)	Excluded from Huso	Excluded from Shoenfeld
4/6/2018	30	golden-crowned kinglet	road/pad	38	0-1	Yes	Yes
4/9/2018	8	ring-necked pheasant	road/pad	1	0-1	Yes	Yes
4/17/2018	36	golden-crowned kinglet	road/pad	92	0-1	Yes	Yes
5/7/2018	6	eastern red bat	full plot	24	2-3	No	No
5/7/2018	12	silver-haired bat	road/pad	213	8-14	Yes	Yes
5/7/2018	6	silver-haired bat	full plot	17	0-1	No	No
5/15/2018	33	evening bat	road/pad	3	2-3	No	No
5/15/2018	38	silver-haired bat	full plot	16	2-3	No	No
5/29/2018	25	eastern red bat	road/pad	60	2-3	No	No
5/29/2018	24	hoary bat	road/pad	7	2-3	No	No
6/4/2018	9	silver-haired bat	road/pad	30	2-3	No	No
6/4/2018	9	silver-haired bat	road/pad	34	2-3	No	No
6/5/2018	44	evening bat	road/pad	2	2-3	No	No
6/5/2018	50	silver-haired bat	road/pad	8	4-7	No	No
6/11/2018	19	eastern red bat	road/pad	4	2-3	No	No
6/19/2018	32	killdeer	road/pad	75	2-3	Yes	Yes
6/26/2018	31	eastern red bat	road/pad	33	2-3	No	No
7/3/2018	43	eastern red bat	road/pad	8	0-1	No	No
7/17/2018	52	eastern red bat	road/pad	3	8-14	Yes	No
7/23/2018	20	hoary bat	road/pad	27	0-1	No	No
7/23/2018	1	killdeer	road/pad	3	4-7	Yes	Yes
7/24/2018	44	hoary bat	road/pad	47	2-3	No	No
7/24/2018	49	hoary bat	road/pad	77	4-7	No	No
8/1/2018	31	big brown bat	full plot	7	4-7	No	No
8/1/2018	3	hoary bat	road/pad	24	0-1	No	No
8/1/2018	10	killdeer	full plot	34	8-14	Yes	Yes
8/3/2018	43	big brown bat	road/pad	21	0-1	No	No
8/3/2018	45	big brown bat	road/pad	5	0-1	No	No
8/3/2018	11	eastern red bat	road/pad	47	2-3	No	No
8/3/2018	29	eastern red bat	full plot	38	4-7	No	No
8/3/2018	36	eastern red bat	road/pad	56	2-3	No	No
8/3/2018	15	evening bat	full plot	1	0-1	No	No
8/6/2018	1	eastern red bat	full plot	29	2-3	No	No
8/6/2018	12	eastern red bat	road/pad	15	4-7	Yes	No
8/6/2018	5	eastern red bat	full plot	3	2-3	No	No
8/7/2018	29	big brown bat	full plot	37	4-7	No	No
8/7/2018	29	eastern red bat	full plot	24	0-1	No	No
8/7/2018	41	evening bat	road/pad	5	4-7	No	No
8/9/2018	4	eastern red bat	road/pad	65	0-1	No	No
8/9/2018	4	hoary bat	road/pad	6	0-1	No	No
8/10/2018	11	eastern red bat	road/pad	13	0-1	No	No
8/10/2018	37	eastern red bat	road/pad	5	0-1	No	No
8/13/2018	3	big brown bat	road/pad	24	0-1	No	No
8/13/2018	8	big brown bat	road/pad	5	0-1	No	No

Appendix A. Complete listing of carcasses found at the Hoopeston Wind Project during the 2018 study.

Date	Turbine	Species	Plot Type	Distance from Turbine (meters)	Estimated Time of Death (days)	Excluded from Huso	Excluded from Shoenfeld
8/13/2018	10	eastern red bat	full plot	39	2-3	No	No
8/14/2018	38	eastern red bat	full plot	33	8-14	Yes	No
8/14/2018	46	eastern red bat	full plot	20	2-3	No	No
8/14/2018	47	eastern red bat	full plot	42	0-1	Yes	Yes
8/14/2018	46	evening bat	full plot	24	4-7	No	No
8/14/2018	44	mourning dove	road/pad	2	0-1	Yes	Yes
8/17/2018	39	eastern red bat	road/pad	23	4-7	Yes	No
8/17/2018	47	hoary bat	full plot	5	0-1	No	No
8/21/2018	22	eastern red bat	road/pad	3	0-1	No	No
8/22/2018	41	big brown bat	road/pad	30	0-1	No	No
8/22/2018	37	eastern red bat	road/pad	10	0-1	No	No
8/22/2018	43	hoary bat	road/pad	22	2-3	No	No
8/23/2018	22	eastern red bat	road/pad	18	2-3	No	No
8/23/2018	1	silver-haired bat	full plot	30	0-1	No	No
8/24/2018	44	eastern red bat	road/pad	2	0 (Injured)	No	No
8/24/2018	20	hoary bat	full plot	26	2-3	No	No
8/24/2018	44	hoary bat	road/pad	22	0-1	No	No
8/24/2018	37	silver-haired bat	road/pad	6	2-3	No	No
8/27/2018	10	eastern red bat	full plot	27	4-7	No	No
8/27/2018	21	eastern red bat	full plot	20	0-1	No	No
8/27/2018	28	eastern red bat	full plot	32	4-7	Yes	No
8/28/2018	11	eastern red bat	road/pad	51	0-1	No	No
8/28/2018	15	eastern red bat	full plot	29	8-14	Yes	No
8/28/2018	15	eastern red bat	full plot	37	8-14	Yes	No
8/28/2018	15	eastern red bat	full plot	38	8-14	Yes	No
8/28/2018	40	eastern red bat	road/pad	21	0-1	No	No
8/30/2018	10	eastern red bat	full plot	27	2-3	No	No
8/30/2018	14	eastern red bat	road/pad	5	2-3	No	No
8/31/2018	20	eastern red bat	full plot	36	4-7	Yes	No
8/31/2018	44	eastern red bat	road/pad	56	0-1	No	No
8/31/2018	44	eastern red bat	road/pad	1	2-3	No	No
8/31/2018	47	eastern red bat	full plot	11	0-1	No	No
8/31/2018	47	eastern red bat	full plot	36	0-1	No	No
9/5/2018	33	hoary bat	road/pad	20	0-1	No	No
9/6/2018	31	eastern red bat	full plot	34	2-3	No	No
9/6/2018	51	eastern red bat	road/pad	3	2-3	No	No
9/6/2018	7	eastern red bat	road/pad	28	4-7	Yes	No
9/9/2018	41	hoary bat	road/pad	10	0-1	No	No
9/10/2018	31	eastern red bat	full plot	36	0-1	No	No
9/10/2018	21	silver-haired bat	full plot	27	0-1	No	No
9/11/2018	39	big brown bat	road/pad	9	2-3	No	No
9/11/2018	15	eastern red bat	full plot	43	2-3	Yes	Yes
9/11/2018	15	silver-haired bat	full plot	16	0-1	No	No
9/14/2018	15	silver-haired bat	full plot	31	2-3	No	No

Appendix A. Complete listing of carcasses found at the Hoopeston Wind Project during the 2018 study.

Date	Turbine	Species	Plot Type	Distance from Turbine (meters)	Estimated Time of Death (days)	Excluded from Huso	Excluded from Shoenfeld
9/14/2018	52	silver-haired bat	road/pad	41	0-1	No	No
9/17/2018	7	eastern red bat	road/pad	12	0-1	No	No
9/18/2018	50	evening bat	full plot	16	8-14	Yes	No
9/18/2018	45	silver-haired bat	road/pad	39	2-3	No	No
9/21/2018	18	eastern red bat	road/pad	65	4-7	No	No
9/21/2018	38	rock pigeon	full plot	39	unknown	Yes	Yes
9/21/2018	18	silver-haired bat	road/pad	12	2-3	No	No
9/21/2018	38	silver-haired bat	full plot	39	2-3	No	No
9/24/2018	31	silver-haired bat	full plot	34	4-7	No	No
9/24/2018	31	silver-haired bat	full plot	27	4-7	No	No
9/28/2018	23	silver-haired bat	road/pad	43	2-3	No	No
10/2/2018	11	silver-haired bat	road/pad	63	2-3	No	No
10/4/2018	27	silver-haired bat	road/pad	1	0-1	No	No
10/4/2018	28	silver-haired bat	full plot	31	0-1	No	No
10/4/2018	3	silver-haired bat	road/pad	30	0-1	No	No
10/4/2018	6	silver-haired bat	full plot	24	2-3	No	No
10/4/2018	7	silver-haired bat	road/pad	12	0-1	No	No
10/4/2018	9	silver-haired bat	road/pad	5	live	No	No
10/8/2018	25	silver-haired bat	road/pad	1	0-1	No	No
10/9/2018	50	eastern red bat	full plot	38	0-1	No	No
10/9/2018	50	silver-haired bat	full plot	37	0-1	No	No
10/11/2018	5	killdeer	full plot	8	2-3	Yes	Yes
10/11/2018	8	silver-haired bat	road/pad	2	2-3	No	No

Appendix B. Truncated Weighted Likelihood (TWL) Area Correction Estimate Model Fitting Results

Appendix B1. Truncated weighted maximum likelihood area correction estimates for the Hoopeston Wind Project.

Carcass Type	Plot Type	Distribution	Parameter 1	Parameter 2	Area Correction
Bat	full plot	Gompertz	0.05	0.0	0.44
	road/pad	Gompertz	0.05	0.0	0.08

Appendix B2. Area correction models for bats from the Hoopeston Wind Project. Selected models are denoted by an asterisk in the 'Delta AICc' column.

Distribution	AICc	Delta AICc
Gompertz	10380.95	0*
Normal	10414.79	33.84
Weibull	10456.90	75.95
Rayleigh	10467.11	86.16
Gamma	10541.36	160.41

Appendix C. Bat Fatality Rates at the Hoopeston Wind Project Using the Huso and Shoenfeld Estimators, and the HCP-based Area Correction Estimates

Appendix C1. Estimated fatality rates and correction factors, with 90% confidence intervals, using the Huso estimator and HCP-based area correction for full plot turbines and roads and pads for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 - October 12, 2018.

	SPRING		SUMMER		FALL	
Parameter	**Estimate**	**90% CI**	**Estimate**	**90% CI**	**Estimate**	**90% CI**
Search Area Adjustment						
A (full plot)	0.71				0.71	
A (road/pad)	0.23		0.23		0.23	
Observer Detection Rate						
P (full plot)	0.44	0.33 - 0.58			0.44	0.33 - 0.58
P (road/pad)	0.92	0.85 - 0.97	0.92	0.85 - 0.97	0.92	0.85 - 0.97
Probability of a Carcass Persisting Through the Search Interval						
full plot	0.83	0.78 - 0.87			0.90	0.87 - 0.92
road/pad	0.83	0.78 - 0.87	0.83	0.78 - 0.87	0.90	0.87 - 0.92
Probability of Available and Detected						
full plot	0.37	0.27 - 0.48			0.40	0.29 - 0.52
road/pad	0.77	0.69 - 0.83	0.77	0.69 - 0.83	0.83	0.76 - 0.89
Unadjusted Number of Fatalities						
full plot	3.0				31.0	23.0 - 39.0
road/pad	1.0		12.0	6.0 - 18.0	42.0	31.0 - 54.0
Observed Fatality Rates (Fatalities/Turbine/Season(s))						
full plot	0.60				2.07	1.53 - 2.60
road/pad	0.02		0.24	0.12 - 0.37	1.24	0.91 - 1.59
Adjusted Fatality Rates (Fatalities/Turbine/Seasons(s))						
full plot	2.30				7.40	5.02 - 11.07
road/pad	0.13		1.35	0.71 - 2.10	6.52	4.75 - 8.58
Overall	0.35		1.35	0.71 - 2.10	6.79	5.36 - 8.60
Adjusted Fatality Rates (Fatalities/MW/Seasons(s))						
full plot	1.15				3.70	2.51 - 5.53
road/pad	0.06		0.67	0.36 - 1.05	3.26	2.37 - 4.29
Overall	0.17		0.67	0.36 - 1.05	3.39	2.68 - 4.30

Appendix C2. Estimated fatality rates and correction factors, with 90% confidence intervals, using the Shoenfeld estimator and HCP-based area correction for full plot turbines and roads and pads for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 - October 12, 2018

	SPRING		SUMMER		FALL	
Parameter	**Estimate**	**90% CI**	**Estimate**	**90% CI**	**Estimate**	**90% CI**
Search Area Adjustment using Fowler's results						
A (full plot)	0.71				0.71	
A (road/pad)	0.23		0.23		0.23	
Observer Detection Rate						
P (full plot)	0.44	0.33 - 0.56			0.44	0.33 - 0.56
P (road/pad)	0.92	0.85 - 0.97	0.92	0.85 - 0.97	0.92	0.85 - 0.97
Mean Carcass Removal Time (Days)						
$\bar{t}$ (full plot)	18.15	12.90 - 23.91			18.15	12.90 - 23.91
$\bar{t}$ (road/pad)	18.15	12.90 - 23.91	18.15	12.90 - 23.91	18.15	12.90 - 23.91
Probability of Available and Detected						
full plot	0.59	0.46 - 0.69			0.73	0.62 - 0.80
road/pad	0.81	0.74 - 0.85	0.81	0.74 - 0.85	0.89	0.85 - 0.92
Unadjusted Number of Fatalities						
full plot	3.0				38.0	29.0 - 48.0
road/pad	1.0		13.0	7.0 - 19.0	45.0	35.0 - 57.0
Observed Fatality Rates (Fatalities/Turbine/Season(s))						
full plot	0.60				2.53	1.93 - 3.20
road/pad	0.02		0.27	0.14 - 0.39	1.32	1.03 - 1.68
Adjusted Fatality Rates (Fatalities/Turbine/Seasons(s))						
full plot	1.44				4.91	3.69 - 6.49
road/pad	0.12		1.41	0.78 - 2.13	6.39	4.91 - 8.24
Overall	0.25		1.41	0.78 - 2.13	5.94	4.84 - 7.36
Adjusted Fatality Rates (Fatalities/MW/Seasons(s))						
full plot	0.72				2.46	1.85 - 3.24
road/pad	0.06		0.70	0.39 - 1.07	3.20	2.45 - 4.12
Overall	0.13		0.70	0.39 - 1.07	2.97	2.42 - 3.68

Appendix D. Bat Fatality Rates at the Hoopeston Wind Project Using the Huso and Shoenfeld Estimators and the Project-specific Area Correction Estimates

Appendix D1. Estimated fatality rates and correction factors, with 90% confidence intervals, using the Huso estimator and project-specific area correction for full plot turbines and roads and pads for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 - October 12, 2018.

	Spring		Summer		Fall	
Parameter	**Estimate**	**90% Confidence Interval**	**Estimate**	**90% Confidence Interval**	**Estimate**	**90% Confidence Interval**
Search Area Adjustment						
A (full plot)	0.44	0.32 - 0.58			0.44	0.32 - 0.58
A (road and pad)	0.08	0.05 - 0.11	0.08	0.05 - 0.11	0.08	0.05 - 0.11
Observer Detection Rate						
P (full plot)	0.44	0.31 - 0.56			0.44	0.31 - 0.56
P (road and pad)	0.92	0.85 - 0.98	0.92	0.85 - 0.98	0.92	0.85 - 0.98
Probability of a Carcass Persisting Through the Search Interval						
Full plot	0.83	0.77 - 0.87			0.90	0.87 - 0.92
Road and pad	0.83	0.77 - 0.87	0.83	0.77 - 0.87	0.90	0.87 - 0.92
Probability of Available and Detected						
Full plot	0.37	0.26 - 0.47			0.40	0.29 - 0.51
Road and pad	0.77	0.68 - 0.84	0.77	0.68 - 0.84	0.83	0.75 - 0.90
Unadjusted Number of Fatalities						
Full plot	3.0				31.0	23.0 - 39.0
Road and pad	1.0		12.0	6.0 - 18.0	42.0	31.0 - 54.0
Observed Fatality Rates (Fatalities/Turbine/Season(s))						
Full plot	0.60				2.07	1.53 - 2.60
Road and pad	0.02		0.24	0.12 - 0.37	1.24	0.91 - 1.59
Adjusted Fatality Rates (Fatalities/Turbine/Seasons(s))						
Full plot	3.72				11.95	8.23 - 17.76
Road and pad	0.38		4.01	2.11 - 6.24	19.42	14.23 - 25.15
Overall	**0.72**		**4.01**	**2.11 - 6.24**	**17.13**	**13.48 - 21.65**
Adjusted Fatality Rates (Fatalities/Megawatt/Seasons(s))						
Full plot	1.86				5.98	4.11 - 8.88
Road and pad	0.19		2.0	1.06 - 3.12	9.71	7.11 - 12.58
Overall	**0.36**		**2.0**	**1.06 - 3.12**	**8.57**	**6.74 - 10.83**

Appendix D2. Estimated fatality rates and correction factors, with 90% confidence intervals, using Shoenfeld estimator and project-specific area correction for full plot turbines and roads and pads for studies conducted at the Hoopeston Wind Project, Vermilion County, Illinois, from April 2 - October 12, 2018.

	Spring		Summer		Fall	
Parameter	**Estimate**	**90% Confidence Interval**	**Estimate**	**90% Confidence Interval**	**Estimate**	**90% Confidence Interval**
Search Area Adjustment						
A (full plot)	0.44	0.33 - 0.60			0.44	0.33 - 0.60
A (road and pad)	0.08	0.06 - 0.11	0.08	0.06 - 0.11	0.08	0.06 - 0.11
Observer Detection Rate						
P (full plot)	0.44	0.31 - 0.56			0.44	0.31 - 0.56
P (road and pad)	0.92	0.85 - 0.97	0.92	0.85 - 0.97	0.92	0.85 - 0.97
Mean Carcass Removal Time (Days)						
$\bar{t}$ (full plot)	18.15	13.19 - 23.49			18.15	13.19 - 23.49
$\bar{t}$ (road and pad)	18.15	13.19 - 23.49	18.15	13.19 - 23.49	18.15	13.19 - 23.49
Probability of Available and Detected						
Full plot	0.59	0.45 - 0.68			0.73	0.60 - 0.80
Road and pad	0.81	0.74 - 0.85	0.81	0.74 - 0.85	0.89	0.85 - 0.92
Unadjusted Number of Fatalities						
Full plot	3.0				38.0	28.0 - 48.0
Road and pad	1.0		13.0	7.0 - 20.0	45.0	34.0 - 57.0
Observed Fatality Rates (Fatalities/Turbine/Season(s))						
Full plot	0.60				2.53	1.87 - 3.20
Road and pad	0.02		0.27	0.14 - 0.41	1.32	1.0 - 1.68
Adjusted Fatality Rates (Fatalities/Turbine/Seasons(s))						
Full plot	2.32				7.94	5.08 - 11.84
Road and pad	0.36		4.19	2.06 - 7.04	19.03	12.20 - 28.43
Overall	**0.56**		**4.19**	**2.06 - 7.04**	**15.63**	**10.41 - 23.06**
Adjusted Fatality Rates (Fatalities/Megawatt/Seasons(s))						
Full plot	1.16				3.97	2.54 - 5.92
Road and pad	0.18		2.10	1.03 - 3.52	9.51	6.10 - 14.21
Overall	**0.28**		**2.10**	**1.03 - 3.52**	**7.82**	**5.20 - 11.53**